Odontological report on dental CAD/CAM

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CHAPTER 1

OPTICAL IMPRESSION CAPTURE

Optical impression capture, with plaster then inside the mouth of the patient, has had an extremely important evolution since its beginnings (1973) until today. Studying today's impression taking supposes having in memory the successive followed steps. Moreover, it will enable a better understanding of how, step by step, a theoretical principle has become an odontologic reality.

1.1 History

In 1973, we had used as dental optical analysis theoretic principle, holography. Several reasons justified this choice:

- the innovating aspect of the technique
- the great publicity that existed around laser, which meant the possibility for the young student that I was to easily find available documentation.
- the fact that it was 3D reading.

But, as soon as 1976, we had to admit that this choice wasn't excellent because the hologram capture needed a much too long waiting period with regards to the possible availability of the patient. Digitalisation was far, and is still far from being an automatable action within the minimum time limits given to a practice. For this reason, from 1980, we decided under the advice of GREPA (Strasbourg CNRS) to study and finalize an interferometric technique known since 1896, known as MOIRE. In 1981, we created a particular project under the name PHOTODON and during several years (1981 – 1983) we tried to enrich it to adapt it to the mouth of our patients. We won't come back on the theoretic principle of this process. We explained it in several articles adjoined in appendix, here are the references:

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To summarise, we will simply say that in 1981, we wished to capture three micro moiré views, associated with a MICROM system. The exploitation would be done by a non determined CCD camera. A that time, we had defined, in a complete report the mounting characteristics as follow:

- distance with reference plan: 13 mm
- weft dimension: 0.05 mm
- view capture basis: 7 mm
- facial distance: 5.682 mm

From May 1981 to December 1983, we have worked with THOMPSON then MATRA. The result of this work was the finalization of the first endobuccal capture probe, used during the "entretiens de GARANCIERE" in September 1983. This probe, presented on 26th September 1982 had the advantage of being easy to handle but the greatest disadvantage was a bad image quality. The basic elements were as follows (fig. 1 and 2):

- a 150 W power supply
- a light transmitting and image conducting fiber
- 2 wefts of 50µ
- 2 optics with 40° opening

The optical finalization of the device is realised on a reference plan situated at a known distance of the optical center of the device. Two identical systems linked together by a support adaptable inside the mouth enable to visualise both the vestibular and lingual side of the tooth. Moreover, a needle with marking plan enables the situation with precision of the distance D (see further). The optical fiber used for projection is a double cover metal cable, 4mm diameter and 1200mm long. It is equipped with:

- a 40, 45 or 50µ DTE weft
- 2 optical capacitor with 2 doublets
- a total reflection prism, 90° deviation
- an optical system with a 30° F4 opening

The recapture fiber is composed of image conducting fibers with a diameter of 15 to 18µ, 3x3 mm section ordinates and a length of 1000mm with an optical system composed of:

- image capture side, a lens composed of doubles, total reflection prism, 90° deviation and 30° or 40° angulation.
- images restitution side, a DTE weft of 40.45 diameter and dimension of 100 or 150µ, a lens composed of two doubles and a C frame.
- data treatment side, we use a matrix photosensor with charges transfers (CCD), type THX 311 35. This photosensor is linked to an evaluation card THX 1038 and a logic card THX 1042. The three implementation cards are gathered inside the same box and linked through a VHS VCR to a standard TV monitor. The used captor is an n-MOS channel technology CCD device buried at two levels of polycristal sillicium. Its weft transfer organisation makes practically the whole image zone photosensitive.

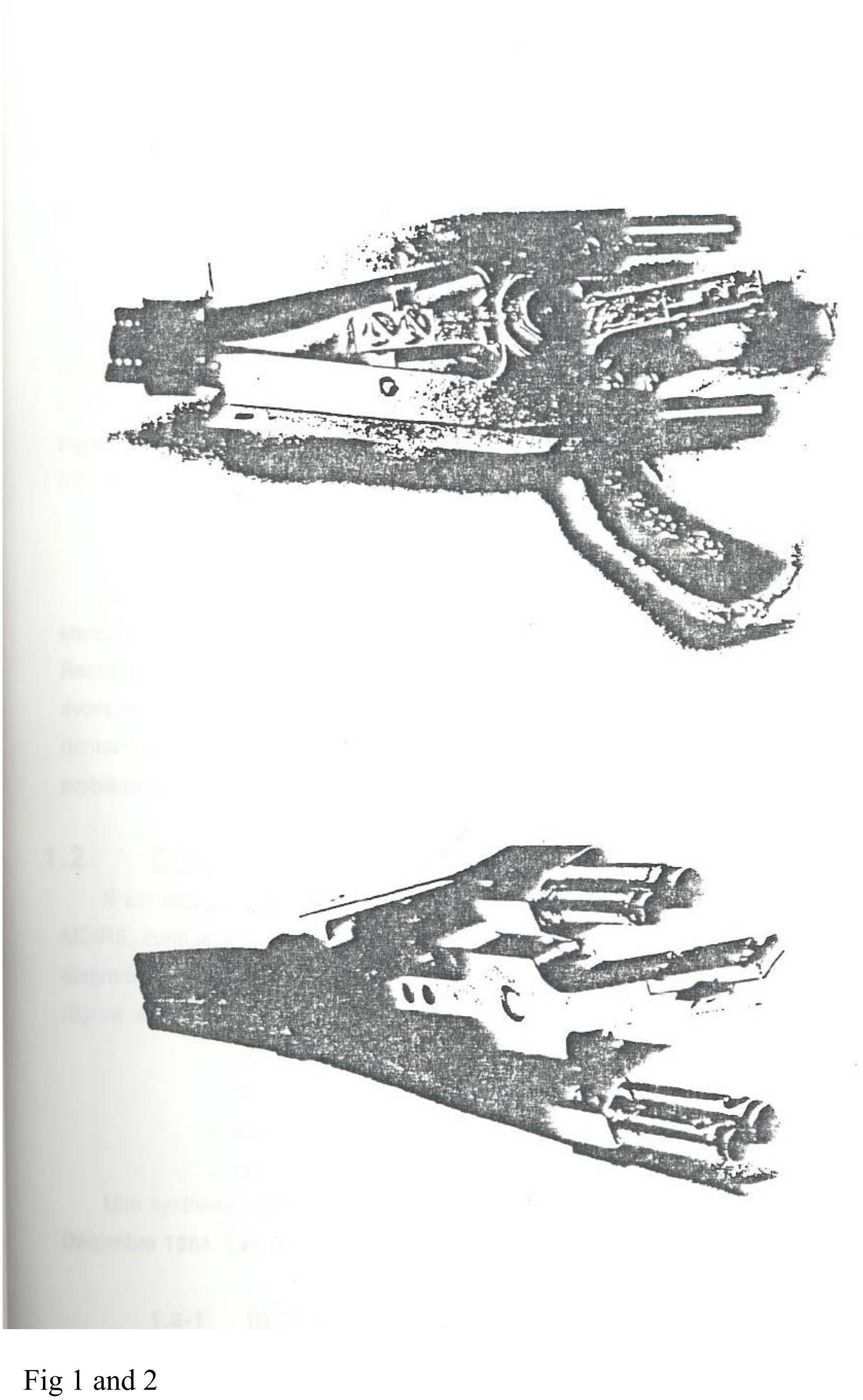


Fig 1 and 2

GARANCIERE's optical probe (sept 1983)

The fact that the whole thing is flat makes it very apt to any metrological micro study.

The PEL measures 30µ x 28µ and the image zone represents 4.32 mm x 5.824 mm, which means around 29 952 analysis points for 25mm² (figure 3). The analysed object not being bigger than 6mm by 6mm, the 500µ precision is very probable for values in OX, OY and OZ. We have admitted for this study OX and OY coordinates axes fixed and known (interlines) and an OZ depth variable, which can be measured. The 145 lines are transferred line by line in the memory zone, placed in a parallel fashion in the reading area. At the exit, there is a charge-tension conversion thanks to the floating diode. The photosensitive THX 311 35 matrix is associated to a THX 5001 evaluation card so there is adaptation of the logical command signals (suppression of the continue component…). We use an exit delivering a sampled video signal. It is piloted by the quartz, this module provides CCIR signals for the standard 625 lines/ 25 images second. For this reason, we associate to this card:

- the THX 5002 card frequence generator and command logic.
- the THX 5003 video card + analogue/digital conversion

The THX 5003 card is linked to a VHS VCR, itself linked to a standard 625 lines TV monitor. This work constituted the first phase presented to the Research and Industry Ministry which accepts to finance it in December 1983. At this date, we had the luck to meet the OCE. HENNSON company, specially created for dental application and implementation, who was born in January 1984. It will completely reconsider the collaboration problem with BERTIN, IS2 and THOMSON.

1.2 Fundamental study for the choice of 3D reading

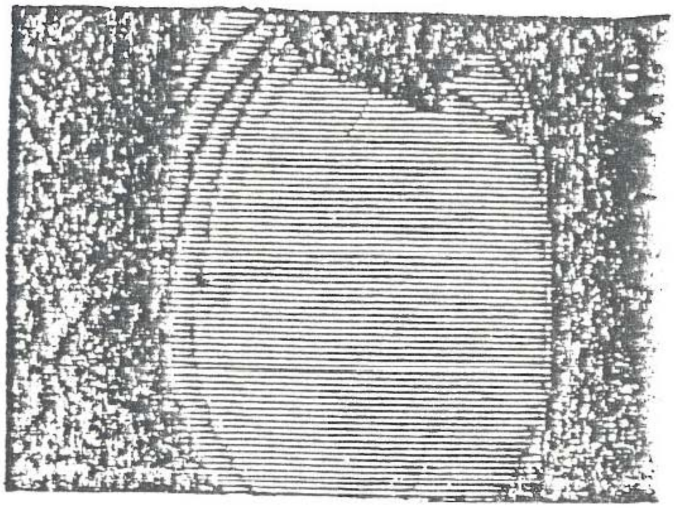
It is decided in January 1984 to realise a complete study of all the MOIRE processes known to this date in order to choose the best of them (figure 4). As show the joined diagram, 4 great sectors have been studied according to an extremely complete plan (figure 4):

- bibliography
- performance and limit
- aptitude for dental miniaturisation
- 3D measurement quality
- experimental verification on optical bench, scale 3 then 1

A complete synthesis of all the points aforementioned was done and presented on December 5th 1984. The results were as follows:

1.2-1 Network versus object

The light source code of the tooth through a network, the observation done through the same network, the problems are:



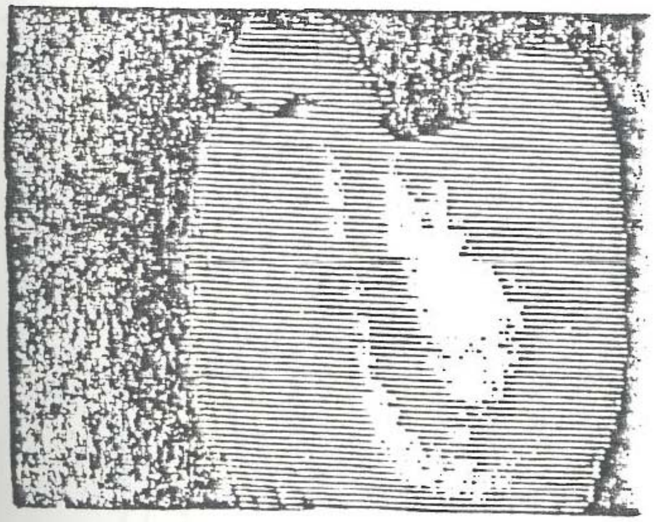


Figure 3
MOIRE RESULTS

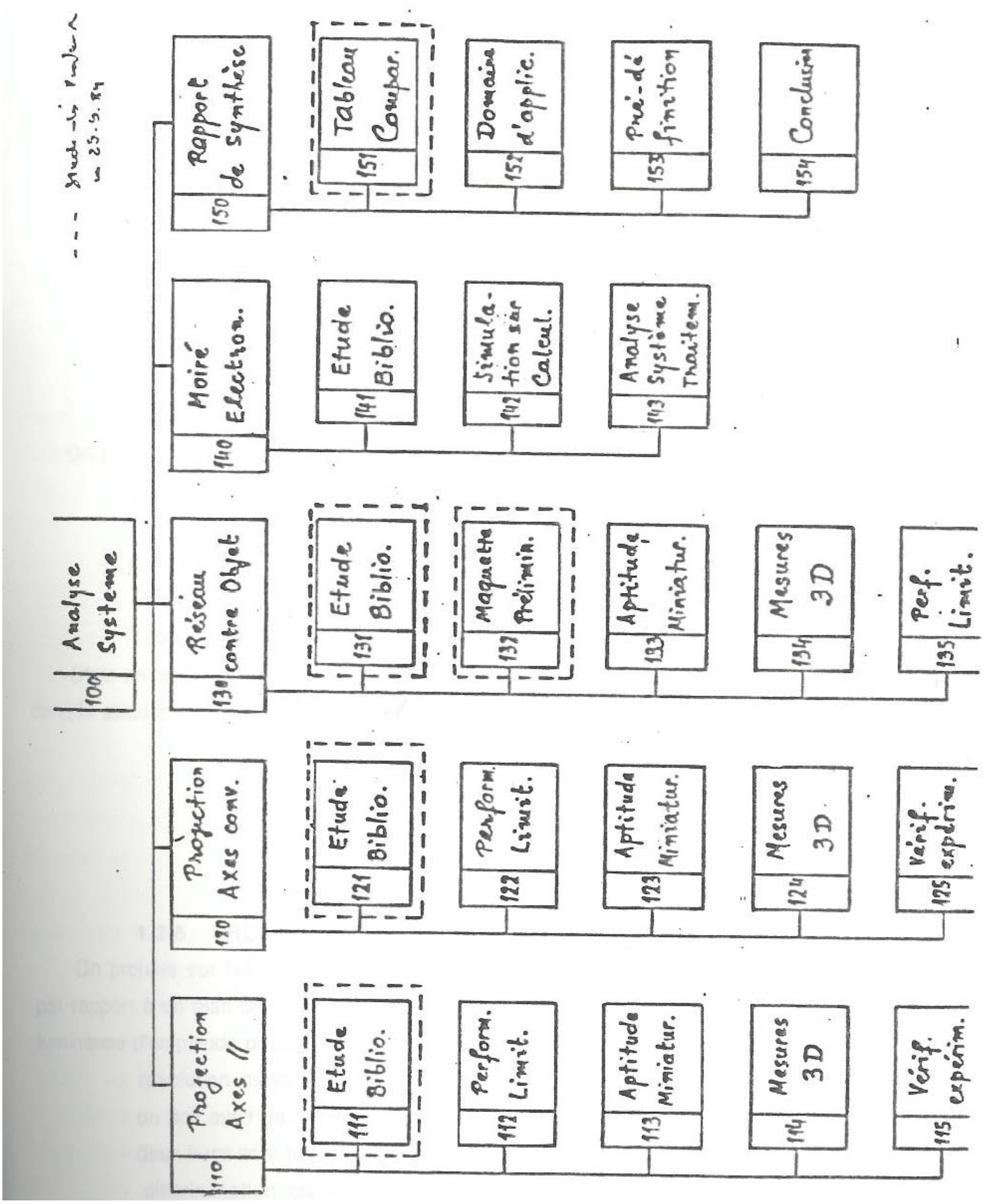


Figure 4
ANALYSIS PRINCIPLE OF MOIRES

- limit for depth and length
- delicate interpolation
- too much influence of object reflectivity

1.2-2 Moiré by simple projection

It is about the method we have used at the GARANCIERE in November 1983.

- depth stays low
- delicate interpolation
- too much sensitivity to the mounting parameters
- relief variation way hard to establish
- influence of object's reflectivity stays important

1.2-3 Moiré by double projection

We project on the object both charts and we visualise it without chart. The problems are:

- depth insufficient
- mediocre contrast
- complex mounting
- difficult interpolation

1.2-4 Multiplication of image-shots

It is a simple projection moiré but the second network is obtained by digitalisation in the calculator:

- interpolation is delicate
- we need a fast detector
- the noise filter is complex
- the digital system is complex
- the hollows/bumps discrimination is difficult

1.2-5 Profilometry by amplitude coding

We project on the object a network which we visualise and we measure the difference in height compared with a reference plan depending on the modification of the periodic modulation of the luminance (coding amplitude). The problems are:

- average resolution
- we need a detector which resolves the porter
- 2 views are necessary
- difficult hollows/bumps discrimination

1.2-6 Profilometry by Fourier transformation

Very close to the last method, the image of the network deformed by the tooth can be considered like a composite signal having a porting spatial frequency modulating in amplitude by the reflectivity of the object and in phase through its relief. Thanks to a series of one-dimensional FOURIER transformations, it is possible to isolate the phase variations of these amplitude modulations and so to get to the tri dimensional geometry of the object. There are still a certain number of problems:

- complex mean and calculation time
- necessity of reference plan
- limited object slope
- quick detector
- average precision

1.2-7 Sampling analysis method

Close to the profilometry method, we project the network on the reference plan to know the non deformed network (not apparent). We then sample the image of the tooth coded at the dimension of the non deformed network, for different phases at the origin (0 to 2π). We get different intensities which will give, through calculation, the moiré fringes. What's left is that:

- interpolation is necessary
- a good detector is necessary
- the object's reflectivity can have an influence

1.2-8 Profilometry by phase coding

We project on the tooth a sinusoidal network of which we make, through a "SHIFTER PHASE", the origin phase vary. We project on each point of the object the network by varying the origin phase from 0 to 2π. For each point of the successive images, we register the signal's sinusoidal variations, of which the amplitude is linked to the characteristics of the tooth (reflectivity, diffusion) and of which the origin's phase knowledge enables to quantify the value of the object's relief. The knowledge of the object's relief is linked to the dephasing observed on the object (at a 2π precision) with regards to where it is on the reference plan. We need:

- a good detector
- several images (which brings in the movement risk)

It is this method we have chosen and which is part of an important patent (n°87 02339 of February 13th 1987).

A summary tbale enables a better comprehension of the interest of this last method (figure 5 and 6).

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Figure 5

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MÉTHODES	Nbre de réseaux	Nbre d'images	Précision relative attendue exprimée en fonction de pas p.	Profondeur de champ	Influence de la réflectivité	Complexité de la méthode *	Interpolation **
Moiré simple projection	2	1	p/2	10 mm	Oui	2	4
Moiré double projection	2/3	1	p/2	10 mm	Oui	3	5
Moiré réseau contre l'objet	1	1	p/2	3 mm	Oui	1	4
Multiplication de plans images	1	1 + 1	p	10 mm	Oui	1	5
Profilomètrie par codage d'amplitude	1	1 + 1	p/2	10 mm	Oui	2	3
Profilomètrie par transformée de FOURIER	1	1	p/2	10 mm	Oui	5	0
Méthode d'analyse par sous échantillonnage	1	1	p/10	10 mm	Oui	3	2
Profilométrie par codage de phase	1	3	p/100	10 mm	Non	4	0

* la complexité est quantifiée de manière croissante par un nombre compris entre 1 et 5,

** les problèmes soulevés par l'interpolation sont quantifiées en termes de difficulté croissante par un nombre compris entre 0 et 5.

Figure 6
COMPARISON OF METHODS

1.3 The dental method

1.3-1 Determination of height Z (figure 7)

We dispose of a certain number of optical references which are:

- the view capture axis
- the projection axis
- a know dimension network

These two axes are, on an imaginary reference plan, at an α and β angle (the reference plan is parallel to the plan defined by the optical centres of the lens). We code the object with projection of a sinusoidal weft of known p period:

$T(xy) = ½ + ½ \sin(2\pi\, x/P)$

As this T (xy) projection is done at an α angle, the period will increase on the reference plan:

$Po = P \sin \alpha$

Also, on the detector, it will be:

$Pr = Po \sin \beta = P \sin \beta / \sin \alpha$

Firstly, it is about knowing exactly the projection effect on the reference plan, depending on the used mounting. It's the calibration phase. We then project this light on the tooth and we get a new image whose phase is different depending on the altitude of the object. This phase difference:

$\Delta\varphi = \varphi$ of the object – φref.

is the expression of the altitude.

The intensity received by the captor issued from point A will be:

$I_A = a_A + b_A \cos(2\pi\, 0A / P0)$

And the one received by D will be:

$I_D = a_D + b_D \cos(2\pi\, 0A / P0)$

So both phases will be the same if B is the projection of D on the reference plan (z = BD).

$AC = AB + BC = BD/Tg\alpha + BD/Tg\beta$

Where from

$BD = AC\,(Tg\alpha – Tg\beta / Tg\alpha + Tg\beta)$ with $\overline{AC} = \overline{0A} - \overline{0C}$

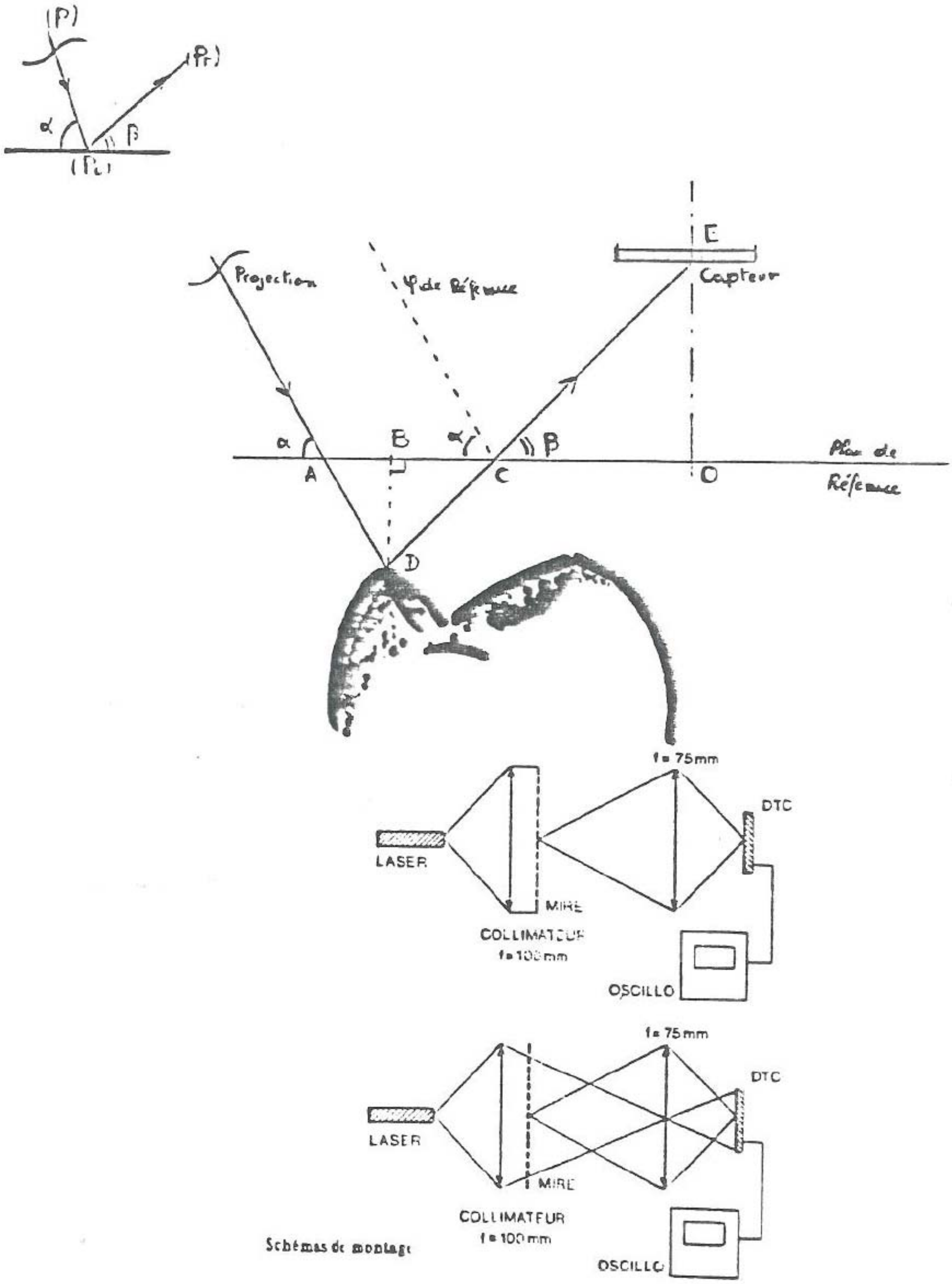


Figure 7
MATHEMATICAL AND PHYSICAL DETERMINATION

for a sinusoidal movement $T(xy) = a(xy) + b(xy) \sin (2\pi x / Po)$

intensity is $I(xy) = a(xy) + b(xy) \cos (2\pi x / Po)$

and the phaseφ $(xy) = 2\pi x / Po$

in C the phase will be $\varphi C = 2\pi\ OC / Po$ and $\varphi A\ (2\pi\ OA / Po)$ in A

The phase φ difference between A and C will be
$AC = Po/2\pi\ (\varphi A - \varphi C) = Po/2\pi\ \Delta\ \varphi AC$

But the phase in D is the same as the one in A ($\varphi A = \varphi D$)
So $AC = Po/2\ \pi\ \Delta\ \varphi DC$

And then $BD = z = \Delta\varphi\ DC\ Po/2\ \pi\ 5\ (Tg\alpha\ .Tg\beta / Tg\alpha + Tg\beta)$

We often represent the z value by the expression

$$z = \Delta\varphi\ c$$

Where $\Delta\ \varphi$ is the phase φ difference between the reference plan and the object (so an excellent calibration is interesting) and the c term :

$$c = \frac{Po}{2\pi} \left(\frac{Tg\,\alpha \bullet Tg\,\beta}{Tg\,\alpha + Tg\,\beta} \right)$$

This c term only depends on the optical system and the position of the E point on the detector. We easily understand all the importance that represents an excellent calibration and good optical systems in the determination of z.
A phase difference enables us to know the value of z.

1.3-2 Determination of the influence of parallel or diverging projection

A complete study has been led by HENNSON and BERTIN to know the importance that the choice of using rays projected parallel or on the contrary diverging (cones) could have. Numerous trials have been done on the limitation in projection of the visibility of fringes, depending on the angle α of the source, the diffraction due to the network used or the coherence of the source, and all this with regards to the distance of observation. Also, the influence of increase has been studied. Each study has taken the affectation of a reduction of the modulation depending on the distance between the source and the object.

They have enabled to establish that the dimension must be between 0.5 and 3.2mm, that the source didn't have a great influence (with the exception of the flux and he physical mounting qualities) and that if we wanted to characterise a great surface with small diameter lenses, it was necessary to previously use diverging projection. The necessary specificities have led to the use of a diverging projection, the use of a laser (good flux) with lenses of small size. The only solution which appeared logical is represented by attached drawings.

1.3-3 Calibration

In order to perfectly know the used elements, for the determination of z, a calibration procedure has been implemented. It enables, quickly, for each probe to have its own physical reference and to auto control before its use at the practice. It took more than a year and a half to get the absolute control characteristics and there are still some improvements to add.

1.3-4 Influence of the object for the choice of system

The visibility of the projected fringes on the object is conditioned by the photometric attitude in surface and in value. We particularly note:

- the Albedo
- the reflection coefficient
- the surface diffusion index
- the volume diffusion coefficient

The sinusoidal quality (of the modulation) certainly depends physically on the way it is reflected back to the detector. Thus the absorbed ray can't be detected and it will then be impossible to receive the phase which enables to know the height of z. Moreover, some parasite rays can completely degrade the data. For teeth, studies led from June 1985 to August 1986 have helped to understand that the tooth is far from being a perfect diffuser (Lambertien). Have been tested:

- natural teeth (vital and non)
- prosthetic teeth (resin and ceramics)
- metal (amalgam, Nickel Chrome)

Natural teeth reflect inside the whole the spectre with a maximum of specular and diffuse reflection towards 600nm (86% according to analyses done by us). The prosthetic teeth have a similar attitude but the rapport of the fluxes, reflected and diffuse, is different. For both types of objects, studied at tables, the surface attitude is intermediary between a perfect diffuser and a perfect reflector. For real in-mouth observations, the reflective aspect is still privileged then the presence of an intermittent liquid film. Moreover, the volume diffusion coefficient is relatively (specifically in the red = 633nm) important and limited. Practically, the spatial coding frequencies have around 0.5 pairs of lines per millimetre.

The crowns evidently have a different attitude: not absorbed light so no volume diffusion. The surface attitude is close to the reflector's one. Finally the amalgams, with a less regular structure, add to the absence of volume diffusion already noted on the crowns a diffusing aspect very favourable to coding.

This attitude disparity between the types of objects or more to the point the materials submitted to measurement, have led to signal dynamics problems that the performances announced by the CCD detectors have solved.

In order to solve this problem, from October 1985, by associating with the SPAD laboratory, we have devised a special coating spread on the teeth with a brush (ADF 1985) then pulverised, the coating gives to these different objects the photometric properties close to perfect diffusers. We had to study:

- the shape of the film
- its adherence
- its bio compatibility
- its efficiency
- its conditioning

Today, we have a coherent coating which we now have to experiment thoroughly (regular spreading).

In the same line of work, we look to develop with great precision the quality and power of the source as well as the quality of CCD and cameras. To optimise the source choice, we do our handlings by using several rays, different captors and several mountings. We present here the essential elements of this analysis (figure 7).

The studied sources are:

-
- a conventional lamp with mercury vapours, wavelength 546nm, power 100mW and emission angle 2II sr
- a laser diode of 800nm, 200mW and 1.18 sr
- a He-Ne laser with 632.8nm, 50mW and 10^{-6} sr

- a Ge-Cd laser with 442nm and 40mW
- an Argon laser with 540nm cooled with air (50mW) and with water (1400mW)

The studied DTC captors are:

- 3 Thomson n° 7808 and 7815 CCDs
- 1 Fairchild 122/142 CCD
- 1 Sony CCD (ICV 500 camera)

Thanks to the described mountings, we were able to choose between the different types of emission with regards to:

- the commercially available optical power
- the photometric results (teeth, optics and CCD)
- the opto- electric chain transfer function
- the speckle dimensions

We obtained the following results:
For the commercially available optical power and by studying the spectral luminance of the mercury vapour lamp, the diode and the He-Ne laser, we will note the great quality of the latter for the envisaged application. Any laser whose rays have a wavelength between 0.4 and 1nm can apply to the application.

- the photometric summary takes into account the following optical parameters:
  - diverse transmissions
  - sensitivity
  - tooth's albedo…

Taking into account the different factors, it is possible to know the received flux corresponding to the saturation exposition and detector's illumination. It appears that the Sony and Thomson DTC detectors don't have the same maximum spectral sensitivity (530 and 800 nm) and that a power of 50mW is enough for the considered mounting (4W in 1986).

- if the projection and resumption optics as well as the captors can influence the value of an image, the source stays the essential elements of its quality. The modulation resulting from using a diode is lower than the one obtained with the He-Ne laser (in percentage: 67 against 75). Using a coating still seems necessary for powers of 100mW, on natural teeth (in percentage: 70 against 10).
- linked to physical and geometrical parameters, the speckle is the result of parasite interferences superposing to the physical phenomena that is happening. However, in our case whatever the laser source used, the grain diameters:

($\acute{\varepsilon} - 1.22\lambda\ .\ L/D$)
is identical and negligible with regards to the pixels dimensions of the DTC captors (34 per PEL on average).

It is still true that their suppression is necessary to get a good modulation quality.
About the sources:

- the laser diodes are remarkably compact, they can, because of their dimensions, perfectly integrate the tri dimensional capture probe. The low life span is a recurring disadvantage but we mustn't forget that adding a Pelletier can multiply it by 2 or 4. However, this component stays currently a low power instrument and very sensitive to parasites from electrical networks. However, we were able to adapt it successfully.
- Argon laser is very powerful. Cooled with air or water, it is the best of soruces for this type of application. A remarkable compromise between power and width of spectral rays, its attitude on the tooth insures a correct transfer of the modulation. We can reproach it its high electrical consumption (35A for 208 Volts) and water consumption (8l/h) as well as being bulky.
- He-Ne laser is interesting for any application if the artificial vision domaine, it was integrated in 1984 in experimental probes. However, its low power compared with its size lead us to be much more reserved on its use in the future.

We can today define what the mounting must be:
-laser diode source (200nW)
-projection and diverging resumption
-coating for a low flux
-anti speckle filter (HENNSON/BERTIN patent)
-Sony and I2S captor and camera
-well known characteristics optical system

1.3-5 Principal of research and calculation of phase

We can remember there is a direct link between the Φ "object/reference" phase difference and the height of the object with regards to the same reference plan.
We also know that the intensity in point is given by the formula:

$I = a + b \cos \Phi$ (with Φ is the phase = $\int_0^x \frac{2\pi}{p} dx$)

Φ becomes equal to itself for each 2π period, so we can talk restrictively of what happens between 0 and 2π and present the real phase under the form:

$$\phi = \varphi + 2\pi N$$

$$\text{où } \phi = \varphi \quad \text{modulo } 2\pi$$

Now let's suppose that instead of envisaging only one coding, we try several slightly off. We thus realise N images such as the coding of each of them is moved from 2π /N with regards to each other. For four images, the value will be

2π/ 4 = π / 2 for the first one

2 x 2π / 4 = π for the second

2 x 3π / 4 = 6π /4 pour the third

2π or 0 for the fourth image.

We classically express this function by 2kπ / N.
With K is the number of the image and N the number of images.

We have for objective to know the phase of the object which by difference with the phase of the reference plan will enable us to know the altitude (z) of the object with regards to the reference plan. The only thing we received from the object, except the (xy) value of a pixel, is the light intensity. WE had, as the intensity on the object, the formula:

$$Ik\ (xy) = a(xy) + b(xy)\ \cos(\Phi(xy))$$

This is true for a non off phase.
Is we have a gap of 2kπ / N, from the phase to the origin, the value I will be on the object (in xy) influenced by a gap of 2kπ / N.

$$Ik = a\ (xy) + b\ (xy)\ (\ \varphi + \frac{2k\pi}{N}\ )$$

And on the reference plan, the same x point has for intensity

$$I_R = a_R + b_R \cos\left(\frac{2\pi}{Po}\ ox + \frac{2k\pi}{N}\right) \quad \text{voir } (1)$$

Moreover, we know the value of $\sin\left(\frac{2k\pi}{N}\right)$ et $\cos\left(\frac{2k\pi}{N}\right)$ with regards to the image number (gap at the origin).
If we calculate this rapport:

$$R = \frac{-\mathcal{E} I_k \sin\left(\frac{2k\pi}{N}\right)}{\mathcal{E} I_k \cos\left(\frac{2k\pi}{N}\right)} \quad \text{où } I_k = a + b\cos\left(\varphi + \frac{2k\pi}{N}\right)$$

We demonstrate that it is equal to:

$$R = \frac{\sin\varphi}{\cos\varphi} = \mathrm{Tg}\,\varphi$$

$$\text{donc :} \quad R = \mathrm{ArcTg}\ R$$

$$\text{donc ::} \quad R = \mathrm{Tg}\,\varphi = \frac{\sin\varphi}{\cos\varphi} = \frac{-\mathcal{E} I_k \sin\left(\frac{2k\pi}{N}\right)}{\mathcal{E} I_k \cos\left(\frac{2k\pi}{N}\right)}$$

If on the CCD, when receiving the image, we multiply at the level of each pixel, the intensity sin 2π/N of the used weft and by the cos of this same weft and if we do the rapport we get the value of the phase we want.

By measuring the intensity, we find the height by difference with the reference table.
In fact $\varphi = \mathrm{ArcTg} \quad R = \mathrm{ArcTg}\dfrac{-\mathcal{E} I_k \sin\left(\frac{2k\pi}{N}\right)}{\mathcal{E} I_k \cos\left(\frac{2k\pi}{N}\right)}$

To get a network of high enough contrast and without any thermal and mechanical effects, we have created a fringes field with a Wollaston whose fringe dimensions given by the formula:

$$P = \frac{\lambda}{2\Delta n\ \mathrm{tg}\,\Theta}$$

Where Θ is the image of Wollaston's prism
Δn difference of material index.

The method, thus described, enables us to hope for a precision of P/100 for a dimension between 1 and 1.5mm (HENNSON patent n° 87 02339).

In the dental system, the CCD described in paragraph 1.3 will received 4 images:

$$I_0 = a + b\cos\varphi$$
$$I_1 = a + b\cos\left(\varphi + \frac{\pi}{2}\right) = a - b\sin\varphi$$
$$I_2 = a + b\cos(\varphi + \pi) = a - b\cos\varphi$$
$$I_3 = a + b\cos\left(\varphi + \frac{3\pi}{2}\right) = a + b\sin\varphi$$

To be precise, we could increase the view step but the necessary reading time (20ms) added to the necessary transfer time (20ms) would make the moving a problem.

$$\varphi = \text{ArcTg}\ \frac{-\,\Sigma\, I_k \sin\left(\frac{2k\pi}{N}\right)}{\Sigma\, I_k \cos\left(\frac{2k\pi}{N}\right)} = \frac{-\,(\text{ somme des sinus })\, I_k}{\text{somme des cosinus } I_k}$$

$$= \text{ArcTg}\ \frac{-\,(I_0 \sin O + I_1 \sin \pi/2 + I_2 \sin \pi + I_3 \sin 3\pi/2)}{I_0 \cos O + I_1 \cos \pi/2 + I_2 \cos \pi + I_3 \cos 3\pi/2}$$

Which, by simplification shows:

$$\varphi = \text{ArcTg}\ \frac{I_3 - I_1}{I_0 - I_2}$$

So the phase can be simply calculated from a n intensity difference on the CCD pixel at the level of 4 images.

The calculation of the phase needs a subtracter, a divider and finally an arc calculation module.

With only 2 blades, the formula is:

$$\varphi = \text{Arc tg}\ \frac{(I_0 + I_2) - 2I_1}{I_0 - I_2}$$

1.3-6 Calculation of the impression's relief

Thanks to the intensities measurements for each point of the CCD, we have calculated on the one hand the phase on a reference plan and on the other hand the phase on an object. These two phases enabled us to know the value of the third dimension (z) of the object:

$Z = C\ \Delta\varphi$

The value of the other two dimensions (x and y) is simply obtained by the position (address) of the pixel on the CCD. To get the real values of x and y of the object, it is necessary to note the distances on the CCD from the object, taking into account the distance and the specific characteristics of the mounting on the reference plan. These characteristics are called of calibration and are calculated in the manufacturing plant and reported to the measured value of each impression. The used formulas are as follows:

$x = \varphi x + Px\ z$

$y = \varphi y + Py\ z$ Where φ and P are calibration coefficients.

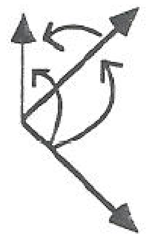
1.3-7 Surface correlations

Capturing an impression isn't enough, as we have explained numerous times during the Moermann process analysis. It is necessary to capture several views (vestibular, lingual, occlusal, antagonist) and occlusion views. To gat the totality of the objects and their functional rapport (occlusion) we must do the correlation operation.

After each impression capture, the treatment system has semi points referenced to the view capture axis. The surface correlation enables the gathering of all the semi points in the same relief whose coordinates are defined with regards to one and only common referential. For that, we dispose of the analysed for, the points per shape analysis enable the detection of each view their i,j position then by interpolation on the relief, their x,y,z value. An automatic association system of the points enables the mating of the identical points of two different views. Three points at least are necessary. If there are more than three, we choose the ones who are in the best coded zones (type 3 zone). The points having been associated, the system calculates the transformation matrices enabling the referencing of each view in the common axis system. We apply a transformation matrix, with T translation factor. In the direct 1 Cartesian

S (x,y,z) —⊖→ S (X,Y,Z)

$$\begin{vmatrix} x \\ y \\ z \\ 1 \end{vmatrix} = \begin{vmatrix} \text{coefficient de translation} & T_x \\ \text{coefficient de translation} & T_y \\ \text{coefficient de translation} & T_z \\ 000 & 1 \end{vmatrix} \begin{vmatrix} X \\ Y \\ Z \\ 1 \end{vmatrix}$$



sens contraire des aiguilles d'une montre

These points can have particular shapes, mainly triangles or crosses which facilitate their detection. They have the inconvenience of not being easy to lay and can during in mouth handlings fall and be swallowed by the patient. Numerous tries have been made between 1985 and 1987 in order to choose their shapes. We think today that we must place triangles with large sides on a precise plan and on the vestibular face of the arch of the future crown and on the antagonist vestibular face. We then place the marking triangle appearing on the video screen and make the summits correspond and for each view. The marking point, that is to say one of the three summits of the triangle (a plan inside the space defined y three points), will be defined at the intersection of side lines. However, it is possible that this intersection be superior to a pixel. A method, in this case, consists of lining the image, by grey levels histogram analysis then to select the black blots of a convenient size (for example, by calculating the number of pixels inside a blot) and finally give the gravity center pondered by levels of grey inside these micro blots. The histogram analysis can be a method by entropy maximisation, a discriminating factorial analysis, a study of moments or separation by Gauss curve, the choice depends on the studied cases.

1.3-8 Data coding

As we will see in the chapter about CAD/CAM, it is necessary to present the whole set of data issued from the impression capture in a logical manner for CAD so that it can build the study model and working model. Moreover, it will be necessary to address the same CAD with complementary data such as:

- the ray lines (occlusal gutter)
- eventually the finishing line
- the indication of the occlusal view, the clenched teeth view and the antagonist view.

From the semi points and following the isoparameters (at constant x), the lines lean on the surface. The lines are obtained by smoothing and are of polynomial type or parametric type. It enables a considerable reduction of data without being a problem for the results precision. We can only keep the parameters or coefficient of each curve.

1.4 The dental material

We have four great parts:

- the probe (with the camera)
- the source (laser)
- the data treatment cards
- the video screen
- the interactive elements

1.4-1 Source

It has been described in chapter 1.3-4

1.4-2 **Probe** (fig 8. 9 and 10)

As is shown by the attached figure, it is about a compact block with:

- 2 endoscopes (image retaking and weft projection)
- An optical system generating fringes (Wollaston) and creating gaps (continuous engine barrel)
- A 512 x 512 pixel CCD with micro IS2 camera

It gets 12 volts power.

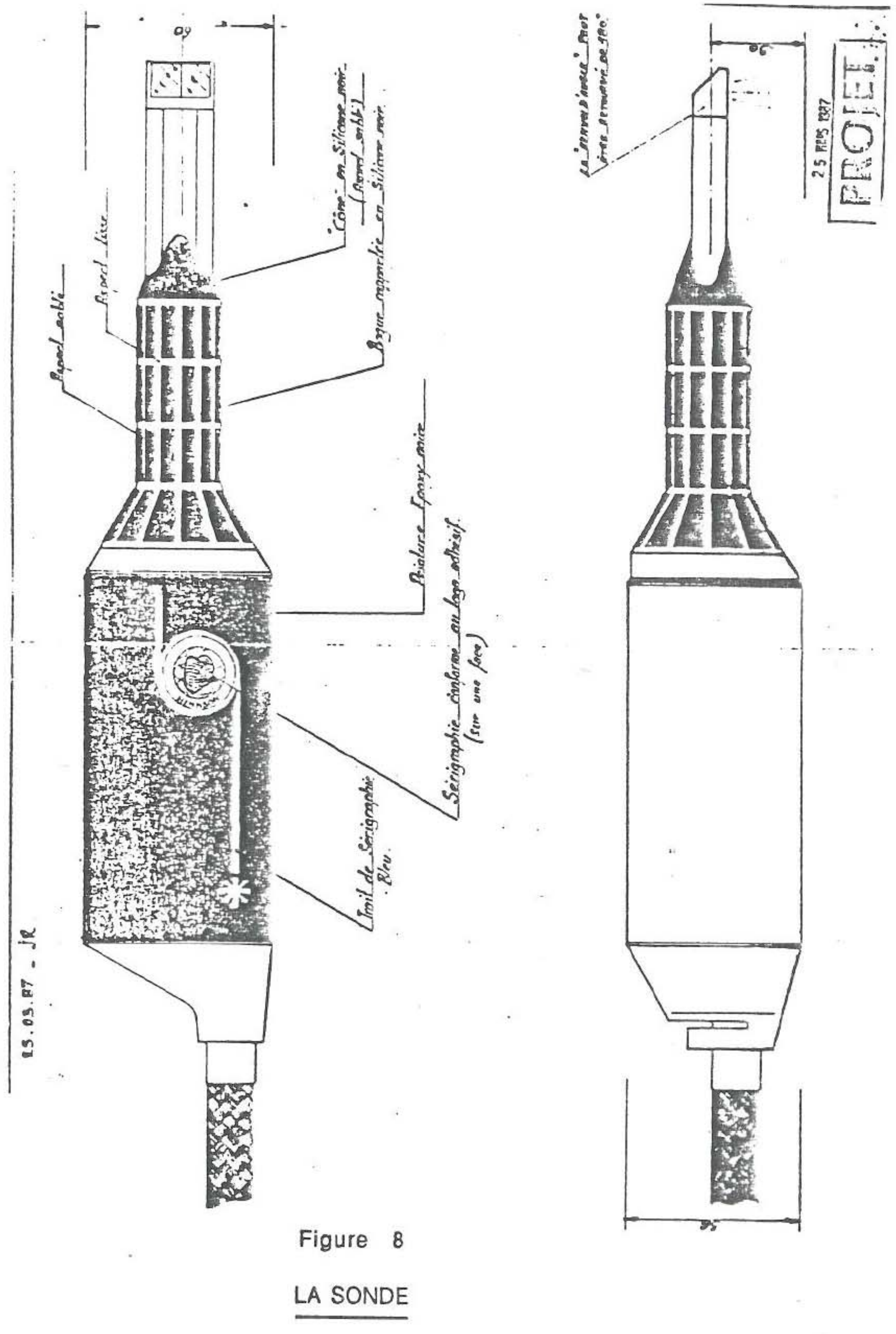


Figure 8

LA SONDE

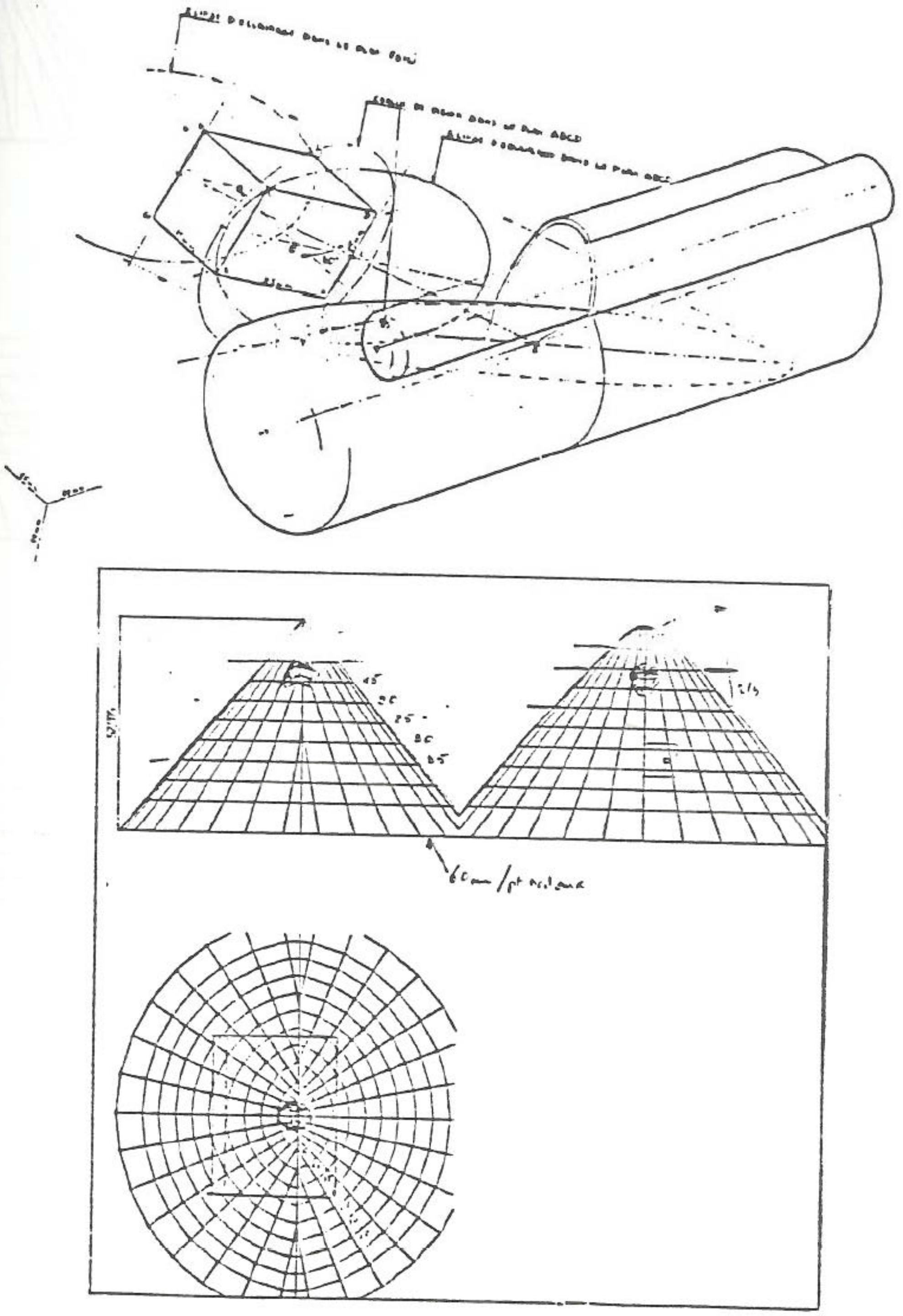


Figure 9

LE CHAMP DE LA SONDE OPTIQUE

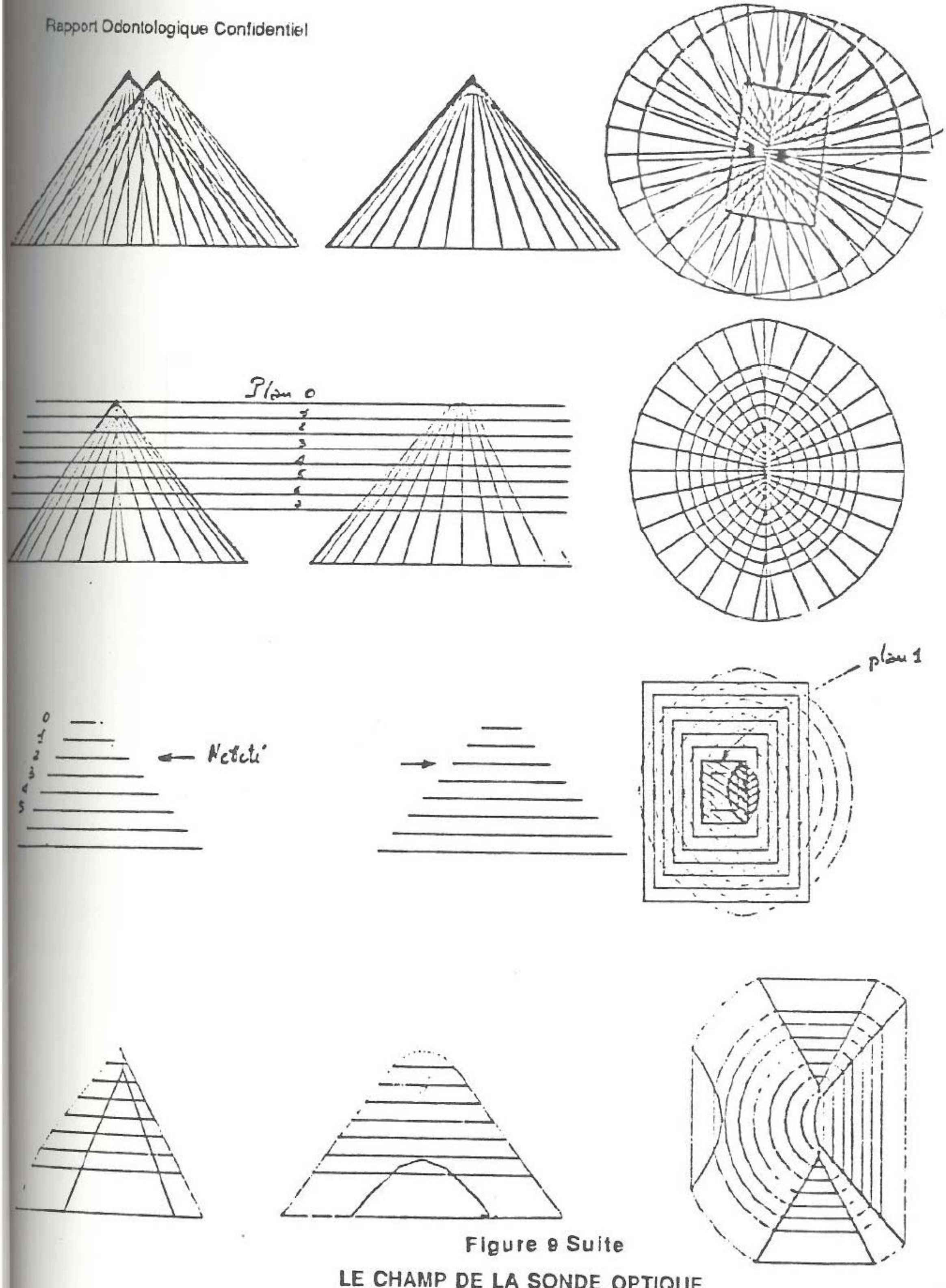


Figure 9 Suite

LE CHAMP DE LA SONDE OPTIQUE

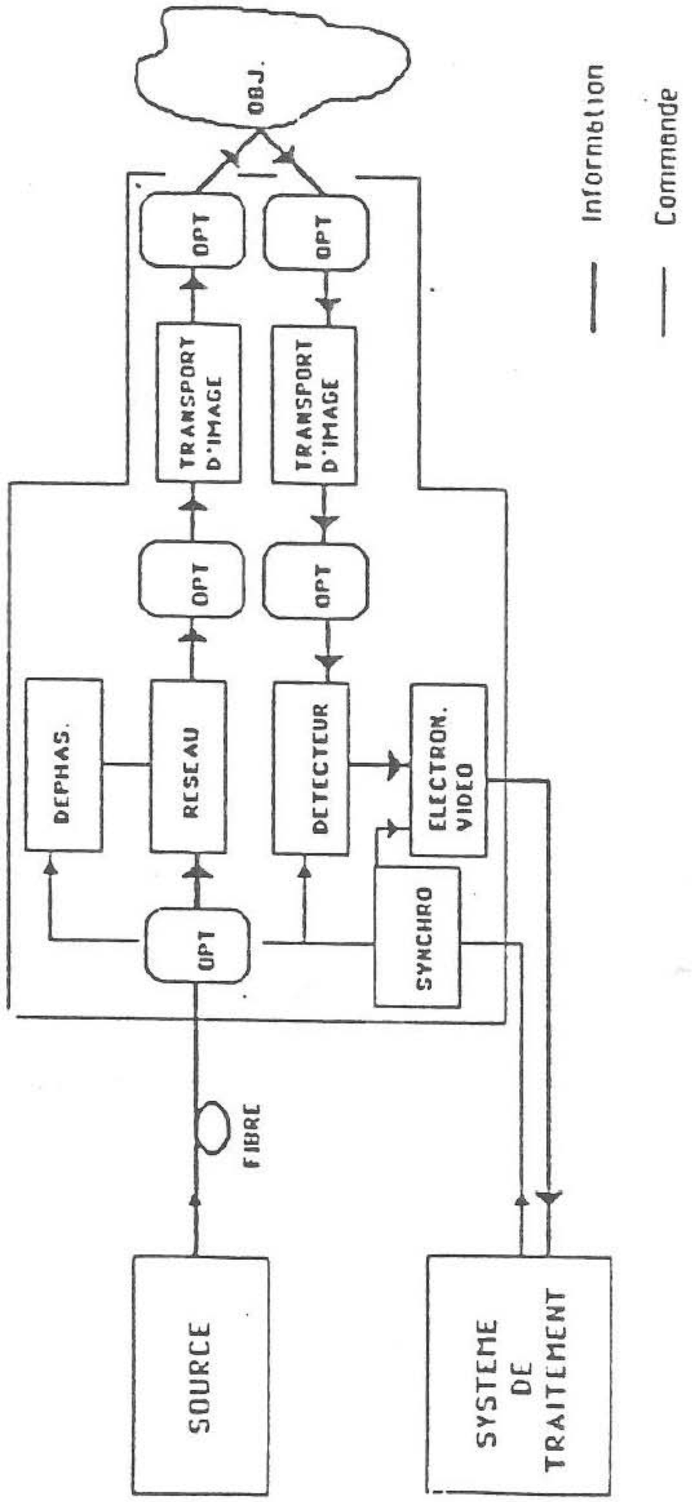


Figure 10

DESCRIPTION DE LA SONDE
Voie de reprise/voie d'observation

1.4-3 Video display screen

It is a classic 625 lines colours video screen

1.4-4 Interactive elements (figure 11)

We find:

a) the impression capture indication pedal (starting)
b) the mouse and interactive table to indicate the marking points, the lines, the finishing lines, validate or cancel an impression and say which are occlusal, occlusion and antagonist impressions

These elements are of extremely simple handling:

a) the pedal: all or nothing data by simple pressure
b) the table: it is divided into a moving zone and a dialogue with 10 information zone: validate, cancel, marking points, finishing line, interaction, lines, occlusal impression, antagonist impression, other impressions, clenched teeth impression.
c) The mouse: has three buttons: indication of validation (centre), zoom + (left) and zoom – (right). Moving the mouse and its functioning on a dialogue zone will make appear the 10 instructions, validate the latter. Finally a movement on the right when we are in zoom, past the zoom zone, cancels the latter. We need less than 15 minutes to learn how to handle this interaction.

1.4-5 Treatment system (figure 11)

The treatment system is composed of a box on which are connected the probe and the light source. It contains the command electronics and the synchronisation of different modules (camera, laser, engine, calculation processor, memory…), the treatment electronics and calculation electronics and electrical power supply.

We note the following connectors:

- for the fiber coming from the light source
- for the probe
- for the visualisation screen relays
- for the interactive console
- for the data communication
- for the command pedal
- for the 220V power supply

The heart of the system is constituted of a set of electronic modules linked to each other with three buses. Each of these modules can easily be contained on an electronic card. The modules are:

- the central unit
- the calculation live memory
- the specialised interface
- the video signal treatment
- the image memory
- the specialised calculation processor

The buses are:

- the digital video bus
- the processor bus
- the system bus

The digital video bus is synchronised to the television sweeping of the visualisation screen. It insures the transfer of the images from the optical probe towards the images memory through the analogue digital 8 bits converter (256 levels of grey), and on the opposite, visualises the image. The data processor and address bus enables a very fast communication (5 to 10 Mhz) between the processor card and the image card. The system bus insures the communication between different modules of the system.

The central unit cad insures the global management of the treatment system (dialogue with the dentist, surveillance, folders, images and impressions). It is composed of 32 bits a micro processor. The live calculation memory keeps the data of each impression (with possible access) and the stocking of the calculations. The specialised interface card insures the electronic management of the ins/outs. It is composed of 2 groups of sub-groups. The first filters and synchronises the source and the engine of the probe; the second pilots the pedal and the external links. The video treatment card insures the analogue treatment of the image. It is used as interface with the camera disposed inside the probe (CCD detector) and the visualisation screen.

The images memories are composed of 4 image plans of 512 x 512 x 8 bits and of a graphic plan of 512 x 512 x 4 bits which enables the rapid stocking of the impressions which is necessary to insure the in mouth captures. The processor card enables the quick treatment of the images. It is constituted of a processor associated to the local memories of the works. The memories are of 4 types (programming, in/out data and internal registry). It is in this processor that are done all the calculations described previously (phases).

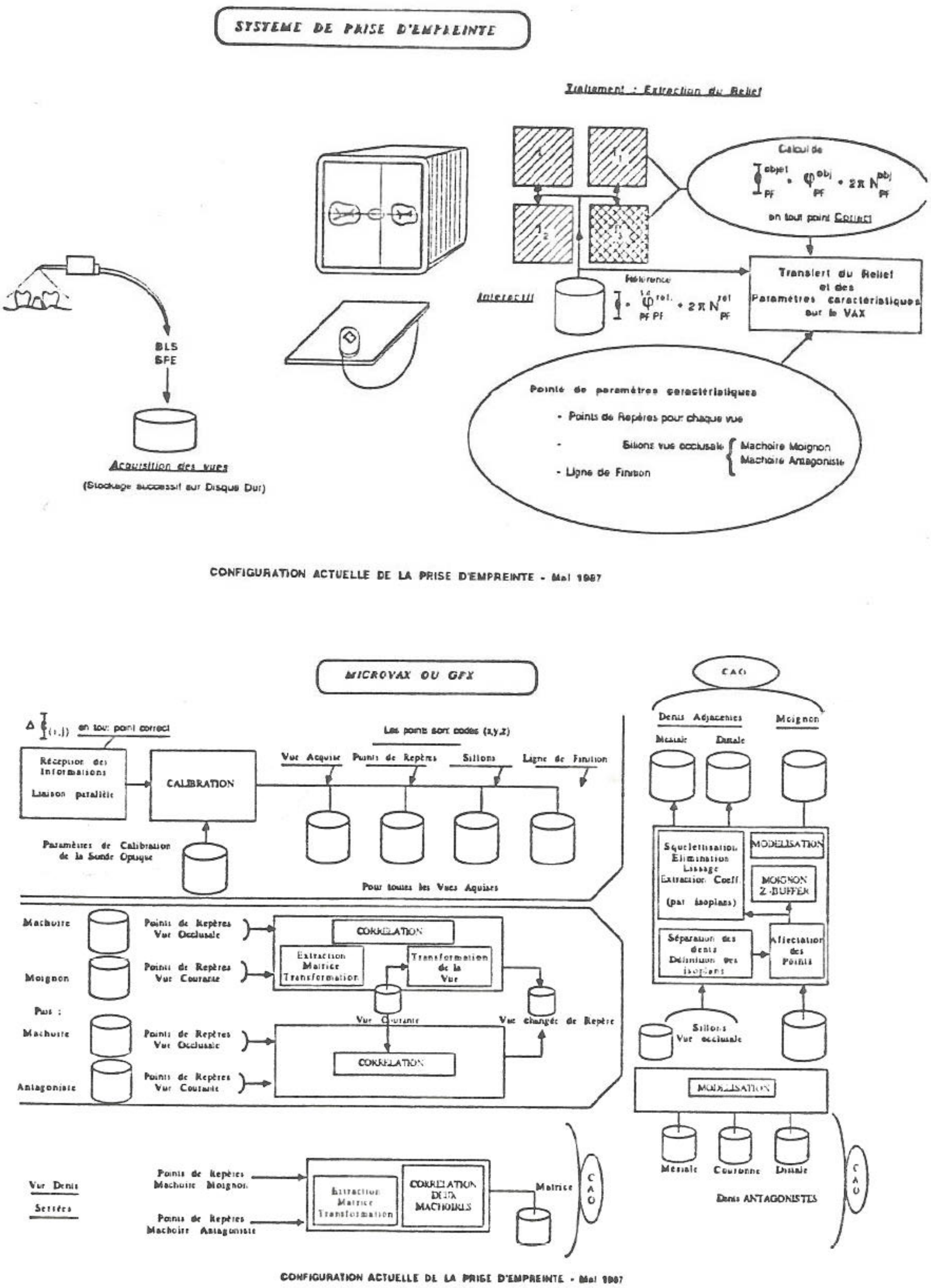


Figure 11

LA SONDE ET LE TRAITEMENT DE L'IMAGE

1.5 Clinical gesture

1.5-1 Ergonomics (figure 8, 12, 13)

A very thorough ergonomics study has defined the presentation and handling of the device criteria. Particularly, the triple function pedal and the paddle have disappeared, the shape of the probe and the number of connexions has diminished, making the work and the handling easier. At the same time, a study of biocompatibility has been started with the Faculty of Marseille. The set of components have been crushed and analysed in order to be certain of the absence of risk for the patient. Also, some coatings and paints have been evicted to the profit of other ones having an AFNOR "food" label. Also, a very thorough sterilisation study has enabled the aiming of sterilisers and the choice of coating which accepts them.

Facing this presentation, we are more capable of noticing the extraordinary work that was the implementation of this dental probe and the quickness with which this work has been led by HENNSON (3 year follow-up).

There is a last problem left: the weight. It is actually the object of reflexion and th subject of essays. We don't reject the fact of reaching 20 mg but the current weight makes us use an articulated arm mounted on the block's potency. The arm has the advantage of reducing the movement too present when the action is taking place (160 ms).

1.5-2 Impression (figure 14)

This handling is described with the use of coating (CO_2 laser diode).

The patient sits on the seat and has nothing particular to do (other than try not to move during the impression capture, as during X ray examinations). A layer of coating is spread regularly on the surface of the teeth with a spray. The dentist fixes, on the vestibular faces, a special correlation system at the top and bottom, as close as possible to the preparation without risking being in the way of the impression captures. He installs the camera's endoscope inside the patient's mouth and captures the impressions. He is practically not limited in time since "recharging" his camera between two captures takes less than 10s and will be even faster later. It is possible to take up to 12 shots (2 complelt maxillary hemis) in 1 minute 30 seconds. We see that the most complex impression capture time won't be longer than the time it took the traditional method (3mn).

The probe is simply handled and the arm enables:

- to avoid a fall
- to stabilise the hand during the capture
- to ease the weight

Moreover, it doesn't limit the movements and rotations.

Poids de l'arrière	Poids de la Sonde	Toute en longueur	révolver	tout en longueur avec poignée
150g	200g	X		
200g	250g	X		
250g	300g	X		
300g	350g	X		
350g	400g	X		
400g	450g	X		
450g	500g	X	X	X
500g	550g		X	X
550g	600g		X	X
600g et au delà				X

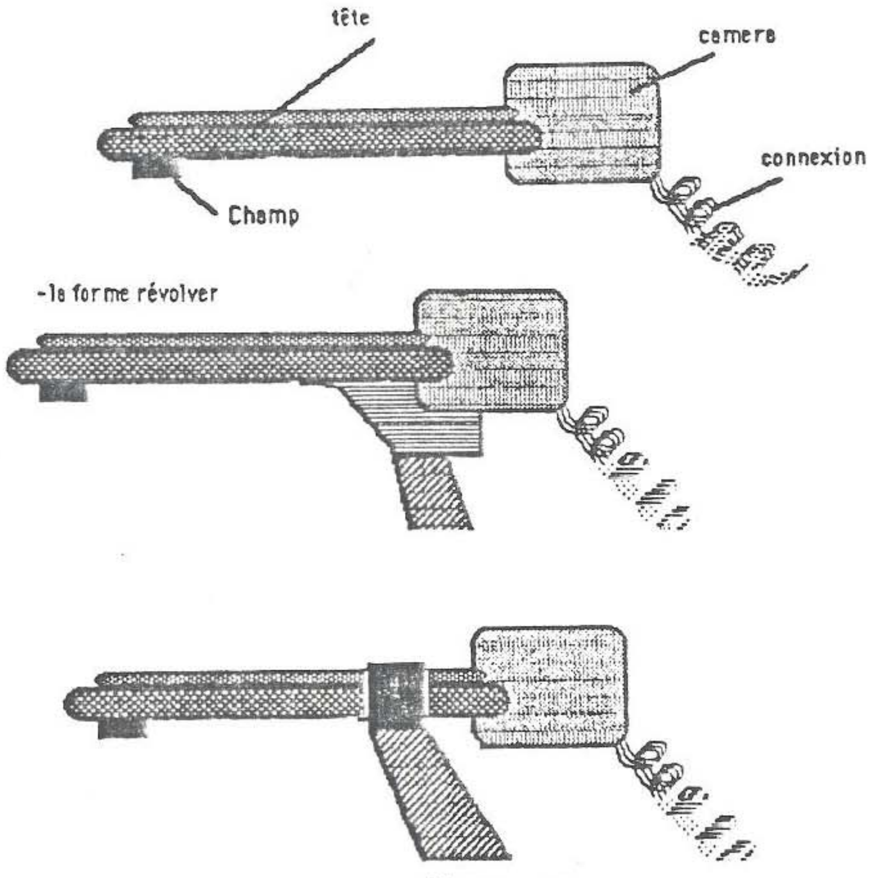


Figure 12

ERGONOMIE

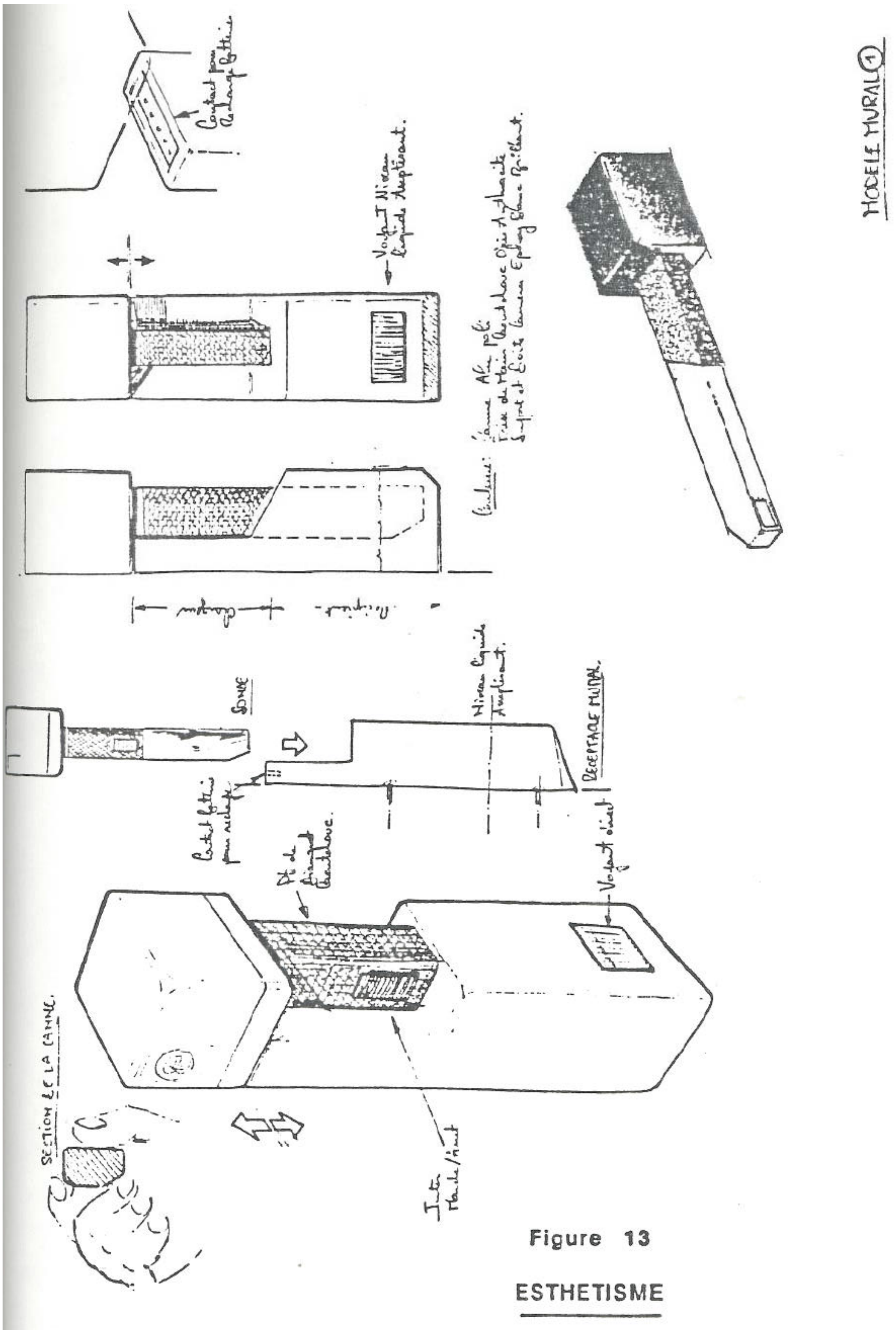


Figure 13

ESTHETISME

1.5-3 Image treatment

This phase is divided in two parts: an interactive phase of the dentist and an automatic phase totally transparent for the dentist.

1.5-3.1 Interactive phase

A few seconds after the last impression capture appears on the screen, in the shape of small images called in this case labels, the whole set of impressions captured by the dentist. He will be able when he wants, to validate or cancel them. Moreover, he will have to indicate to the computer the different identities of the impressions on the following order:
a) occlusal impression: this impression will help indicate the finishing line. Moreover, he must:

- mark the correlation triangle
- indicate in the shape of 3 vector (6 points) from the mesial to the distal the furrows lines (occlusal gutter). It is this indication which will enable the CAD modelling in isoplan (see further along).

b) antagonist impression: the second to signal, eventhough it is not imposed
c) "other impressions" without any precise order: there is only one indication for the dentist at the level of the "other" and antagonist impression, it is the marking triangle for the correlations
d) clenched teeth impression: this impression enables the software to know the occlusion position. All you need to do is indicate to the computer the position of the correlation triangle of the maxillary and the mandibule.

One must note that for each impression it is possible to trace a part of the finishing line. The software will link these portions into one line at the time of the correlation and will propose it to the dentist on the CAD screen.

Note: it is planned that an automatic recognition of the correlation triangles is set up. This means that only the gutter and possibly the finishing line will have to be indicated on the impressions. The handling will then be as follows: we ask the dentist to capture his impressions in the order reminded on the screen:

1. clenched teeth impression
2. antagonist impression
3. occlusal impression
4. other impressions

and this with an automatic detection of the correlation triangles. The practioner will only have to trace the gutter on the occlusal impression which will automatically appear after the last impression capture (3 second press on the pedal) and possibly portions of the finishing line. This will represent less than 3 minutes of interactive action. We currently work towards this.

1.5-3.2 Automatic phase

As we have said earlier, with these impressions captured by the dentist, the image treatment software calculated the relief (φ_0 - φ_R) and insure the correlation of the impressions. You will need today to count 1 minute per impression and 1,5 minute of correlation. This length of time can be shortened in the future. The dentist can then turn towards the CAD screen as he will start the second part of the handling.

1.6 Precision of optical impression

INTRODUCTION

It isn't very to talk about the precision of a system objectively. The complexity of the dental CAD/CAM chain, the diversity of the used technologies and the objectives of each link as well as the use conditions don't enable to give a sure factor of global precision.

However, all along this project, we have attached ourselves to divide, specifically on the measurement front, the theoretical parameters issued from error calculations and observed experimental values. The theoretical parameters have been evaluated depending on mathematical models enabling the simulation on a computer of different possible technological choices.

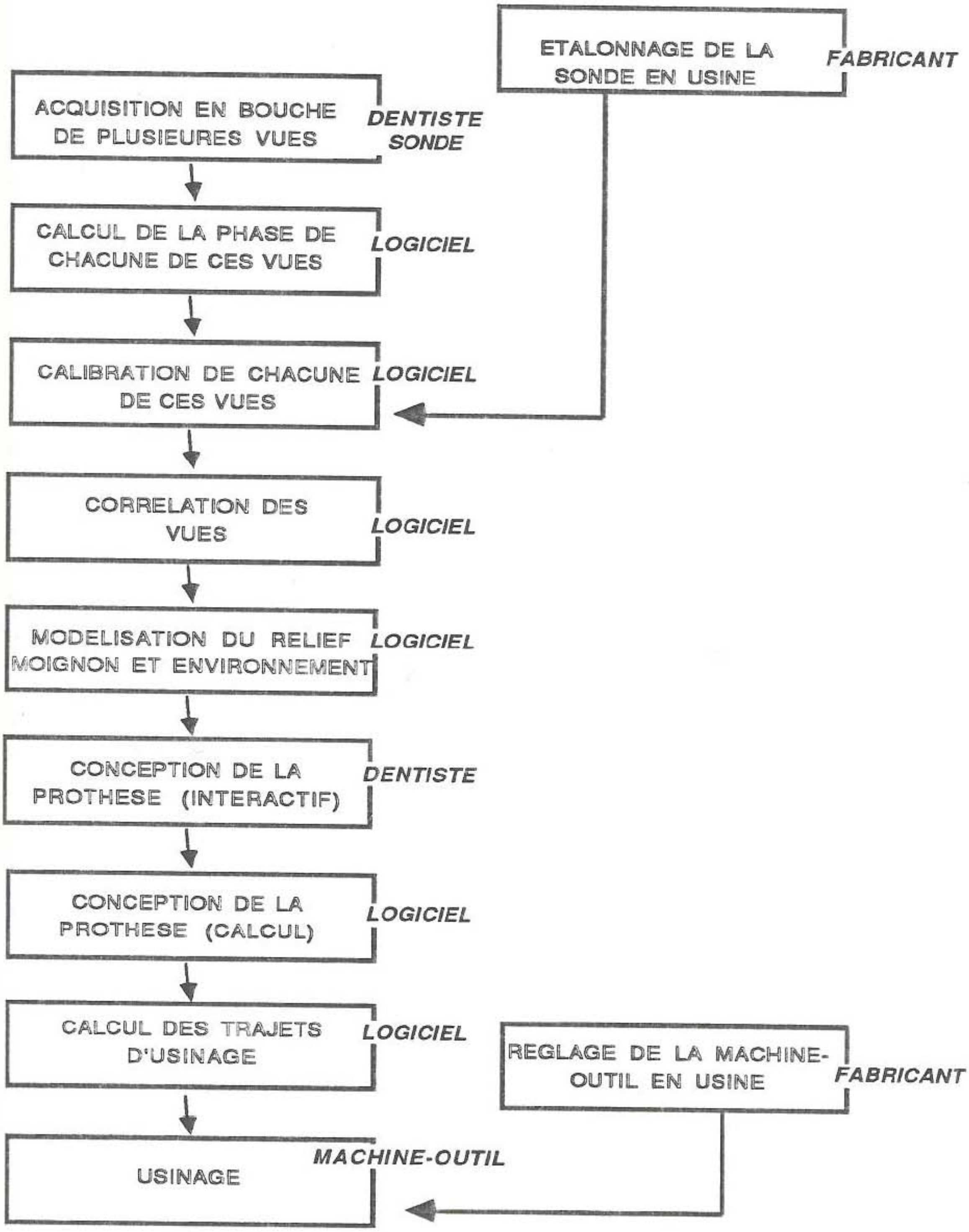
In 1986, these studies have enabled the conclusion on two essential points:

- the used processes are potentially very precise with regards to their application in odontology and so they have no limit in time
- the first models had insufficient levels of precision even if they were satisfying within the development framework (around 200µ) and the implementation of affordable and reasonable technologies will enable the hope of factor 10 gain.

At the end of the works in 1986 and until this day have enabled the validation of some hypotheses of amelioration, the compilation and analysis of experimentation results and the perfection of our knowledge of the global attitude of the system.

From the point of view of precision, we will distinguish:

- the optical probe and the images acquisition sytem (SPE)
- the modelling of captured reliefs
- the prosthesis conception (CAD)
- the digital command tool machine (CAM)



-VCFAO DENTAIRE-
INTERVENANTS SUR LA PRECISION

1.6-1 Reminder on precision in dentistry

Numerous books (Phillips) and publications have been totally or partially written about the estimation of what precision in dentistry must be. A certain number of authors, only during these oral reports, haven't hesitated to talk about 20µ of precision in dentistry. It stays stupid with regards to what must be the physical stability of the environment if we don't want to induce variations of our piece of more or less 20µ. We recommend to the reader who wants to learn with the excellent book of Brassière and Gaignebet's Metrology at Dunod's (1966).

But what is really dental precision in current exercice (and not on regular dies). Some students such as Ph. Jourdan (Thesis n° 42.23.84.44) have tried to answer this question. Articles as interesting as contradictory can be read in professional press. Old as well as recent studies have had this value for subject. Each of these steps tends to want to reveal exactly what could be the famous precision everyone talks about and that is very rarely seen inside a mouth (Cahier de Prothèse, thesis…) to get to the following conclusions: 100µ is within the domain of reason for set of chains as complex as the realisation of a unitary element, this "precision" can reach more or less 800µ for a complete bridge (see Roucoules, ID n°45).

Today, after an in depth study on precision, we note 2 types of articles, classical and recent ones. If classical articles can't be questioned, recent ones are very random. They will be listed according to their youth.

ARTICLES RECENTS

R.A. OLIVA	J. Prost.dent.,	1987	58	:	29-35
SCHELB	J. Prost.dent.,	1987	58	:	19-22
D.R. DAVIS	J. Prost.dent.,	1987	58	:	229-234
W.M. TAY	Quintessence,	1987	18	:	599-602
R. OMAR	J. Prost.dent.,	1987	58	:	13-19

ARTICLES CLASSIQUES

MCLEAN J.W. (Coll.),	Br.Dent.J.,(1971) 107-111, 120 µm
BJORN A.L. (Coll.),	Odontal Rev. 21,(1970) 137-346, 200 µm
SATO J. (coll.),	J. Prostodont. Rest. Dent.,(1986) 6, 9-20, 50 µm

Results obtained by these authors clearly show that, to hope for a precision above 100µ is a sweet illusion and even in experimental laboratories. Moreover, by studying numbers by cycle portions we obtained more than convincing results.

TAY	≈ 100 µm	- average level (complete process)
SCHELB	≈ 20 µm	- impression + plaster average level (of ceramics)
OMAR	≈ 85 µm	
	≈ 25 µm	
	≈ 40 µm	
DAVIS	≈ 15 µm	- deformation of moulding wax

Finally a certain number of speakers pretend to a precision of 50µ in occlusal contact. This appears evidently stupid as:

1. ideal precision for confection doesn't go below 100µ
2. tooth growth during a week between the preparation of the tooth can be over 250µ.

It seems that we have in fact an occlusal tweaking by compensation of the tooth's growth and bone biosynthesis (confidential). W e finish by reminding you of the Degrange article.

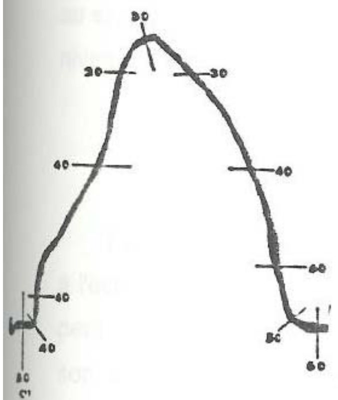
DEGRANGE M. et coll. J. BIOMATERIAUX DENTAIRES,(1985),1,N°2,p 133-141

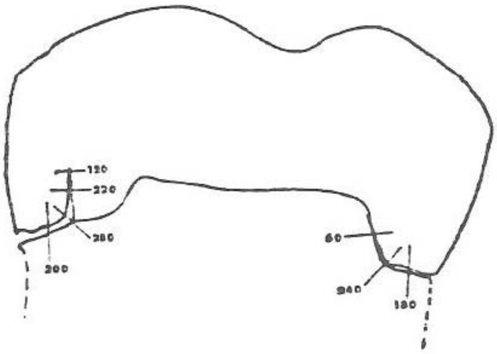
Prouving there exist in each point a random character of duplication of surfaces bringing to a quantic level any reproduction whose precision must be lower than 25µ.

TABLE 1.—CEMENT FILM THICKNESS AT DIFFERENT REGIONS OF RESTORATIONS (μM)

	Axial wall	Occlusal floor	Mesio-cervical external line angle	Mesio-cervical internal line angle	Disto-cervical external line angle	Disto-cervical internal line angle
MOD inlay	105·3 ± 71·9	142·0 ± 94·6	60·0 ± 71·8	155·5 ± 139·5	68·0 ± 89·9	120·5 ± 89·0
Class II inlay	49·5 ± 28·1	99·5 ± 73·1	38·4 ± 28·9[2]	78·3 ± 65·2[2]	85·9 ± 86·0[3]	—
Metal ceramic crown	75·4 ± 38·0	138·6 ± 61·9	66·7 ± 60·8	86·7 ± 59·3	26·1 ± 26·2	56·7 ± 48·5
Porcelain jacket crown (aluminous)	92·9 ± 53·1	112·3 ± 66·4	77·7 ± 45·6[1]	99·6 ± 59·5[1]	48·8 ± 51·1[1]	70·0 ± 46·0[1]

[1]For PJC, labio-lingual aspect determined.
[2]Class II—Mesial/distal—cervical line angle.
[3]Class II—Disto-occlusal external line angle measured.





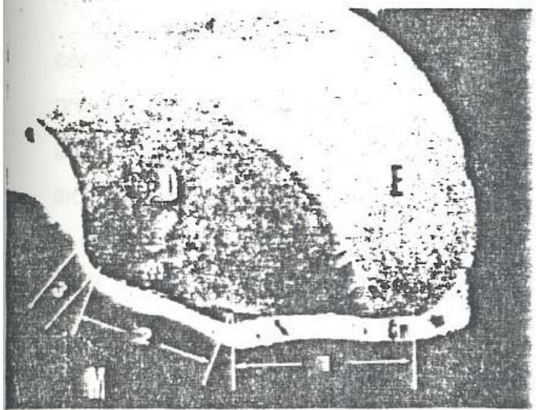


FIG. 6.—(Cm) cement; (D) dentine; (E) enamel; (M) metal.

FIG. 7.—(D) dentine; (E) enamel.

Figure 14

LA PRECISION EN DENTISTERIE

1.6-2 Precision of optical probe

1.6-2.1 Precision of phase measurement

When the dentist captures an impression of the environment of the in mouth preparation, he gives basic images to the system (deformed coding) of the phase calculation. We understand at this level that 3 principal parameters will alter the measurement precision.

- projected coding quality
- general contrast of observed image
- general dynamics of observed image

By pure analogy, when we do photography, we can assimilate the quality of coding to lighting, contrast to grain and focus, and finally dynamics to the clarity of the photo. We can always, when the camera is bad or the operator has either moved or closed the objective too much, "correct" the photo during development but the results are often unsatisfying except if the produced effects are voluntarily considered as artistic. It is better, to have a good photo, to have a good subject, a correct objective , to light the scene with care, to have a good quality film and a lot of method and capability.

The multitude of parameters which influence the measurement precision of the phase has led us to experimentally globally consider it in terms of reproducibility. The employed protocol is to repeat a series of measurements on objects known in advance an in identical conditions each time. A typical difference calculation enables us to obtain a good indicator of reproducibility. Then we vary a conditional parameter, for example the distance of the object with the probe or the light energy emitter or the camera gain, which enable us to differentiate the influences of each element.

1.6-2.1.1 Analysis of quality of projected coding

a) Noise improvement

The principal noises which we can observe easily, come from the conjoined use of laser and optical rays (fibers, lenses, prisms, blades) which enable us to "build" the sinusoidal coding. Since November 1986, we have proceeded to the improvement of the speckle mixer (adaptation of the frequency of the vibrations of the fiber and associated digital filtrering) and the use of a 600µ fiber instead of 125µ, thus deleting certain parasite strioscopy effects. These two improvements of optica noise however diminish the fringes contrast.

b) Coding dimension (fringes period)

The choice of coding dimension is a very important parameter.

The value of the dimension is directly linked to the measurement of z. The smaller a coding dimension is, the greater the precision. However, there are technological limits to the lowering of this parameter, notably in the case of micro moiré. It is currently practically impossible to project and observe through endoscopes dimensions smaller than 700µ. Deteriorations brought to codings are too important. An experimental series done inside the laboratories of the BERTIN Company in December 1986, have enabled us to choose a coding dimension of P/50 and P/70. Today we can reasonably say we can get to 1mm.

c) Alignment of coding blades

To correctly realise the extraction of the deformed coding signal phase, it is necessary to acquire 4 images of the same spatially gapped coding. The perfect theoretical gapping corresponds to a quarter of the dimension for each image. We have led two studies enabling the perfect mastering of this gapping between images.

- a modification of the training system of blades of gaps and notably the replacement of continuous current engines by a step by step engine which insures a position stability in time and a good reproducibility of measurement.
- The compensation by software of a possible gap error that can possibly happen during the mounting of the probe (parameters δ_1, δ_2 and μ_0). An additional calibration procedure when the final control of the probes happens enables for each delivered probe, these error parameters and to compensate them during use by the practioner.

Both actions lead to, on the one hand, the insurance of repeatability of functioning of the system and on the other hand, the increase of the measurement precision. We can thus show that certain observed parasite oscillations ("waves") on plan reliefs for example, have been absorbed, which is in accordance with the theory (modulation residual).

1.6-2.1.2 Contrast of fringes

This parameter is very important and we can, to understand it well, assimilate it to a graduated ruler. The neater and visible the marks are, the easier and just the measurement is. We have done, in 1985 and 1986, numerous theoretical studies and some experiments to appreciate the influence of this parameter on the measurement of relief. We are today certain that the phase measurement and also the relief are even more precise when the dynamics of the modulation amplitude is important. We call here "modulation" the periodical component of the observed and acquired coding (otherwise said, what is left of the fringes at the end of the chain). We won't spend anymore time on the theory. However the physical function corresponding to the contrast deterioration is called the **modulation transfer function** (equivalent to the frequency response of a system). This transfer function is always decreasing depending on the frequency. Otherwise said, the tighter the fringe period, the greater the contrast attenuation.

Each element of the chain:

- projection way
- objects – teeth, stumps, gums
- observation way
- camera

contribute to the contrast deterioration.

The chosen coding dimension, the improvement of the endoscopes quality, the use of a coating on the teeth enable us to get, in image memory at the clearness plan level, contrasts from 40 to 60% of the initial contrast.

REMARK: The probe acts as a macro objective. Its field depth is low. The notion of **clearness plan** corresponds to the distance setting we find on classic objectives. The optical impression capture in mouth imposes a reduced bulkiness and a position of the clearness plan (or focus distance). But the fact of approaching the clearness plan lead to a decrease of the field depth.

This means that the closer the focus distance, the faster the fringe contrast attenuation by distancing from the clearness plan (figure 9).

We have tried to clearness plan positions (figure 9):

- at 10mm which leads to a field depth of 7 to 16mm
- at 13mm which leads to a field depth of 8 to 23mm

We see that the field is more important if we remove the clearness plan from the probe. For the practioner, it means obtaining more dental surface per impression capture with a better definition towards a third of the tooth. On the contrary, the positioning inside the mouth is a bit bulkier and the general precision lower because of the homothetic aspect of the optical rays. Trials are underway to definitively fix the position of this clearness plan (between 10 and 13mm).

1.6-2.1.3 Dynamics of observed image

All measurement devices currently known have a measurement span and inside this span, a discretisation of the information. The number of discrete values that can be put inside the measurement span corresponds to the dynamics of the device. In the same manner, any signal has its own dynamics. For comprehension, we can by analogy take a graduated ruler. If the ruler measures 10 cm and has markings every millimetre, its dynamics are 100. It enables the measurement of objects up to 10cm with a precision of 1 millimetre. In the same manner, if a signal evolves, for example between 0 and 1 volt and we observe a noise of 10mV, its dynamics are 100 (we see the relationship which exists between the signal rapport, the noise and the signal dynamics).

We have tried to improve the precision following two axes. The first one consisted of working on the amplitude of the projected coding signal by limiting the noise. The second, to adapt better the camera and digital system dynamics. The conjugation of both axes enable today, with standard technologies to obtain very satisfying results. The lessening of the projected coding noise was seen in paragraph 1.6-2.1.1-a). The introduction of the new CCD cameras (notably with the improvement of the rapport signal on noise) and the new image digitalisation cards with programmable gain and offset enable today to get good yields. Settings are still manual and need to be automated in the future (automatic gain control with blocking system). The digitaliser used id 8 bits that is to say 256 levels of grey which constitute the dynamics of the acquisition system.

1.6-2.1.4 Optimisation of precision of phase measurement

We have defined 3 great precision attack points of the phase measurement. The coding quality, FTM or image contrast and the system's dynamics. These parameters act in a conjoined manner on the final precision of the phase measurement and closely depend several variables. None of these variables is really determining for the improvement of precision. Moreover, some of them act in a dual manner on the final measurement of the relied or the cost of the system.

For example:

- coating contributes to a better contrast and a better measurement precision. However it has the inconvenience of the reported thickness
- lowering the coding periods improves the precision after calibration. However it considerably diminishes the contrast
- the clearness plan position acts in an equivalent manner
- the laser ray wavelength is better in blue for the teeth FTM but better in red for the CCD camera FTM
- digital filtering improves the signal quality (noise) but degrades the contrast
- increase of camera integration time considerably favours the measurement dynamics but increases the movement's influence.

Facing the numerous parameters which act on the phase measurement precision, we needed an indicator measuring their effects. This indicator (called B term) is the number of levels of grey reported to the real amplitude of the observed coding. Otherwise said, the modulation's useful dynamics. This reliable indicator is used during the impression capture in the dental practice as well as during the experimentation of different improved technologies to qualify the done measurements. Moreover, this indicator is known in any measuring point (pixel). The discovery of this indicator is fundamental for the mastering of the future technological evolutions. It is a determining addition to the works of end of 1986.

1.6-2.2 Precision of calibration

The calculation of the (x, y, z) coordinates of the points of the object from their different $\Delta\varphi$ phase and their position (I,J) in the observed image doesn't lead to significant errors (of 1µ) is the mathematical model (see calibration equations) is just and the calibration coefficients are measured with "precision". The calculation only depends on the precision of arithmetic instructions of the calculator.

Until this day, we considered that the theoretical model of the probe was enough to insure, form a correct phase measurement, the precision required for the project. In fact, during the experimentations led since 1986, we have noticed that it wasn't the case (250µ in November 1986, 100µ in September 1987). Despite the care brought to the different evaluation processes of calibration coefficients, the results weren't in accord with the theory. What was the phenomenon that were acting?

Since January 1987, we have started an in depth study of these observations and dissected the probe's functioning. Several factors which we had neglected knowingly appeared limitative for a good precision and have led us to use the mathematical model differently without questioning it.

1.6-2.2.1 Phase linearity

a) Modulation residue

The theoretical calibration equations show us that is we have, in space, a plan at a constant P_Z height of the reference plan, the phase difference in any point must be constant. From a macroscopic point of view, it is true. From a microscopic point of view, it isn't so. We clearly observe oscillations whose frequency is generally two times the one of the projected dimension. We can compare this effect to what a pilot inside a plane very high in the sky would see by looking at the sea. It would look flat. But getting closer, he would see waves.

We have mathematically and experimentally analysed the causes of the parasite oscillations which are double.

- incertitude of blade positioning producing coding gap
- coding parasite interference with itself going through the optics.

We have also noticed that the amplitude of these oscillations increased with the amplitude of the movement of the probe during the measurements. These oscillations which we call "modulation residue" are thankfully stable in space. We have checked on a specific mounting on table that if we move a plan in space from a given position,and if we get back to the starting position, the phase differences before the movement and after are identical.

b) Curving

A second phenomena, easily observable, makes appear on a constant height plan, a phase difference "curving" on the whole plan. We had imagined since 1985 that a phenomenon of this type could happen and had integrated in the calculation of the calibration the possibility of taking it into account by a polynomial approximation. In fact, our model approached the curving effects but only took into account the known field curving phenomenon and appeared insufficient. The observation of these phase curving showed that they came from 2 additional causes much more important than the only field curving:

- the non orthogonality of the lining axes of the optical components
- the non physical existence of a nodal point

We have observed that, in an identical way to modulation residue, the phase curving is stable in space.

1.6-2.2.2 Orthogonalities of axes

In the theoretical calibration model, we must consider certain axes orthogonality properties (see simplified drawing). The hypotheses are as follows:

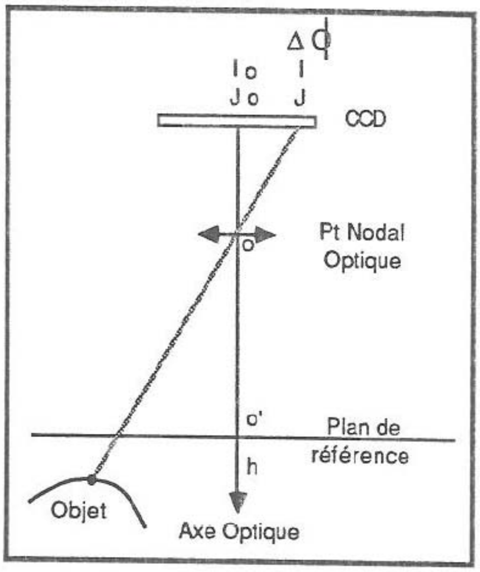
a- the fringes projection, CCD and reference plans are parallel between each other
b- the optics' nodal points are at the same height of the reference plan
c- the optical axes of the coding projection way and the object's observation way are parallel
d- the reference plan is perpendicular to the optic's axes
e- the CCD and the fringes projection plan are perpendicular to the respective optical axes.

The respect of these hypotheses have never been exactly verified but we admit tolerances with regards to these basic positions (which is translated in terms of "tolerable" precision). These tolerances must be respected during the manufacturing or probe calibration steps. They are generally defined according to the final desired precision. In case the tolerances are low enough and effectively obtained, the basic equations of the calibration can be directly applied. There are three of them, defined in the appendix. Let's note that they can be expressed either in the marking system, linked to the reference plan (x, y, z) or in a marking system linked to the nodal point of the observation way (x, y, h). They make appear the first equation giving the height of the point, according to the phase, and a group of two equations perfectly symmetrical giving the abscissa and the ordinate of the point according to its height and position in the image plan. The L, Po, d, Gx, Gy, Io and Jo coefficients are considered as constant whatever are I, J and $\Delta\Phi$ for a given probe, if the orthogonality hypotheses are verified.

Different studies and experiments, done during the summer 1987, have shown that the asked tolerances for prototype probes hadn't been achieved and that it would be delicate to obtain them in the future on prototypes.

LISTE DES EQUATIONS DE CALIBRATION

I	N° de ligne du pixel voyant le point objet
J	N° de colonne du pixel voyant le point objet
Io	N° de ligne du pixel central (axe optique)
Jo	N° de colonne du pixel central (axe optique)
0	Origine des axes par rapport au point Nodal (x,y,h)
0'	Origine des axes par rapport au plan de référence (x,y,z)
x	abscisse du point (direction perpendiculaire au codage)
y	ordonnée du point (direction parallèle au codage)
z	hauteur du point par rapport au plan de référence
h	hauteur du point par rapport au point nodal
L	distance du plan de référence au point nodal
Gx	grandissement suivant l'axe des abscisses
Gy	grandissement suivant l'axe des ordonnées
Po	pas de codage mesuré sur le plan de référence
d	distance entre le point Nodal de la voie d'observation et le point Nodal de la voie de codage
$\Delta \phi$	différence de phase mesurée



Simplification : $\varepsilon = \frac{d}{Po}$ et $\Delta\psi = \frac{\Delta\Phi}{2\pi}$

$$h = L - z$$

Espace x,y,z	Espace x,y,h
Equation générale : $z = \frac{L\Delta\psi}{\varepsilon + \Delta\psi}$ $x = (L-z)\, G_x\, (I-Io)$ $y = (L-z)\, G_y\, (J-Jo)$	**Equation générale :** $h = \frac{L\varepsilon}{\varepsilon + \Delta\psi}$ $x = h.\, G_x\, (I-Io)$ $y = h.\, G_y\, (J-Jo)$
Equation d'erreur : $\frac{\partial z}{z} = \frac{\partial L}{L} + \frac{(L-z)}{L}\frac{\partial\varepsilon}{\varepsilon}$	**Equation d'erreur :** $\frac{\partial h}{h} = \frac{\partial L}{L} + \frac{(L-h)}{L}\ \frac{\partial\varepsilon}{\varepsilon}$ $\frac{\partial x}{x} = \frac{\partial h}{h} + \frac{\partial G_x}{G_x} + \frac{\partial (I-Io)}{(I-Io)}$ $\frac{\partial y}{y} = \frac{\partial h}{h} + \frac{\partial G_y}{G_y} + \frac{\partial (J-Jo)}{(J-Jo)}$

1.6-2.2.3 Nodal point

The nodal point of an optic is defined as the physical point where all the optical resulting rays converge. This nodal point from a macroscopic point of view can be a good macroscopic comprehension base but it never exists in reality and can't be taken into account in a microscopic approach. In reality, this point is microscopically constituted of a more or less "thick" zone, depending on the quality of the optics. For a first approximation, everything happens as if the optical rays meet each other lower and lower as they come apart from the "central axis" (see drawing). The variation law of this point isn't linear according to the angle of the ray and it can be differentiated by the observation and projection ways. This phenomena leads to variations of L, d, Gx, Gy calibration parameters according to the position of the object's point in the image I,J but also its height in space. It also has an incidence on the phase curving.

1.6-2.2.4 Calibration method

a) direct method:

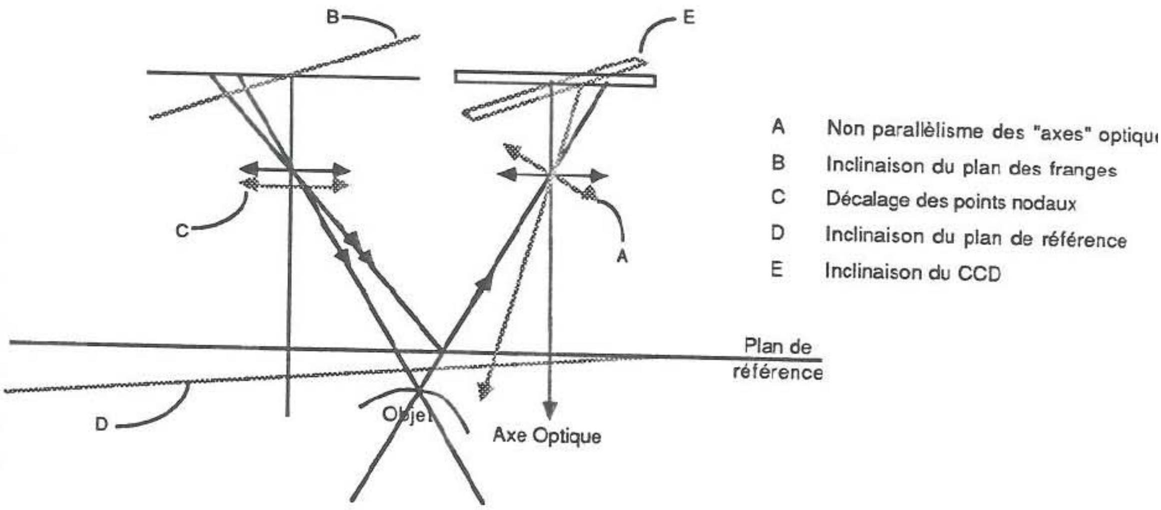
It consists of applying directly the constant calibration coefficients in the working field of the probe. We just saw that this method supposes draconian mounting tolerances and incompatible with a classic industrial manufacture. The obtained precisions with this direct method are of 250µ for an object situated close to the reference plan and of 400µ for an object situated at 15mm of the reference plan.

b) polynomial interpolation:

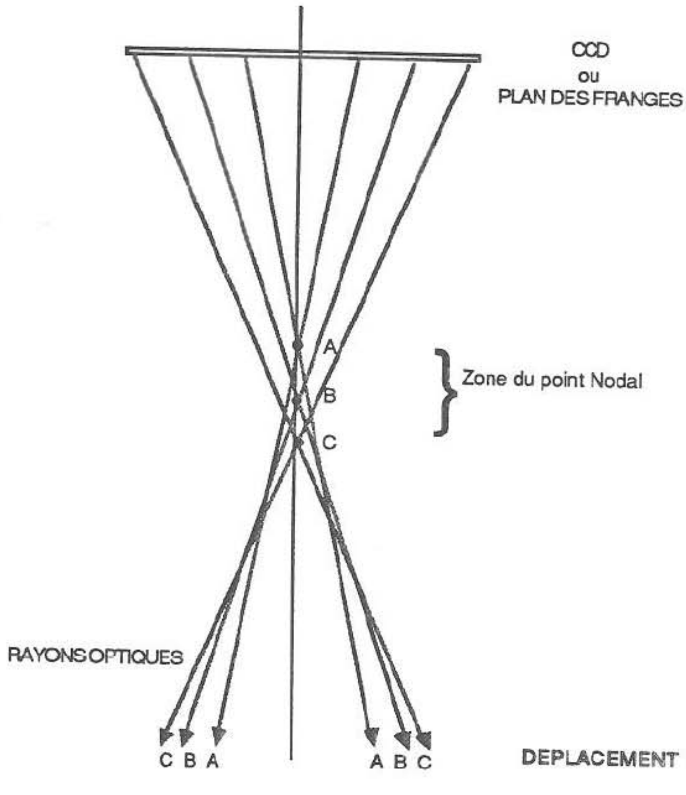
This approach consists of defining the "variable" coefficients according to the optical rays of the observation way. This is the method we currently use. It helps gain more precision but has two major inconvenients:

- a- it doesn't take into account the orthogonality defects of the projection way
- b- it doesn't take into account the modulation residues observed on the phase difference.

However, this method enables us to actually obtain precisions around 100µ at the reference plan level if it have been correctly positioned during the calibration procedure and around 200µ at 15mm from this plan.



FACTEURS D'ERREUR DE LA CALIBRATION



DEPLACEMENT DU POINT NODAL

Figure 15

LA PRECISION DE LA SONDE

c) Space tabulation:

This method starts with the principle that any point in space corresponds to the intersection of a projection optical ray and an observation optical ray. So there is unity of this point with regards to the system. The calibration laws can be applied by considering that for any point in space there are L, Po, d, Gx, Gy parameters which are his. We tabulate the space and each point having a I,J, $\Delta\Phi$ we make a correspondence in a table, an x, y, z (or x, y, h). This value table has been measured previously during the calibration procedure. We notice that these values slowly locally vary. As it isn't possible to calibrate all the points in space in this manner, we will take a few pre determined points which are then used as basic values to realise the linear interpolations for the other non tabulated points (space linking).

We take for example a point every 16 pixel in I and J and all the $\pi/4$ in phase. This leads us to structure the space following a linkage in 3 dimensions of:

$512/16 \times 512/16 \times 20\pi/(\pi 4) = 81\,920$ points

The space being defined by the number of pixels in the CCD, that is to say 512x512 and the dynamics of the phase difference in the whole studied space, that is to say 20π for an optical impression. The other points are deduced from this linking by interpolation depending on their position I,J and their phase difference $\Delta\Phi$.

1.6-2.3 Results

1.6-2.3.1 Phase repeatability error

As we have seen, we consider the phase error as a true measurement error and we take it in terms of reproducibility.

The measuring principle of this error is as follows:

- we place under the probe an object is possible flat and correctly diffusing
- we move step by step this object following the z axis
- for each height and each pixel, we do a series of 40 measurements of $\Delta\Phi$ of which we get the average and the typical spread
- this typical spread, which we call "primary typical spread", is significant of the measurement reproducibility of any point in space
- for each height we realise in the whole plan the average of the primary typical spreads as well as the typical spread of this average (secondary typical spread).

We then get an average typical spread which depends on the distance of the object with regards to the probe which we report on a curve (see appendix). This curve constitutes the reproducibility error variation of the phase in any field. It corresponds to the quadratic precision of the probe. Otherwise said, the average noise of the measurement inherent to the device itself which determines the probe's precision. Generally, this phase error presents a rather significant shape of the field's coding degradations. Its minimum is towards the clearness plan, it increases faster between the clearness plan and the probe and slower under the clearness plan. We find as first approximation the fields law (1/3, 2/3) defining the classical optics. The maximal errors in normal measurement conditions are of 0.12 to 0.16 radians (2% to 2.5%) and the minimal, close to the clearness plan, from 0.05 to 0.006 radians (0.8% to 0.9%).

1.6-2.3.2 Incidence of phase error on relief precision

In the previous step, we only study the incidence of measurement error which is, as we have shown, phase error. We then consider that the calibration coefficients are stable and they don't have any incidence on the error in h. We have traced for each probe and depending on the average values of L, Po, d the following curves: (see appendix).

- curve giving the relief depending on the pahse (H(phi))
- abacus of h error depending on the phase error and the height of the studied point dh = f (d (phi) and h)
- conjugated abacus of previous
  dh = f (h and of d(phi)).

By reporting the curve of reproducibility error on these abacuses, we directly get the induced error on h. For example, for the 3C probe, the clearness plan being situated at 17mm of the nodal point of the probe, the phase error gives 0.8% and the error in h 18µ, which corresponds to the most precise zone of the probe. If we take a point situated at 26mm, the error h becomes more or less 60µ and for a point at 12mm, it becomes more or less 22µ.

h	erreur en phase	erreur en h
12 µm	2,04 %	22 µm
17 µm	0,8 %	18 µm
26 µm	1,2 %	60 µm

We note that even though the phase error is more important at 12mm than at 20mm, the error in h is lower at 12mm than at 20mm/ It is due to the geometry of the probe. A proposition would be to lower the clearness plan, for example to the level of the stump's finishing line and to have the probe "work" continuously above this clearness plan but it is unfortunately very hard from a visual point of view but it would be better for the measurement precision.

1.6-2.3.3 Calibration error

During the study on the incidence of phase error on precision, we have considered that the calibration coefficients don't act. In this paragraph, we are going to take into account the calibration error equation. These error equations expressed in relative error clearly show that the uncertainties on the calibration parameters have an immediate incidence on precision (see appendix):

- the precision in h depends on the precision of L and of ε (= d/Po)
- the precisions in x and y depend on the precision in h and the precisions of the Gx and Gy blowups and of the origin points Io and Jo

a) direct and polynomial method

With these methods the parameters are taken in a global manner and so the uncertainty can't be considered as a reproducibility measurement but as a dispersion in space measurement, given (total for the direct and depending on an optical ray in the polynomial). The analyses we have done give us dispersions from 2 to 5% for the direct method and 1 to 2% for the polynomial. It is clear that these methods are insufficient to get precisions lower than 100µ.

h	1%	2%	5%
10 mm	100 µm	200 µm	500 µm
17 mm	170 µm	340 µm	850 µm
20 mm	200 µm	400 µm	1 mm

b) Tabulation in space method

Contrary to other methods presented above, we can consider here that the calibration uncertainty becomes a reproducibility measurement. On the contrary, the calculation of the calibration after the phase measurement induces an error linked to the linear interpolation between the linking points.

By collaborating with BERTIN and HENNSON quality departments, we have established during the summer 1987 calibration procedures guarantying a good reproducibility precision of measurement of the value of each point in the linking (absence of vibration, positioning at a micron, flatness of the reference plan…). These procedures enable us to reach rates of **1/1000** on linking points that is to say **incidental errors of 10 to 20µ on points coordinates**. We will note that in this approach the x and y measurements don't depend on the measurement in h anymore but only on I,J and the precision of calibration.

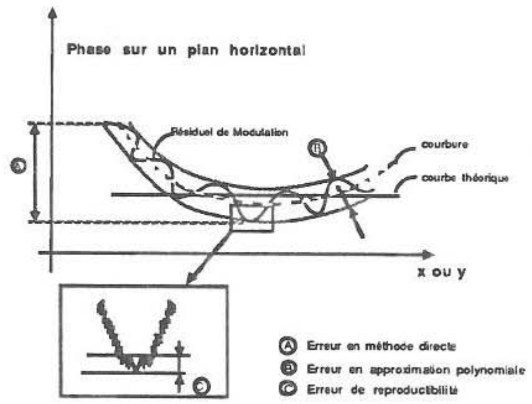
Concerning the error produced by interpolation, we have fixed ourselves as limit that it would be the 10th phase and calibration error. This rule fixes the linking dimension and corresponds to the "arrow" existing between the line and real curve joining both linking points. This leads us to loose 1 point every 16 in I and 1 point every 16 in J and 1 point every π/4 in phase.

c)

	Mesure Phase	Etalonnage	Interpolation	Total
Erreur en h	20 à 60 µm	10 à 20 µm	1 à 8 µm	33 à 88 µm
Erreur en x		10 à 20 µm	1 à 2 µm	11 à 22 µm
Erreur en z		10 à 20 µm	1 à 2 µm	11 à 22 µm

It is clear that these errors will decrease in time with on the one hand an increase of both BERTIN and HENNSON's know-how and the technological advances made in the optical and captor domains. We must also consider that 10 to 20µ represent scale values very low taking into account the studied volumes (35 x 25 x 15 mm) which can be translated in terms of uncertainty of 1/1000. This aspect of the things show us that the optical impression capture is obligatorily a delicate action. The incidence of the environment (temperature, mechanics…) and the care given to the action of impression capture will determine the conservation of precision.

REMARK: we must distinguish what is **precision** of point measurement, which is constant whatever the number of acquired points and the **density** of acquired points which translates the degree of reconstruction of the surface to be measured. The study of point density calls for theories on sampling and makes the spatial frequency of the object correspond with the spatial frequency of the semi points representing the object (cut frequency).

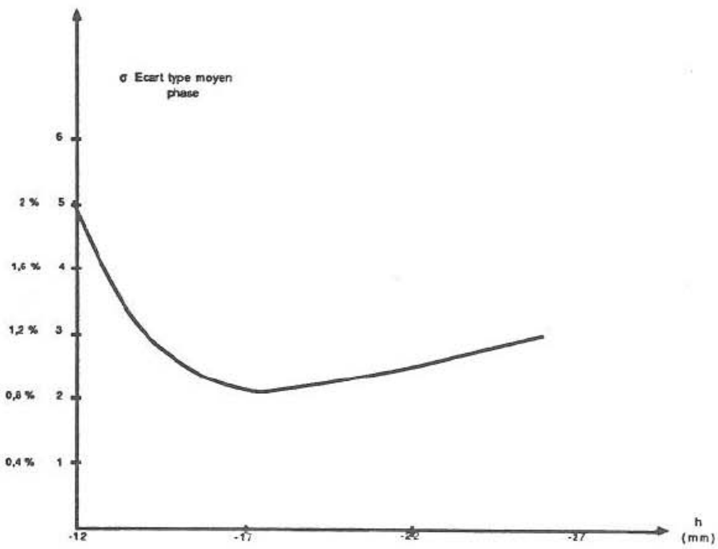


INCIDENCE DE LA DETERIORATION DE LA PHASE ET DES METHODES DE CALIBRATION SUR LA PRECISION DU RELIEF

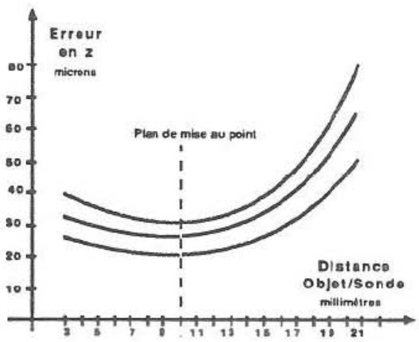
h	Valeur courbe	ε (%)
- 12	5	2,04
- 13	3,70	1,51
- 14	2,95	1,20
-15	2,60	1,06
- 16	2,25	0,91
- 17	2,10	0,85
- 18	2,10	0,85
- 19	2,16	0,87
- 20	2,20	0,89
- 21	2,30	0,93
- 22	2,45	1
- 23	2,55	1,04
- 24	2,70	1,10
- 25	2,80	1,14
- 26	2,95	1,20

EXEMPLE SONDE 3C
-DU 25 AOUT 1987-

PRECISION DE MESURE DU RELIEF EN FONCTION DE LA DISTANCE A LA SONDE
REPRODUCTIBILITE DE MESURE DE PHASE APRES LISSAGE
ET INTERPOLATION DES DONNEES BRUTES



ERREUR DE REPRODUCTIBILITE
DE LA MESURE DE PHASE
SONDE 3C



ERREUR DE MESURE DE LA SONDE OPTIQUE

Figure 16

LA PRECISION DE LA SONDE (Suite 1)

Rapport Odontologique Confidentiel

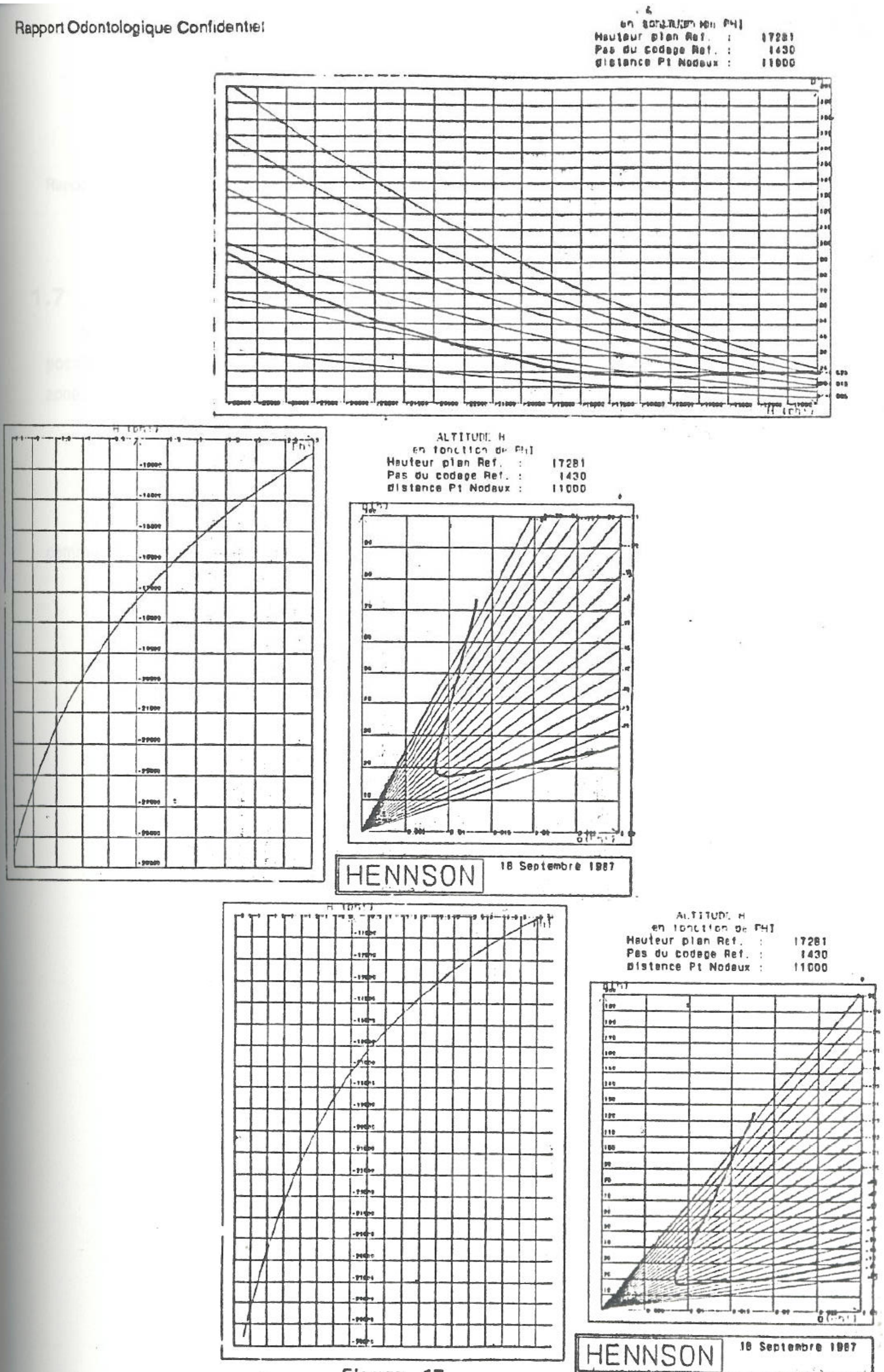


Figure 17

1.7 Conclusion

After about 5 minutes of handling for a dozen impression and 3 minutes of calculation, it is today possible to have an impression in occlusion (top and bottom) of more than 12 teeth in active zone. This may seem long but:

- it is comparable to the current time it takes to get all the indications for an imprint
- this time will decrease in the months to come

Precision conforms or is even superior than professional rules as have shown the works of McLEAN and more recently F. PANNOT (New York)

CHAPTER 2

COMPUTER AIDED CONCEPTION OF DENTAL PROSTHESES

2.1 Introduction

The realisation of a crown has been the number 1 objective for several years. This represents the basis of any prosthesis, even bridges, complex object by excellence whose realisation can be brought, at the CAD level, to the juxtaposition of several unitary elements. It is primordial to be able to model each tooth separately.

The realisation of a prosthesis can be envisaged as the manufacture of an internal part (intrados) and an external part or extrados. If the internal part must be the most faithful possible to the stumps while respecting the space for cement imperative and the errors due to size, the extrados can either pre exist or not exist at the time of the crown's realisation. We have started from the principle that the tooth is in quite a poor state so that it doesn't carry the information for the extrados. We must create wholly, as a technician does with wax, the external part of the prosthesis.

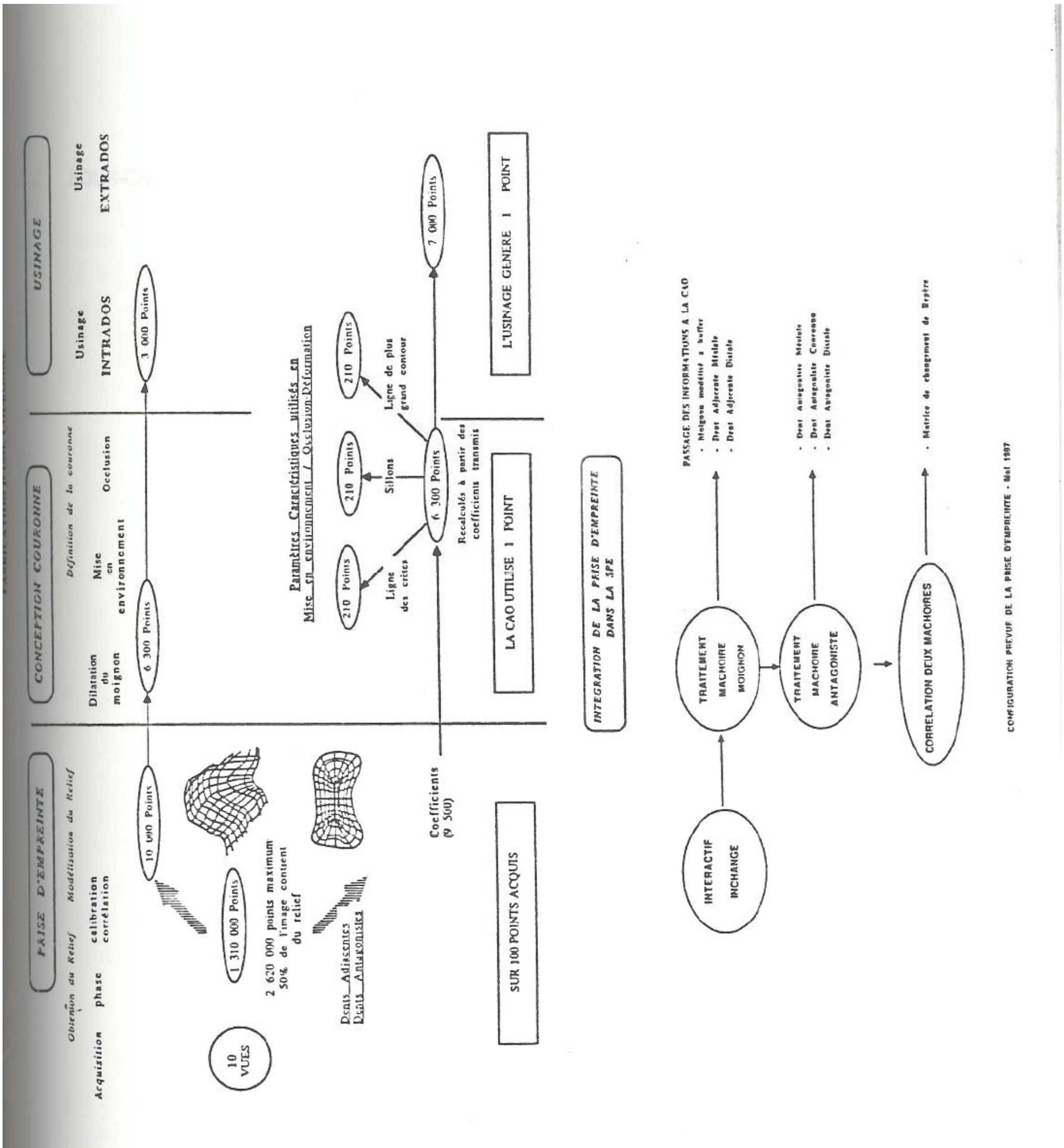


Figure 17 suite

DETAIL DES COURBES PRECEDENTES

2.2 Realisation of a theoretic teeth library

When a technician must realise a prosthetic element, he spontaneously calls on his memory to remind himself of what the external shape of a tooth is in anatomy. This morphology he will transform so it adapts to the environment he disposes of: the patient's mouth. Firstly, he must realise a morphological library of all the teeth so that the computer finds it in its memory, as the technician in his, the basic structural elements of his work BD).

We have realised 5 basic publications:

- F.DURET et coll.,Quand l'ordinateur se fait prothésiste, TONUS,16,pp13-15,1982
- F.DURET et coll.,Vers un nouveau symbolisme pour la réalisation de nos pièces prothétiques,C. d. Proth.,50,pp65-71,1985
- F.DURET et coll.,Principe de fonctionnement et application technique de l'empreinte optique dans l'exercice de cabinet,C.d.Proth., 50,pp73-109,1985
- F. DURET et coll., Q.O.S.,39,pp197-216,1985
- J.L. BLOUIN;F. DURET,De l'empreinte optique à la conception et la fabrication assistées par ordinateur d'une couronne dentaire,J. Dent. du Québec, 23,pp177-180,1986
- A.G. WILLIAMS; ~~F. DURET~~,Dentistry and CAD/CAM Another French Revolution,J.of Dent. Prac.Admin.,pp2-5,1987

These are mainly morphological sheets by Cr. TALLEC (EMC) which we have kept. The other books have enabled us to verify selected elements to possibly modify the previous ones. Each tooth called "theoretical" or, in computer language "A1" is modelled (16 models and the symmetrical selves).

2.2-1 Principle of theoretic modelling

Several types of models have been tried to answer morphological criteria of the teeth. We kept after more than 2 years of more or less fructuous trials the modelling in curves and grids by Béziers, a mathematical tool, very powerful.

2.2-1.1 BEZIERS' curve

Let's consider a broken line constituted of points (Pi)= o,n

We can consider the parametric curve of n degrees according to the mathematical representation

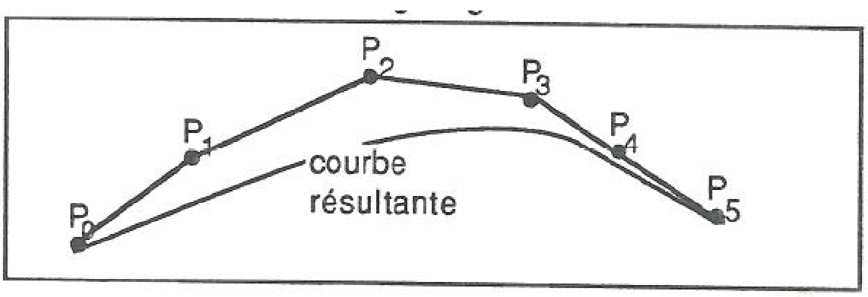
$$Pu = \underset{i=o}{\overset{i=n}{\varepsilon}} \; {}_{n}C^{i} \; u^{i} \, (1-u)^{n-i} \; P_{i}$$

Where the Pu curve is the sum of 0 to n $\left(\underset{i=o}{\overset{i=n}{\varepsilon}} \right)$ of:

$$C_n^i = \frac{n\,!}{(n-i)!\;\; i\,!}$$ Which is a constant

$U^i\,(1-u)^{n-I}$ which is the expression of the linear position along the curve
Pi (which are the curve's pole)

The pole by pole obtained broken line is called descriptor of the curve of n degree. We use for each curve 6 poles from P_0 to P_5.



2.2-1.2 BEZIERS' surface

Given an ensemble n of descriptors having m + 1 points each. The parametered surface will have for values

$$P(u,v) = \sum_{i=0}^{i=n} \sum_{j=0}^{j=m} C_n^i \; C_m^j \; u^i \, (l-u)^{n-i} \; v^j \, (l-v)^{m-j} \; P_{i,j}$$

We find the same expression as for the previous curve by expressing this time a surface where u and v vary from 0 to 1. When a point describes the whole set of values of u and v, from 0 to 2, it sweeps the surface of the ensemble. What is important to understand, on a dental plan, is that this choice wasn't easy for several reasons:

- a modelling must answer to what is found inside the patient's mouth and particularly it must marry the dental morphology and the mathematical needs. To cite an example, several trials have been done in modelling by Fergusson between 1985 and 1986 and were abandoned as they didn't enable the resolution of some brutal morphology inversions (as the difference between the softness of a cusp and the rigor of a furrow).

- the certainty of being confronted to over (if only below the lines of the great contours) stop us from using the surface interpolation type “surfac”.
- The CPU time can be penalising as for example the fact of working on “triangular” surfaces, 212 points occupy 41 sec CPU when 464 points occupy 3mn. We would need 9mn to simply build a 3 teeth environment.
- The handling of a polyedric surface would oblige us, for 50µ of precision, to handle 1 500 000 data for a tooth.

2.2-1.3 Representation of theoretic tooth

All theoretical teeth are constituted of a cylindrical structure composed of a regular weft in Béziers grid. All these grids are linked in a derivable manner with more or less constraints. This harmony is broken at the linking of the vestibular at lingual faces at the occlusal level, on the furrow for the cusped teeth and on the free edges for the other teeth.

Awaited precision is a few dozen microns for the extrados and less than 20µ for the intrados and the finishing line. Each surface is only presented by a few grids (8 or 12) themselves defined by very few points. A tooth can be resumed to a few dozen points as each tooth is represented, in Data Base, by the grids’ poles!

2.2-2 Theoretic teeth (Surface and primary furrows)

2.2-2.1 Incisive (figure 18 and 19)

It is presented in 12 Béziers grids with meridian tangents and parallel under constraint. The top of the teeth have tangents without continuity imposed on the lingual side (meridians). Each tooth finds the same distribution:

- a finishing line
- a great contour line
- a top line
- a primary furrow

2.2-2.2 Canine (figure 20)

It follows the same morphological rules as the incisive under the surface or linear modelling angle.

2.2-2.3 Premolar (figure 21, 22, 23)

First presented tooth (Phase I of MIR and ANVAR), historically it has been very studied to enable a correct description of the morphology and also to represent the knots and significant lines on a dental plan. It had to serve as support for deformation parameters. It enabled the definition of 4 meridians (vestibular, lingual and proximal) and 4 parallels (vestibular margin line, great contour line, top line and furrow line). A very simple structure (1984), we have tried to get a more "computer" model (1985-86) to finally get in 1987 a clearly dental model. Issued from 12 Béziers grid, each grid has 6 * 6 pole enabling the use of C2 class.

2.2-2.4 Molar (figure 24, 25)

The number of 12 grids appeared very insufficient for these massive teeth and it was necessary to use new strength lines and secondary furrows to get a characteristic morphology of molars. The non equality of vestibular and lingual grids was solved by the creation of a unique furrow, 5 degree curve with unfortunately a loss of suppleness of a curve of lower degree. We won't talk about the characteristics of the tangents as it would lead us too late but this analysis will stay one of the most difficult points to solve during numerous months as the molar segmentation process didn't enable the insurance of equality of modules with furrows. The numerous specification propositions (where they were asked) have helped show little by little the proper characteristics of each of the molars.0633583953

2.2-3 Secondary, third furrows and theoretic teeth facets

The secondary furrows (with the exception of the molar) and third furrows and the facets have been the object of an extremely deep study led by dentists and prosthodontists. It has enabled the correction of the "very simplified" aspect of computer morphology. In appendix 1 we will find the example of a study report led with the aim of getting a complete relief.

2.2-4 Arches diagram

Here are presented the whole of the 16 teeth of a maxillary arch and a mandibular arch. The symmetrical teeth are obtained by simple symmetrical effect with regards to the median sagital plan. Moreover the whole set of teeth has been placed on a theoretical arch corresponding to the morphological criteria described by Maurice CRETOT ("the human dental arch"). Have been respected particularly the interarch rapports of a BERNAGIANO occlusion with respect to SPEE and WILSON curves.

2.2-5 Conclusion

It is certain that a number of perfections will come to perfect this modelling work and particularly the personalisation of each model for the practioner himselve won't miss being rich in teachings but if we compare the finesse of the obtained result with regards to the classic working model, the computer morphology obtained won't have to blush in the face of the most sophisticated traditional methods.

Some details can seem anachronic. But we mustn't forget that such a tooth is represented with a zoom of 20 to 40 times the natural tooth, that is to say 1 mm represent between 25 and 50µ (1cm represents 250 to 500µ; that is to say analogue performances with a sweeping electronic microscope)

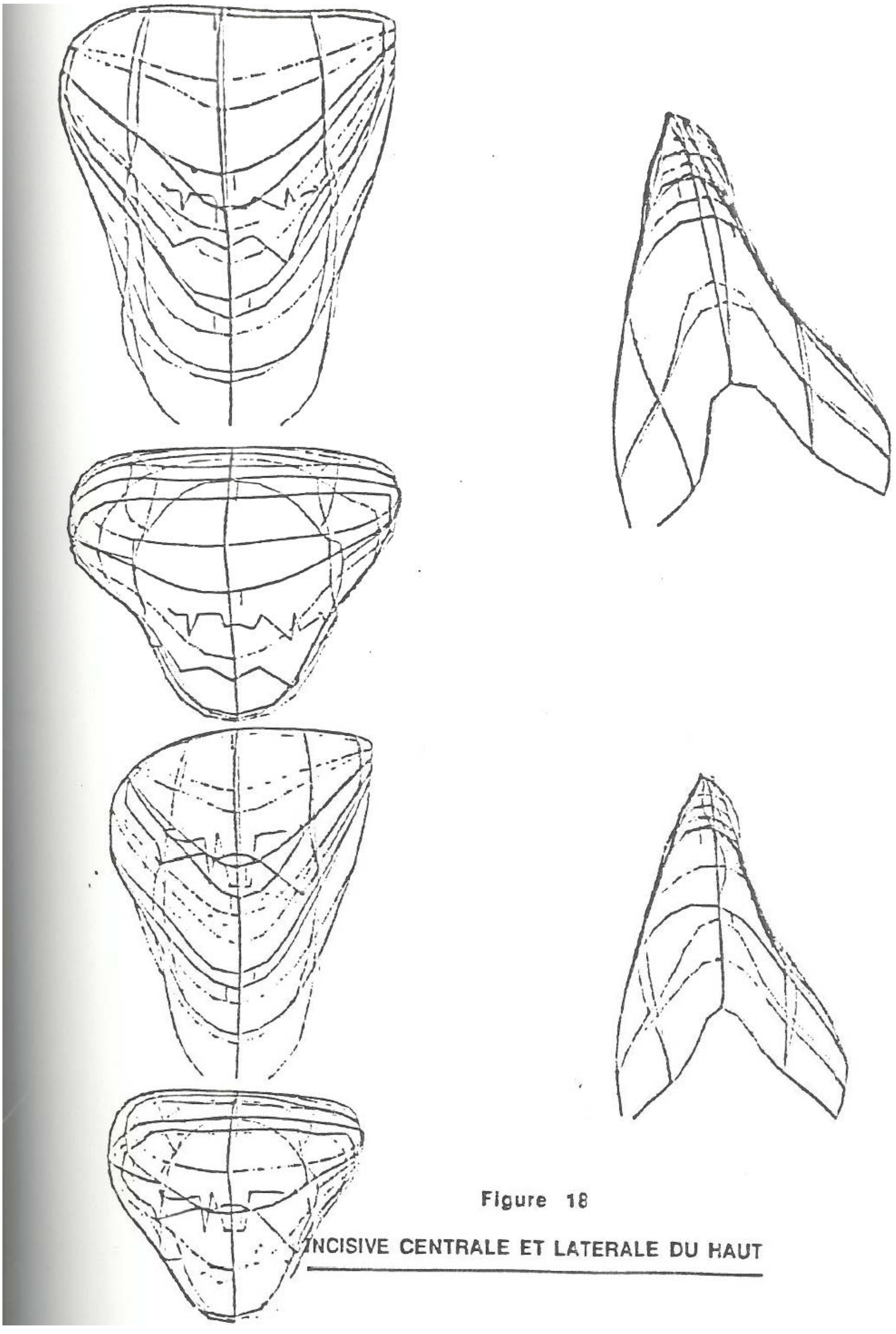


Figure 18

INCISIVE CENTRALE ET LATERALE DU HAUT

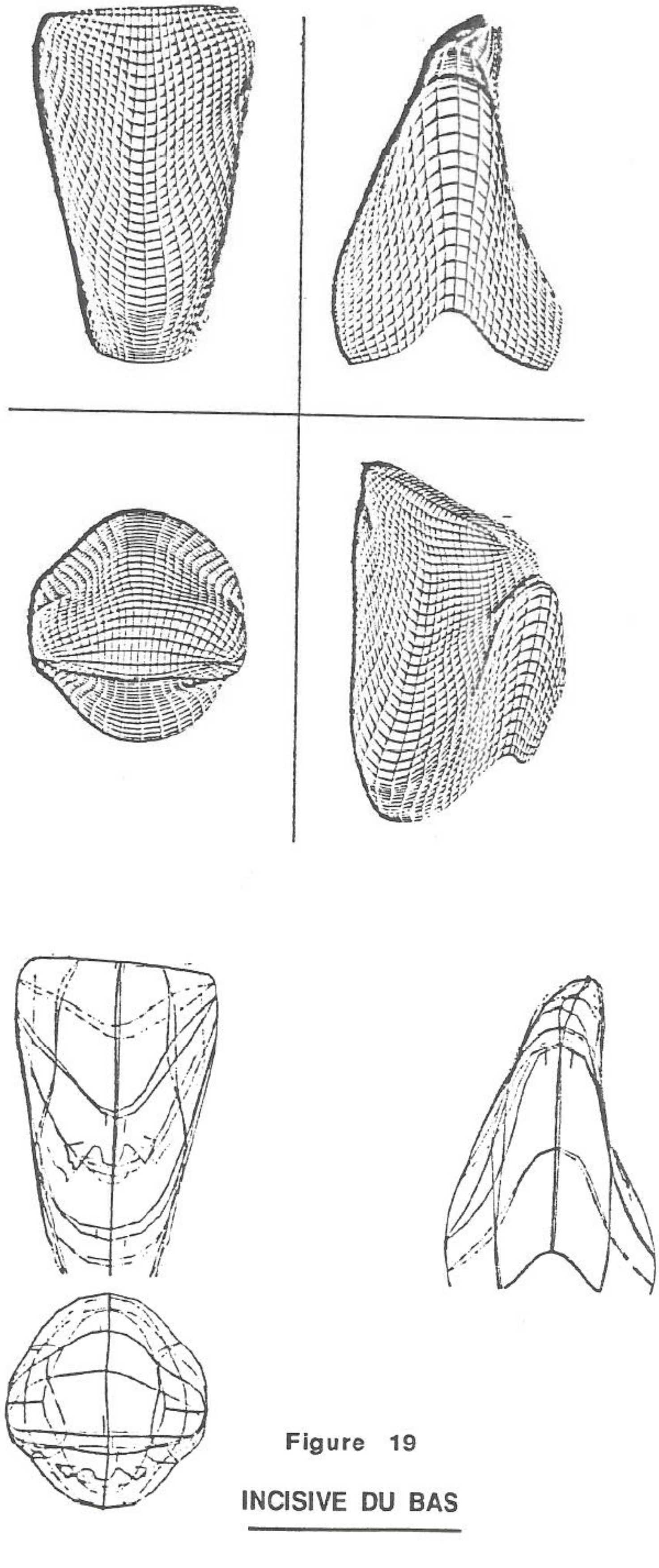


Figure 19

INCISIVE DU BAS

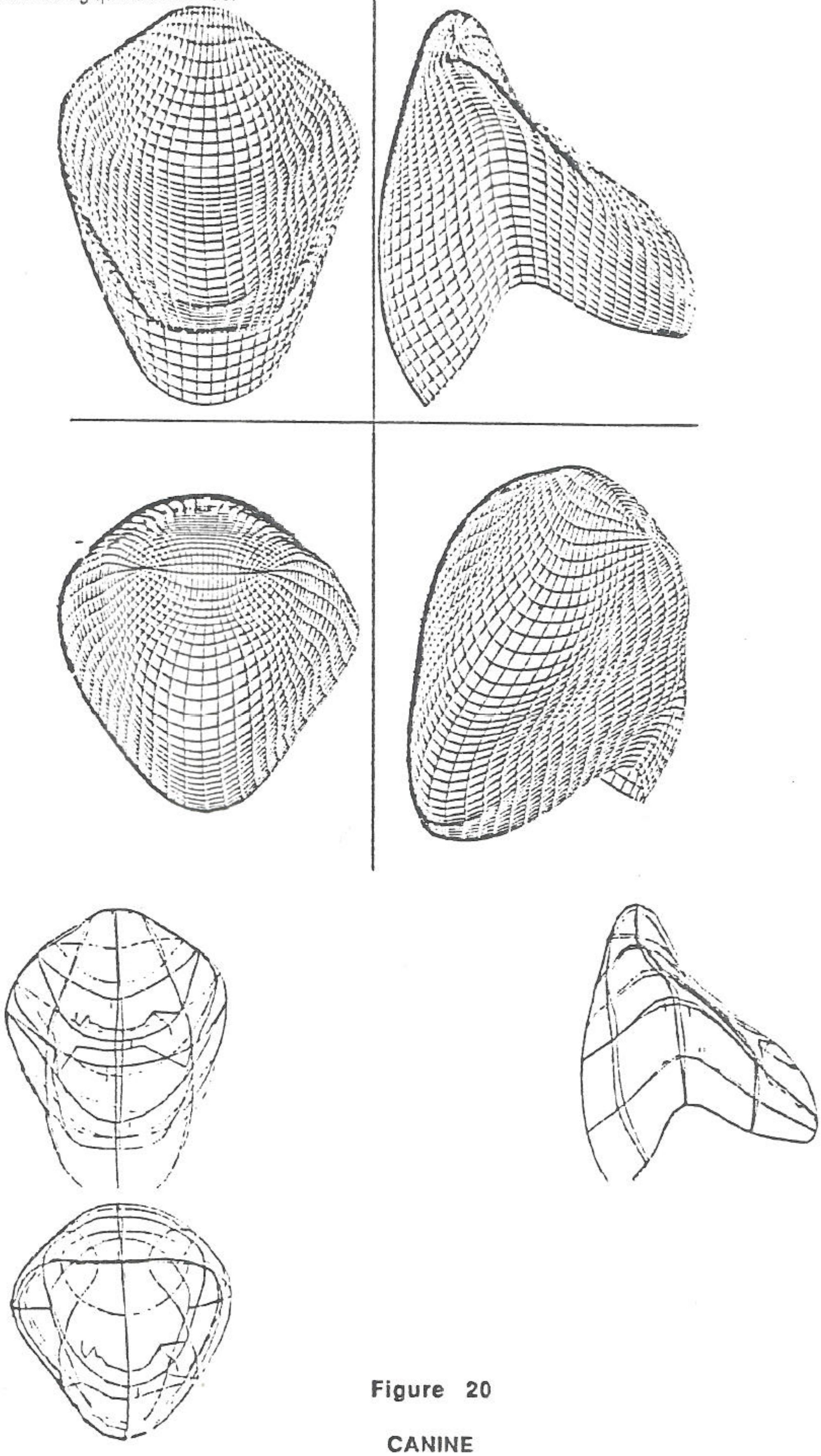


Figure 20

CANINE

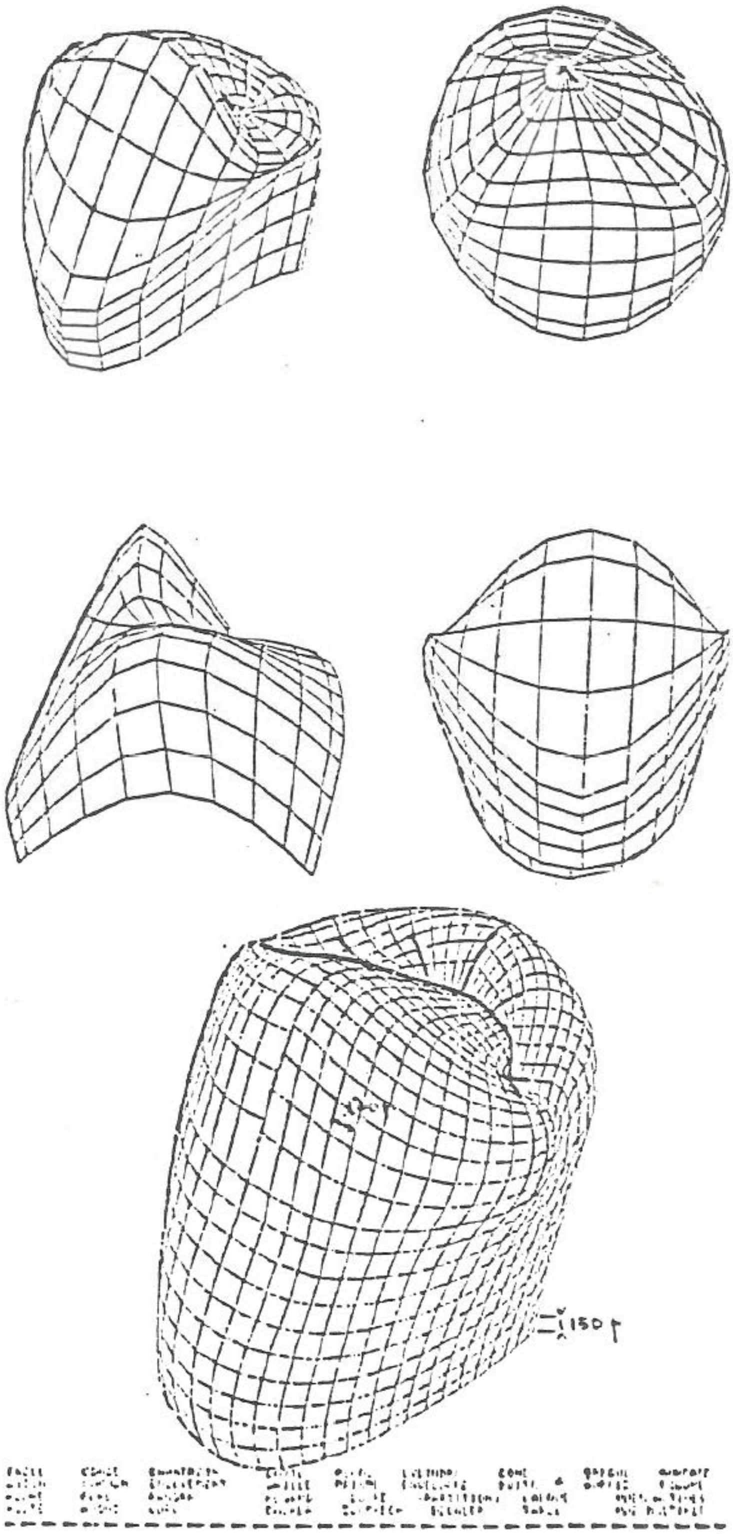


Figure 21

DENT THEORIQUE 1983 ET 1985

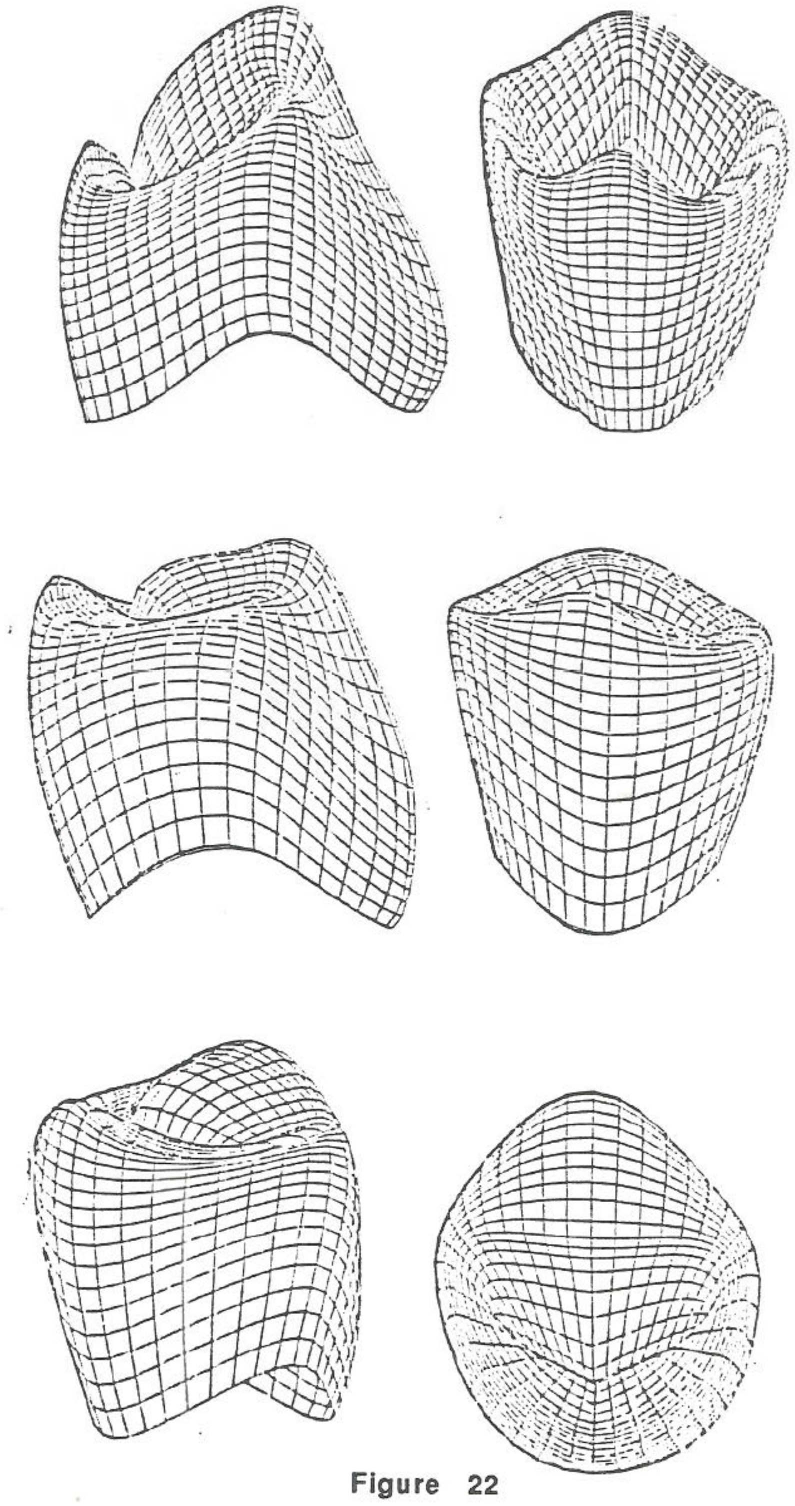


Figure 22

DENT THEORIQUE 1986

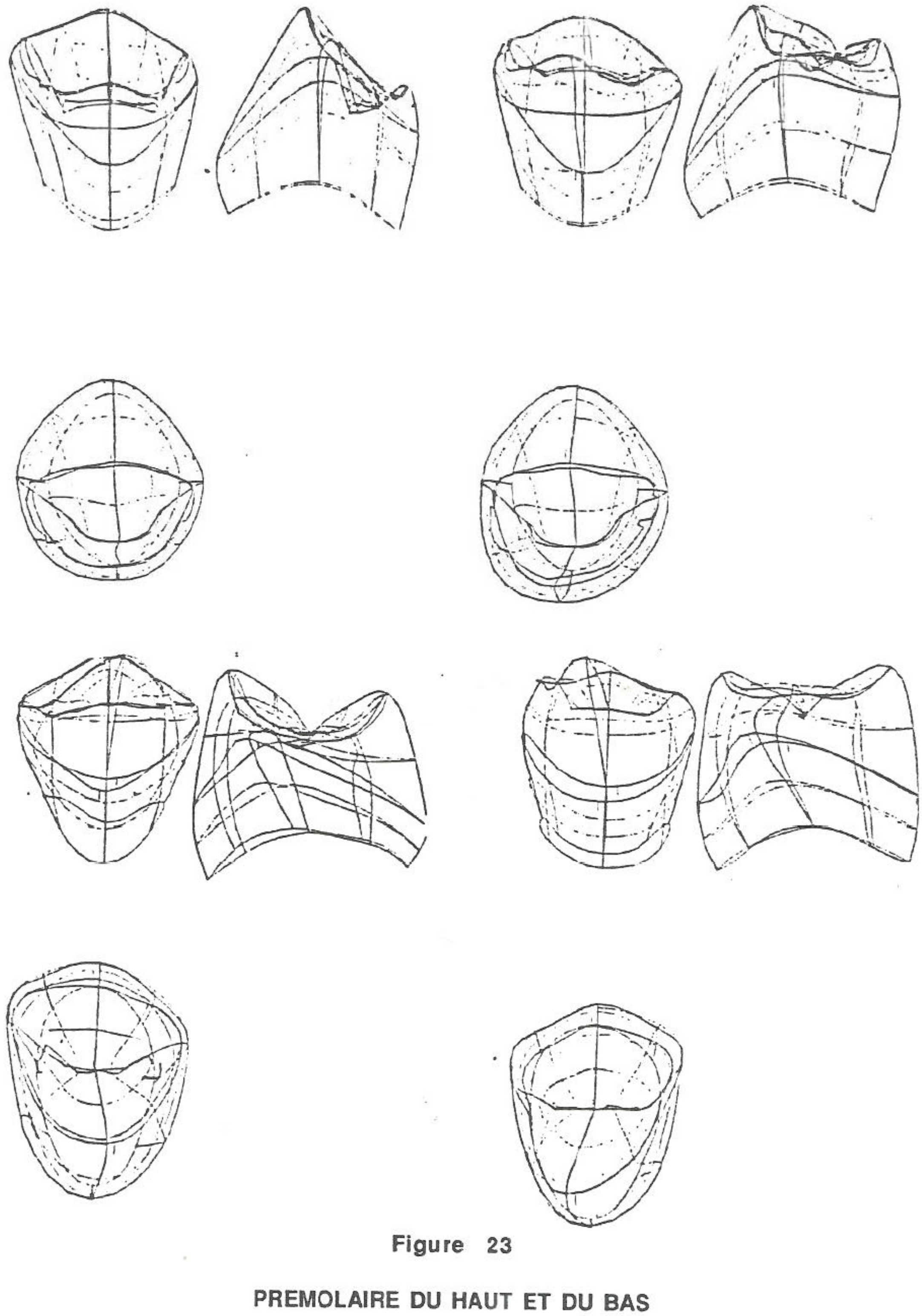


Figure 23

PREMOLAIRE DU HAUT ET DU BAS

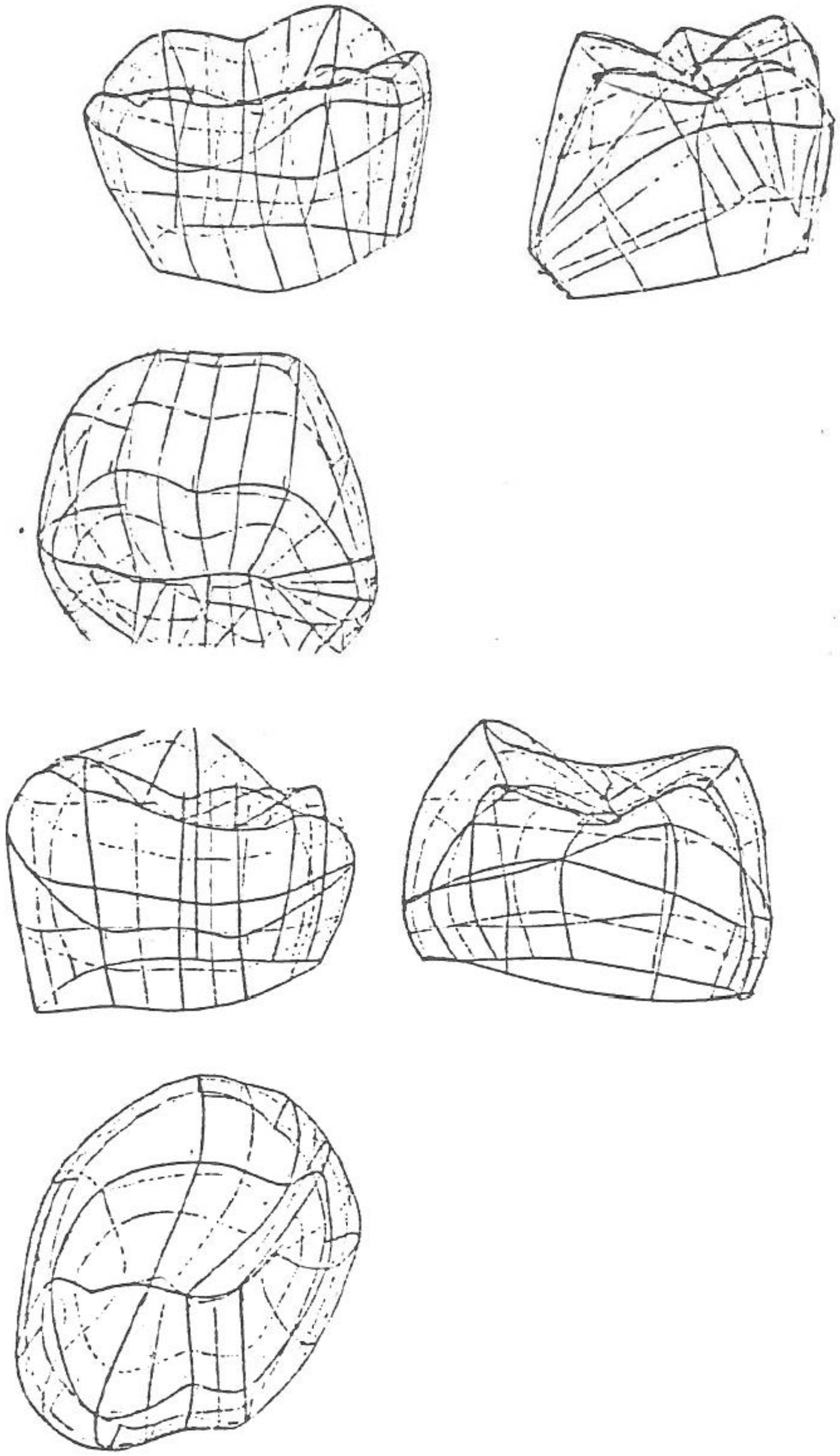


Figure 24

EXEMPLE DE MOLAIRE DU HAUT ET DU BAS

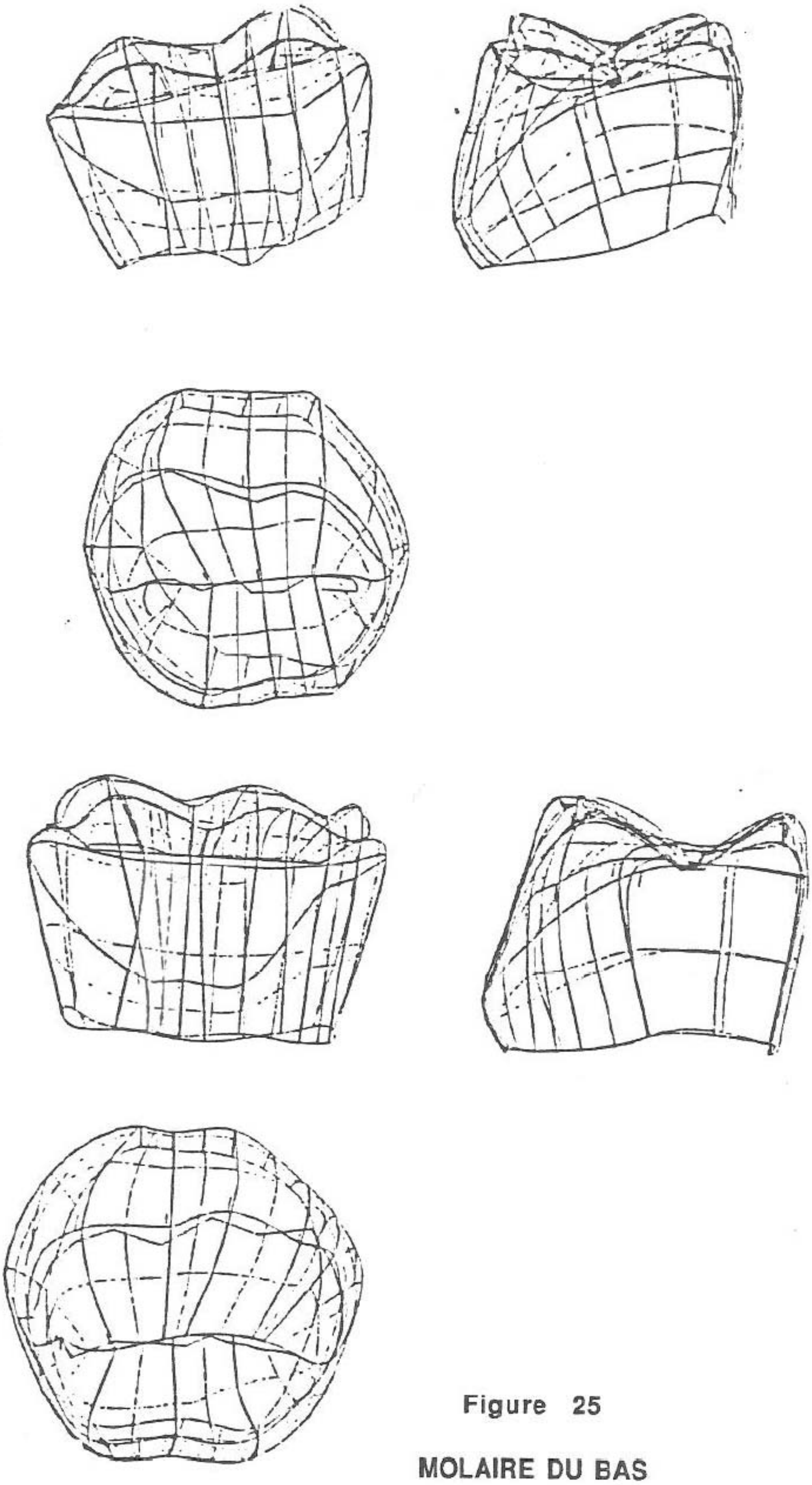


Figure 25

MOLAIRE DU BAS

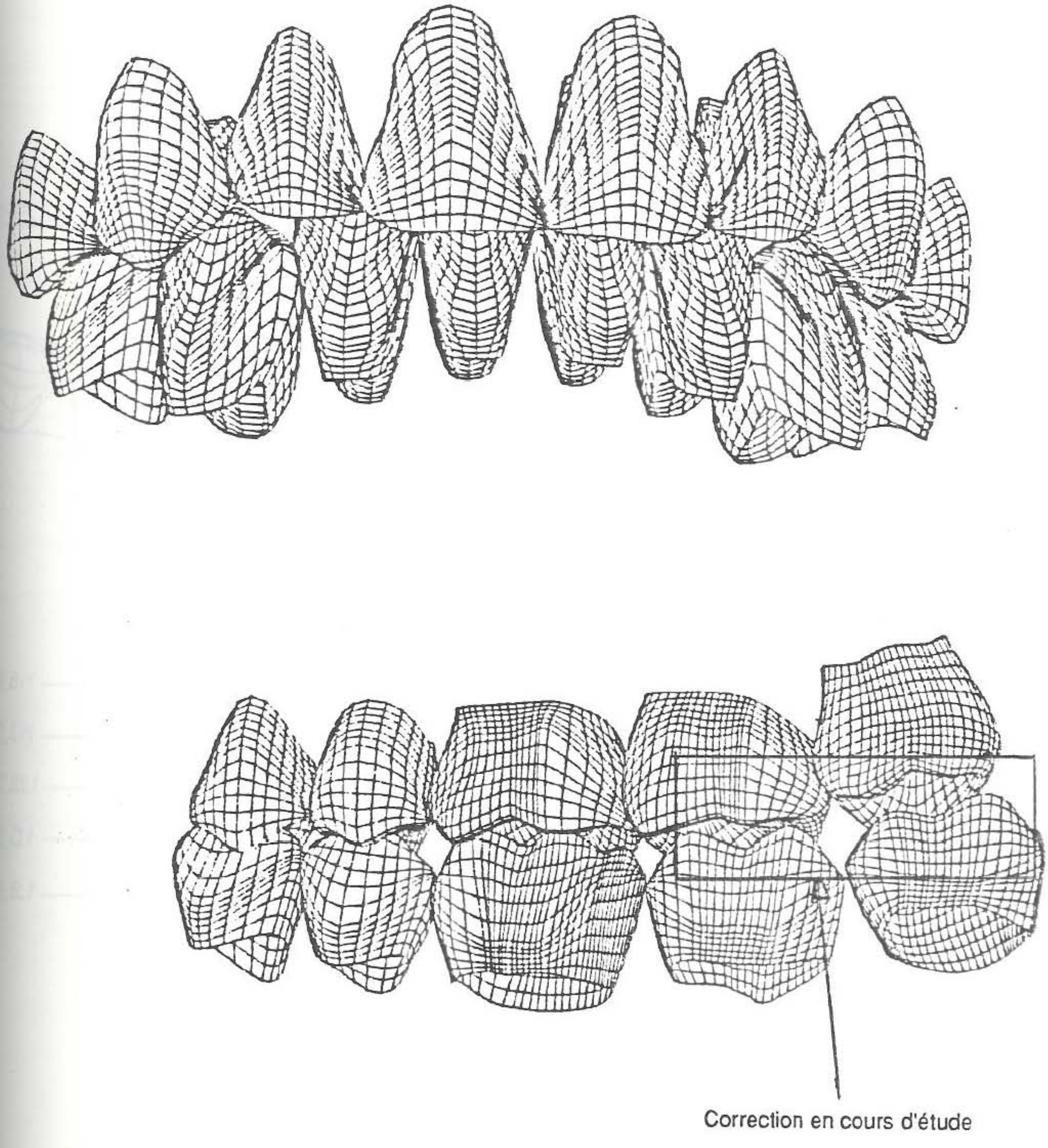


Figure 26

L'OCCLUSION

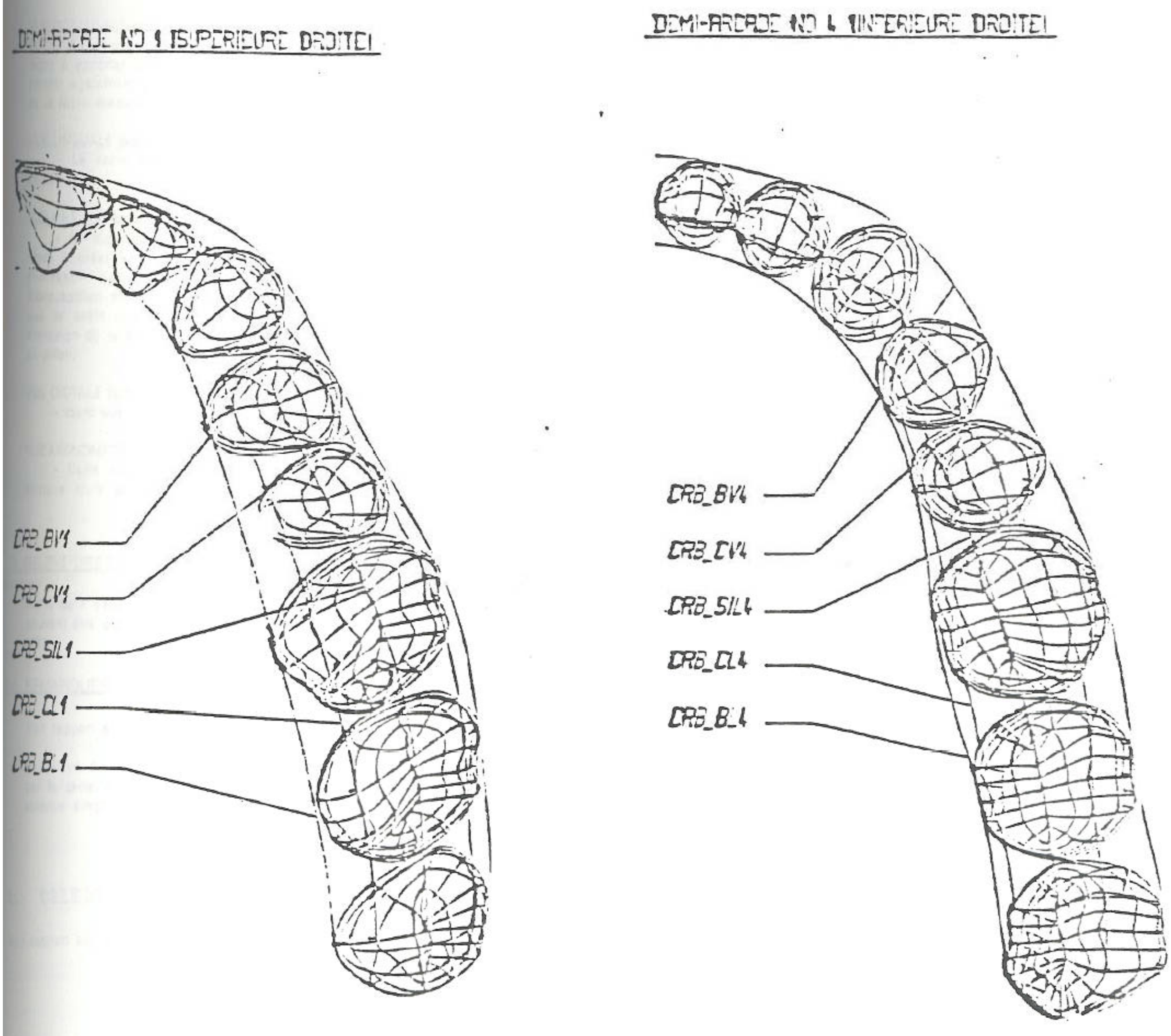


Figure 27

L'ARCADE THEORIQUE

1. MODIFICATION DE LA 44A1 EN 44A2

1.1 INTRODUCTION

Après plusieurs tentatives de modification du relief occlusal par l' utilisation de l' application PRJ, il est apparu plus simple et plus rationnel de se servir de l' application APPLI-DENT pour déformer la dent théorique afin de réduire au minimum l' usinage des sillons secondaires.

1.2 LISTE DES MODIFICATIONS

VUE OCCLUSALE (schéma n°1):

- Le pan mésio-lingual du bol occlusal a été vestibulé de façon à apporter une légère dissymétrie à la dent théorique. Ceci permet également un meilleur échappement du sillon debouchant de la fosse mésiale dans la face linguale.

VUE LINGUALE (schéma n°2):

- La crête mésio-linguale a été légèrement déplacée en apical.

VUE MESIALE (schéma n°3):

- Le modelé de la cuspide vestibulaire a été retouché de façon à créer un angle cuspidien moins marqué et une légère dépression sur le pan lingual. De plus, le fond du sillon intercuspidien est remonté de façon à se trouver plus en occlusal que la crête marginale mésiale, ceci permet également une diminution de la hauteur de la crête marginale par rapport au tracé du sillon..

VUE DISTALE (schéma n°4):

- Idem vue mésiale.

VUE AXONOMETRIQUE (schéma n°5):

- Cette vue n' a pas de correspondance en morphologie dentaire mais permet de mieux apprecier certains détails de la dent.

1.3 RELEVE DES DEPRESSIONS

Riche de l' expérience acquise sur la 45A1, seules les dépressions pouvant être usinées par la machine outil ont été relevées (schéma n°7).

1.4 REMARQUES

Voir rapport sur 45A1.

Le relevé finalement très simpliste des dépressions s' explique par la taille de la dent et par la caractérisation assez poussée obtenue simplement avec le sillon.

3. SELECTION DES OUTILS UTILISABLES

Voir rapport sur les sillons secondaires de la 45A1.

1.3 REMARQUES

L'utilisation de APPLI-DENT permet d' approcher de plus près, la réalité statistique du relief occlusal de la 44. Cependant son utilisation manque un petit peu de souplesse et peut mener rapidement à une impasse. Il est donc conseillé de sauvegarder régulièrement le résultat de la déformation, afin de revenir aisément à une situation viable. De plus, certaines options restent relativement obscures sur leurs fonctionnalitées.
L' usinage a toujours été possible sur les différentes déformations retenues.

2. SCHEMATISATION DU RELIEF OCCLUSAL DE LA 44A2

2.1 INTRODUCTION

Le relevé du relief occlusal a été fait en comparant la dent théorique déformée en 44A2,réalisée par la machine et la dent sculptée par CUENOT. Le TALLEC a également été pris en considération. Cette comparaison a permis la division des zônes à usinées pour approcher de plus près le relief occlusal en deux grands types.

2.2 RELEVE DES SILLONS

Les sillons ont été déssinés afin d' introduire une certaine dissymétrie dans la face occlusale, notamment sur les versants mesio-lingual et disto-lingual de la cuspide vestibulaire. De plus, l' échappement du sillon mésial dans la face linguale a été assez profondément marqué afin de créer la petite constriction visible en vue occlusale. Le sillon est interrompu au niveau le plus occlusal de son parcours intercuspidien afin de laisser intact une zone non usinée ce qui permet de rendre le simili pont d' émail se trouvant entre les deux cuspides. (schéma n°6)

4. DETERMINATION DES TRAJETS D' OUTILS

4.1 INTRODUCTION

La même technique que pour la 45A1 a été appliquée.

4.2 POUR LES SILLONS

Le dessin du sillon déterminé en vue occlusale (X,Y)est représenté par un passage unique de l' outil I01F . Par contre son relief en Z a necessité la superposition de trois trajets à des profondeurs differentes.

4.2.1. Trajet N° 1

Profondeur de passe: -100µ par rapport à la surface originelle de la dent.

Dessin: Il represente l' ensemble du sillon mais laisse intacte une partie de la jonction cuspide vestibulaire/cuspide linguale afin de creer l' altitude la plus élevée sur cette partie du sillon. (voir schéma N° 6)

4.2.2. Trajet N° 2

Profondeur de passe: -200µ par rapport à la surface originelle de la dent.

Dessin: Il contribue à recréer la variation en Z et permet d' accentuer la constriction mesio-linguale en vue occlusale. (voir schéma N° 6)

4.2.3. Trajet N° 3

Profondeur de passe: -300µ par rapport à la surface originelle de la dent.

Dessin: Il dessine la forme définitive de la fossette distale et de la fossette mesiale. (voir schéma N° 10)

4.3 POUR LES DEPRESSIONS

Le diametre extremement faible de l' outil S06F utilisé pour les dépressions nous oblige à dessiner des trajets d' usinage très proches les uns des autres de façon à obtenir un état de surface acceptable. La variation en Z n' a pas été simulée par la superposition de plusieurs trajets, la caractérisation de la face occlusale étant déjà bien réalisé par le sillon principal.

4.3.1. Trajet N° 1
Profondeur de passe: -150µ par rapport à la surface originelle de la dent.

Dessin: Il represente les dépressions mesiale et distale. (voir schema N° 11)

4.4 REMARQUES

Idem rapport sur les sillons secondaires de la 45A1.

5. USINAGE

5.1 INTRODUCTION

Idem rapport sur les sillons secondaires de la 45A1.

5.2 CREATION DU FICHIER D' USINAGE

Idem rapport sur les sillons secondaires de la 45A1.

Seul l' ordre de passage des outils a pu être modifié par rapport à la 45A1. Effectivement, l' usinage de la S06F étant peu profond, il a donc pu être placé avant l' outil I01F.

5.3 TEMPS D' USINAGE

Sillon: Les trajets successifs de l'outil I01F se font en 2 minutes et 20 secondes de la prise de l' outil à sa dépose. Ces trajets permettent de supprimer le trajet original de I01F qui durait une minute.

Dépressions: Les trajets successifs de l'outil S06F se font en 2 minutes de la prise de l' outil à sa dépose.

5.4 REMARQUES

Le temps d' usinage total de l' ensemble sillon / dépressions représente un surplus par rapport à l' usinage théorique de 3 minutes et 20 secondes.

6. CONCLUSION

6.1 RESULTATS

6.1.1. Morphologie

La dent déformée me semble plus proche de la morphologie d' une 44. Toutefois je crois qu' une légère accentuation des dépressions de la cuspide vestibulaire serait souhaitable près du sillon intercuspidien.

6.1.2 Etat de surface

Idem rapport sur les sillons secondaires de la 45A1.

6.1.3. Polissage des fosses

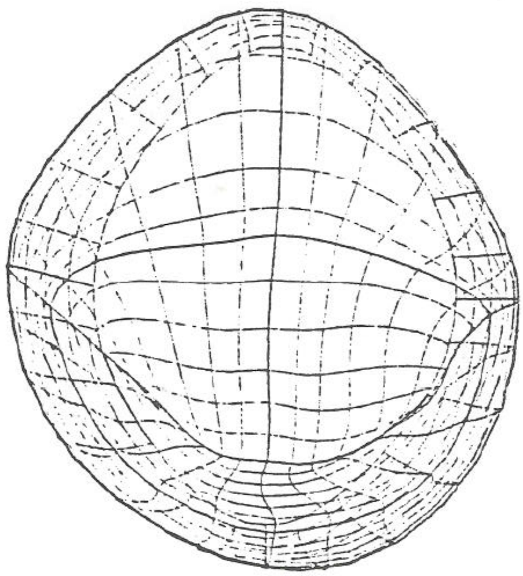
La profondeur des fosses a été minimisée au maximum de façon à permettre un polissage plus facile.

6.1.4. Déformation

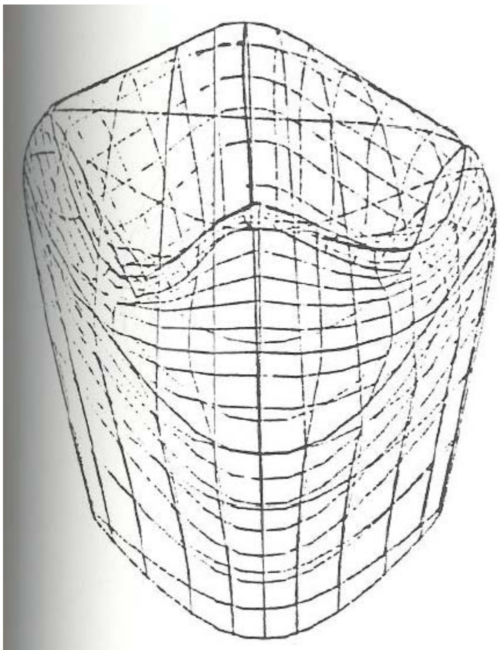
Après avoir fait subir à la dent théorique une série de déformation, la projection des trajets du sillon et des dépressions semble donner des résultats tout à fait cohérent.

6.2 AMELIORATIONS POSSIBLES

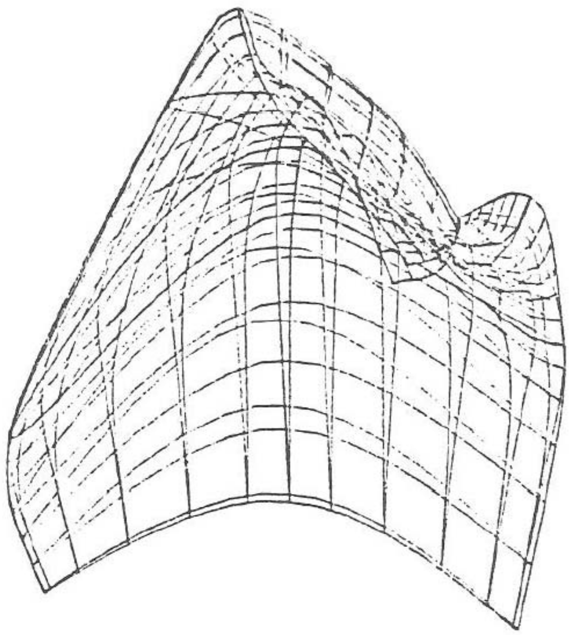
Idem rapport sur les sillons secondaires de la 45A1.



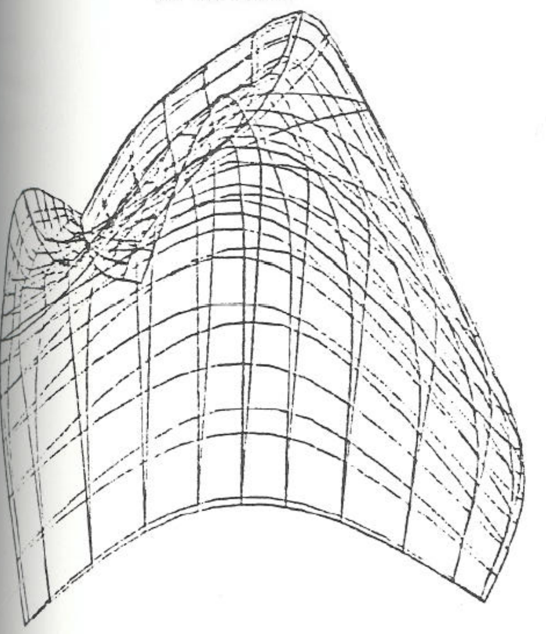
VUE OCCLUSALE
DE LA 44A2



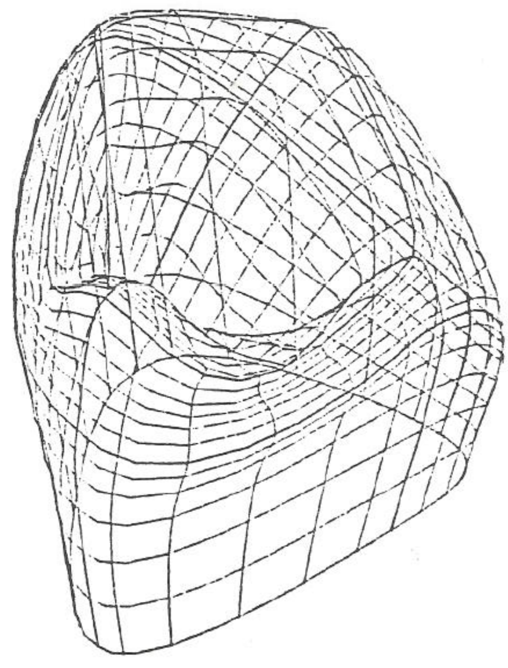
VUE LINGUALE
DE LA 44A2



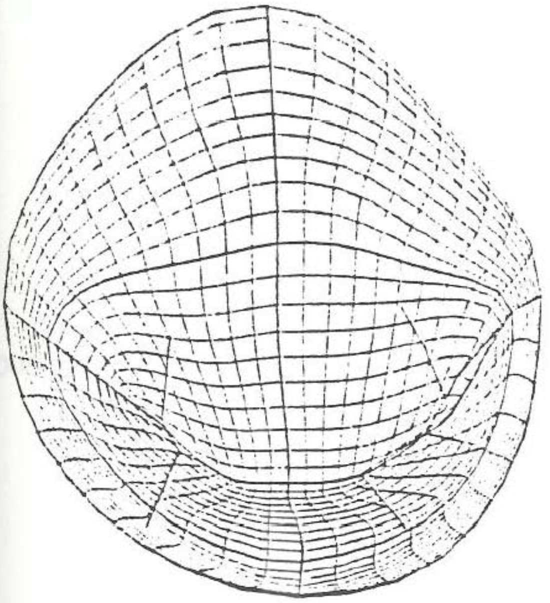
VUE MESIALE -
DE LA 44A2



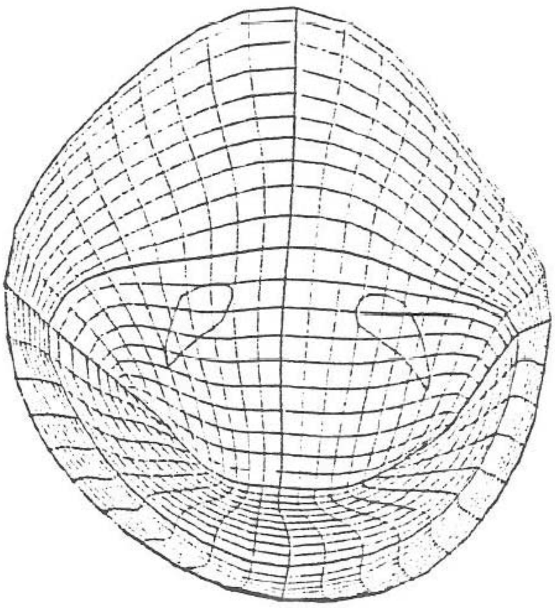
VUE DISTALE -
DE LA 44A2



VUE AXONOMETRIQUE
DE LA 44A2



RELEVE DU
SILLON SUR
LE BOL OCCLUSAL



RELEVE DES
DEPRESSIONS
SUR LE BOL
OCCLUSAL

2.3 Realisation of a crown

A dental crown is constituted of an interior part or shape (intrados) and an exterior shape which must adapt to the arch on aesthetic, morphologic and functional plans. The dental CAD/CAM system must respect the preparation, the environment and the dynamics of the latter. Moreover, it is necessary to optimise "automatic" recognition. We will first treat the work done on the intrados then the one done of the automatic and manual formatting (or placement in environment).

2.3-1 Definition of the inside shape

The interior shape must perfectly match the stump. It corresponds to the external shape of the stump cut inside the mouth. This shape will have to respect the following principals:

- enable the mounting of the crown with sufficient remains
- present the necessary space for the setting of the cement
- adapt perfectly to the finishing line

As it is said previously, a certain number of models have been studied. The fact of have traced a first finishing line on the stump during the image treatment enables us to know and isolate the object called "stump". We have an effective cutting of the image with a creation of the die.

2.3-1.1 Correlation

The interpolation, that is to say the whole grouping of the impressions is done at the SPE unit level. The stump correlation is done before the CAD and it is a set of smoothed points which will constitute the model base.

At the arch impression capture level, called "crown", we have 2 different objects which are, on the one hand, the stump and on the other, the adjacent teeth, separated. Each object has been built from several impressions, correlated amongst each other, following a method progressively developed between 1984 and 1987. The different impressions are obtained by the movement of the probe inside the patient's mouth. Each of them, after the integration of the optical calibration parameters, that is to say the optical characteristics of the probe and the camera, are expressed in a Cartesian marking (x, y, z) with for origin the centre of the CCD. After the impression capture stage, we have "n" impressions each expressed in a specific marking. The restitution of the stump's external envelope and its environment will be expressed in the same referential, that is to say a unique Cartesian marking for all impressions in order to get complete objects.

As it has been expressed in the first part of this technical analysis report, it was decided to use marking points common to each impression to use as correlation database.

Several steps have marked the project:

- comparison of mutual distances between the points taking into account the analysis uncertainty of each point (1985 – 1986). Unfortunately, this match test appeared too dependant on the x, y, z coordinates determination and mostly the testing time is too long. Used during the ADF in November 1985, it is impossible to wait an hour in a dental practice.
- identification of points (personalisation) and common triplet match. This solution dates from 1986 and is used in the Marseille demonstration in May 1986, it appears usable. The chosen referential (common Cartesian marking) and the position of the points in the impression's space are still today the object of perfection. Particularly, we look to:
  - ease the in mouth use
  - increase the speed of correlation
  - respect the precision zones such as the finishing line

2.3-1.2 Modelling

2.3-1.2.1 Adjacent and antagonist teeth (figure 28)

The adjacent and antagonist teeth are modelled in the same fashion. During the occlusal impression capture, called as such by the dentist, the practioner indicates the occlusal gutter by positioning the mesial and distal teeth's furrow and the future crown's furrow. The points defining the furrows will enable the determination of which teeth will be worked on and how to build them. Each tooth will be built from isoplans, that is to say regular vertical gingivo-occlusal lines stretched on the points encountered along this cut. The cuts are done in mesial and distal facets practically perpendicular to the furrow. We had to develop a method enabling, from a cloud of points and the "furrow's little indication", to find automatically the furrow, the top line and the great contour line. It was the most part of the modelling work between March 1986 and March 1987. It is today possible to automatically recognise all these lines characteristic of a tooth's morphology from an impression, if we have an idea about its furrow in occlusal view. On the 9500 points acquired from an environment, 210 are selected for the top line, 210 for the furrow and 210 for the great contour line, that is to say a point every 150 pixel maximum for the great contour line of the biggest tooth (which is more than enough for a precision of 30 to 50µ).

Modelling adjacent and antagonist teeth is done on the basis of these lines and the mathematical concept of Béziers' girds as previously defined. Each tooth will be known as a surface and each of these surfaces will be built after the knowledge of the essential lines (cusps, furrows, top line, contact zones, lingual and vestibular bumps).

.

2.3-1.2.2 Stump (figure 28)

The stump is known within its limits since we have defined the position of adjacent teeth. The modelling is particular since we use the z buffer. Thus, a stump is within a surface of 2 x 2mm at the CCD level, which means an impressive level of pixels. We have decided to average the surface values of 100 per 100 µ for the Z while keeping a good value in x and y, which enables a precision of more or less 25µ (at worse) at this surface level. The stump is built as a set of cubes (63 000 cubes on the surface) which are smoothed to get a "point surface". These cubes being perpendicular to the axis of the occlusal impression capture, we understand that is the latter is bad we risk the loss of the finishing line (figure 29). Between January and June 1987, we have tried to find the ideal modelling axis for the z buffer. After numerous trials, we have found a method enabling, before the modelling, the knowledge of it with precision.

It is evident that the marks are smoothed by this z buffer modelling. The points are then linked to each other for form a net (6300 points) which leads to the building of a polyedric surface on which the crown's intrados will be built.

2.3-1.3 Realisation of intrados

A crown's intrados' limits are evidently the finishing line of the crown. It is traced during the impression capture, on the video screen, and/or on the CAD screen where it can be modified. We think that the creation of this finishing line at the video level is preferable as the impression is easier to handle for the practioner.

2.3-1.3.1 Modification of finishing line

AT the stump level, on the CAD screen, there is a line corresponding to the one traced on the video screen. The handler can:

- see all 4 impressions (mesial, distal, vestibular and lingual) at the same time and zoom in on each impression at the finishing level line level
- possibly modify the line traced on the video screen:
  a) totally
  b) partially
  c) go back to the original at any time

The finishing line is always projected on the stump plan following the curve whatever the space between two points. It isn't necessary to focus on each modelling knot and shutting down is automatic. After the ANVAR 1986 expertise, it was decided to work intensely on the finishing line. It constituted the first working step: great suppleness of handling at the CAD level with correction and easy return to original situation. O do this, we must present the point we wish to move, indicate the new place and validate the information.

2.3-1.3.2 Dilatation

The necessary space for the cement has been defined by numerous authors (figure 30). It is variable depending on the type of cement and materials used. Particularly recent studies have clearly shown that is the juxtaposition of the finishing line was necessary, the space between the crown and the stump had little importance (below 500µ of course) if we adopted a glueing technique.

OWEN	JPD	55, 6	P	674-677	1986
OWEN	JPD	56, 1	P	107-112	1987
OWEN	JPD	56, 6	P	13-16	1987
OWEN	JPD	55, 1	P	551-560	1986

Moreover, we knew that a dilatation had to respect a certain very detailed proportionality of EMC and confirmed by some recent works such as:

BELSER	JPD	53	1	p	24-29	1985
FAULL	JPD	53	1	p	29-33	1985
et surtout						
MCLEAN	Brit.Dent.J.	131	1	p	107-111	1971

It enabled us to propose a null progressive dilatation to the finishing line and spacing progressively towards the top according to the example presented later (figure 31). This dilatation is calculated from the finishing line and progressively respects the loss of cement towards the base. We notice it particularly at the sharp angles levels where the spacing is more important. The work was long and progressive, first marked by the trials during the ADF then clearly more functional in 1986 to give us full satisfaction early 1987. During his daily exercise, the practioner only intervenes if he wants to modify the value of 100µ given by defect corresponding to the spacing at the plateau level. If the dentist wants to modify this value, all he needs to do is indicate a new one.

2.3-1.3.3 Conclusion about intrados realisation

We could talk about the intrados problem, that is to say the one about the joint by talking about the numerous parameters which enable to say that there will be success and sustainability for the preparation. Truthfully, with CAD/CAM, a bad cut doesn't become good. At best, what we can guarantee it that:

- the possibility to meet an intrados point with regards to the stump will be more or less x µ.
- the aspect obtained from the dilatation enables a rational cement flow
- this spacing is defined in its value and in a point by the dentist

However today, with maybe the exception of the finishing line, it isn't necessary to have formidable precision to be precise. With a difference to what A. AUTHER said at the Garancière in 1983, today's materials answer to the adhesion phenomenon. A good mordant associated to a material with minimum elasticity can avoid the apparition of a hiatus. The MÖERMANN system (Zurich) takes all its action from this fact. Even though it only realises the internal part of an inlay, with only one impression and no dilatation, he estimates (and talks about it as a specialist), that today the notion of hiatus is very secondary (Q, 3, 87, P 1 to 14). J.F. ROULET, in a recent article in Quintessence, shouts even louder this new position (Q, 18, 3, p543-52, 1989). Still if the material and cement must have an excellent wettability relationship, it has nothing to do with dental CAD/CAM. What is important for the intrados is to present:

a) an excellent finishing line: CAD will keep the precision acquired by the SPE (camera). The manufacturing trials on the stump, joined to this here report, show the quality obtained today with the first clinical trials (Relief JPD, 47, p496-301, 1982 and BELCER JPD, 53, p24-33)
b) a controllable joint: it is classical to say that the finer the joint, the more efficient the sealing.
c) finally the sealing's solubility depends essentially on the material's nature (François M., CDP, 35, p43.50, 1981)

2.3-2 Realisation of extrados

2.3-2.1 Introduction

We have explained several times the fundamental principle applied to the creation of the extrados of a crown by CAD. WE won't come back on those principles but will explain as introduction the evolution the project has had between 1984 and 1987.

Rapport odontologique Confidentiel

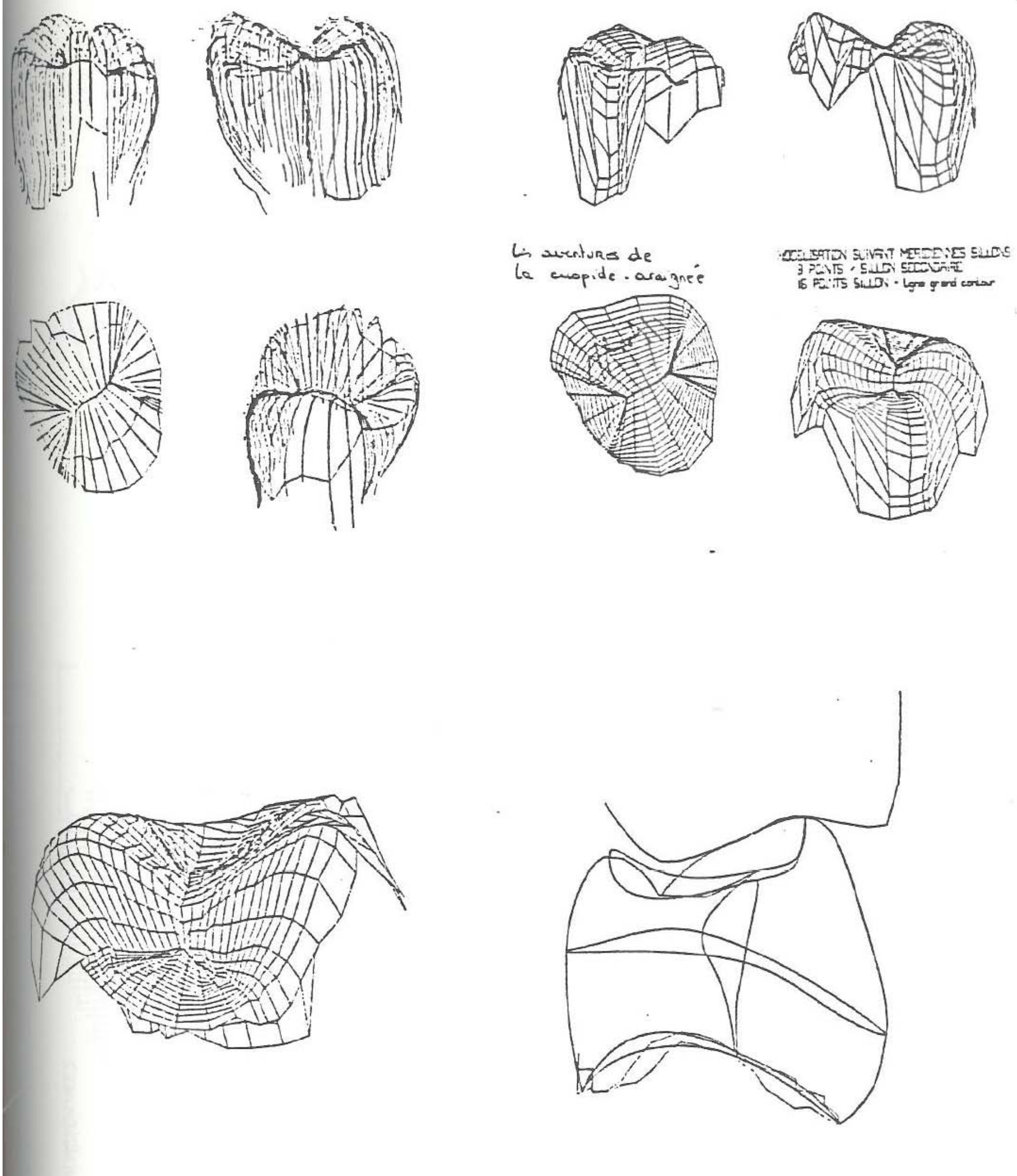


Figure 28

MODELISATION DES ADJACENTES ET DES ANTAGONISTES

Rapport odontologique Confidentiel

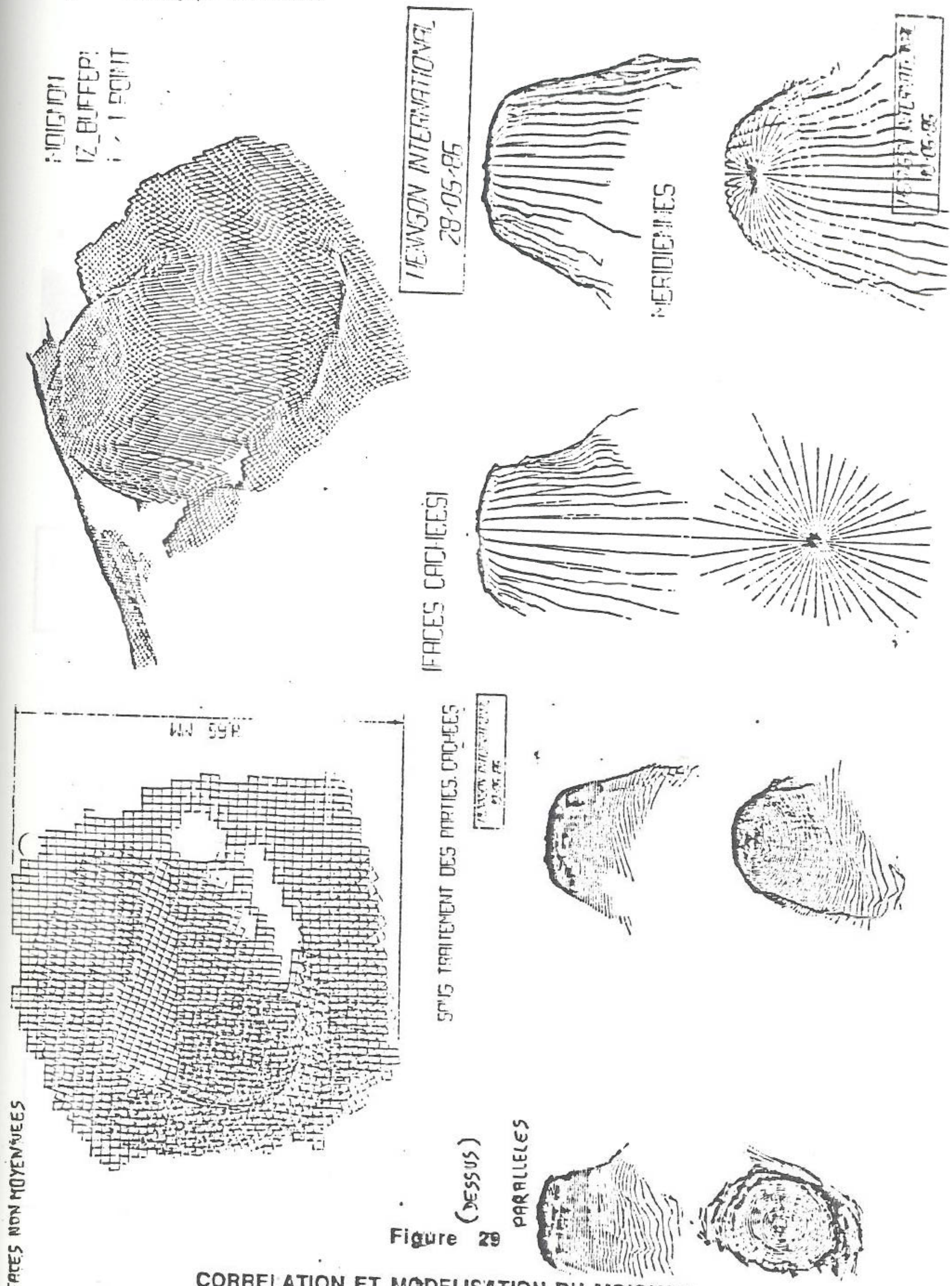
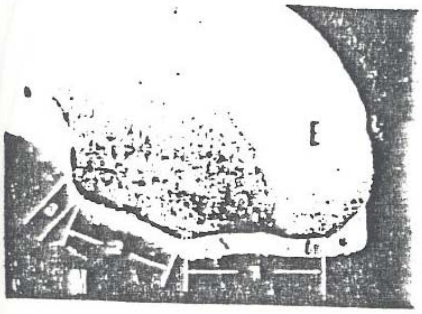
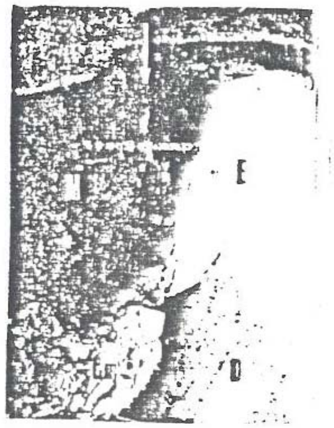


Figure 29

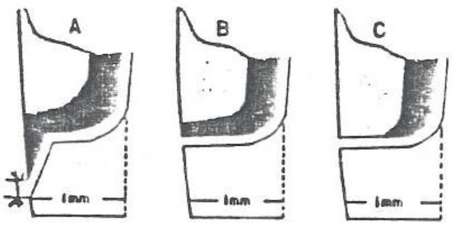
CORRELATION ET MODELISATION DU MOIGNON

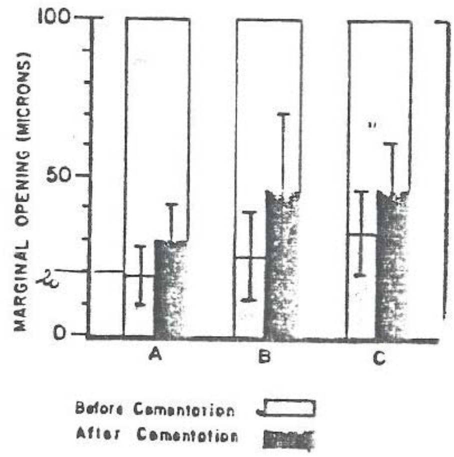
Rapport odontologique Confidentiel





BRITISH DENTAL JOURNAL (April 71)
Dr. D.N. ALLAN, DDS, MDS
UNIVERSITY OF NEWCASTLE





BRITISH DENTAL JOURNAL (August 71)
131,1971 pp 107
Dr J.W. MCLEAN MDS, LDS
Dr. J.A. Von FRAUHOFFER,
MSC, PH.D, ARIC, AIM
UNIVERSITY OF LONDON

Figure 30

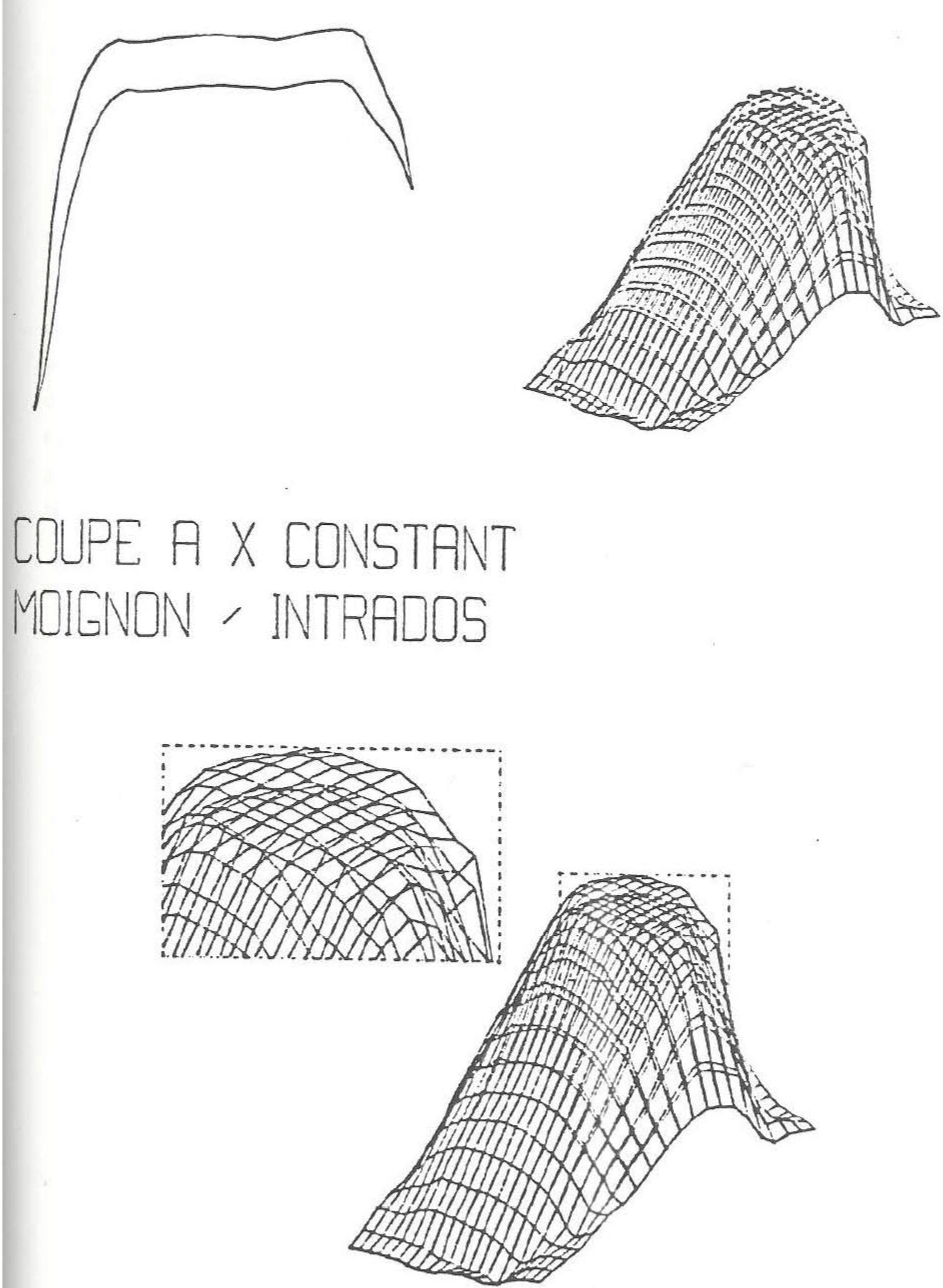


Figure 31

DILATATION DE L'INTRADOS
CREATION DE L'ESPACE CIMENT

Référence articles :

DURET et coll	CDP,	50	P	73-109	1985
DURETet coll	CDP,	50	P	65-71	1985
DURETet coll	QOS,	39	P	197-213	1985
DURETet coll	J.D.Q	23	P	177180	1986

We thought firstly that each theoretical tooth had to be inscribed in a sort of box called envelope of elementary shape and easily malleable. As we can see on the figures joined in appendix in CDP, 50, p73-109, this box would deform in the available environment that is to say between the occlusal surface and the adjacent teeth contact zone. The rapports between the envelope and the theoretical teeth being perfectly mastered, it appeared simple to deform the theoretical teeth in second place. This technique, presented in September 1983 at the Garancière, was defined as follows:

This exterior shape is inscribed in an envelope which is determined as follows:

a) plans 1 and 2 are tangent at the tooth's contact point. They are situated at x_1 and x_2 of the centre of gravity. A corrective factor is adjoined which is linked to the physiological movement of the teeth:

   $x_1 + cst$

   $x_2 + cst$

b) plans 3 and 4 are the most external plans of the anterior and posterior teeth, plans which are tangent to the vestibular and lingual faces

c) plan 5 is the plan defined by the impression of the adjacent tooth. It is issued from the following handlings:
   - global impression of the inferior maxillary with index in place
   - global impression of the superior maxillary with index in place
   - impression of the occlusion anterior fence with the same index
   - impression of the lateral movement then anterior with index
   - isolation of the interesting zone with index
   - adaptation of a portion of movement corresponding to the superior lines of plans 1, 2, 3 and 4 thanks to the index

   There is pure and simple suppression of the occlusion research (see later)

d) plan 6 is really the stump's surface limited by the L1 line (or finishing line)

We have defined an envelope in which the exterior shape of the theoretical teeth which we have stocked is inscribed. The operation is as follows:

1st step: * search for the tooth
* search for the theoretical tooth

2nd step: *adaptation of the theoretical tooth inside the envelope
* the memorised theoretical shapes are inscribed in an $x_2y_2z_2$ envelope

We have admitted a certain degree of freedom where the tooth stays aesthetic.

$x_2 \pm \Delta x$
$y_2 \pm \Delta y$
$z_2 \pm \Delta z$

* adaptation of $x_2y_2z_2$ on $x_1y_1z_1$. If this adaptation isn't possible, a correction must be manually induced on one of the plans (diastema)

We must:

a) search for the theoretical tooth
b) translate the centre of gravity
c) do the homothety of the points of theoretical L on ΔL.

There is adaptation of the memorised theoretical shape in the envelope previously determined.

For more logarithmic than dental reasons this proposition was abandoned first to the profit of "bowl" notion (1985), then to the profit of master lines (1986-1987). The "bowl" notion presented in the second specifications book must be understood as the "Wax added Technique" described by PAYNE, PK THOMAS and LUDEEN and confirmed by STEFANIS in 1970 and whose reference practical book stays "the introduction to LUDEEN's anatomy" (1969). The construction of the tooth happens in two steps:

1st step: creation of a bowl based on the finishing line. It goes up like a flower's corolla towards the contact zones on which it leans (mesial and distal plans) and on each tooth's virtual lines on vestibular and lingual plans. The theoretical tooth is divided in 2 distinct parts, an occlusal one and the other one under the great contour line or bowl. The bowl is LUNDEEN's 3mm reduction step before the use of ivory wax (LUNDEEN P12). This bowl is known by a matrix of coefficients characteristic of the tooth to be crowned and by a set of 3 generators which are:

- the finishing line
- the great contour line
- the separation line between the bowl and the occlusal face

stocked in a library, brought back by homotethy to the patient's mouth's scale then positioned in the prosthetic space, the tooth will be adapted to the occlusion in a second step.

2nd step: The occlusal surface, limited to its inferior part not by its crest line but by the great contour line, rises towards the antagonist tooth's complementary zones. Each point match is done in the "Wax up" method with the exception of the fact that different shades waxes have been replaced by movement vectors of the specific points known in the occlusal surface of the antagonist teeth. Instead of rising a red wax cone for a molar towards the antagonist pit, it is a point of the occlusal surface of the antagonist tooth, known for being the cusp point, which will correspond to its antagonist.
The types of data implemented for this modification are as follows:

- a file of formatted points corresponding to the impression capture of the antagonist teeth
- a set of coordinates of centred points of the teeth to be taken into account
- digital data from the theoretical teeth library, defining the number of centred teeth
- shape of the bowl and the adjacent teeth obtained previously
- indication of the occlusal movements to modify the occlusal movements. These movements were captured by a modified facial arc and reported on an articulator created in the computer

This method, partially used at the ADF in November 1985, appeared to be difficult to use, according to the computer people and we had to compose with this new construction conception.

From February 1986, the notion of "placing in environment" was proposed, a method which is still used today and of which we are going to recall the main principles.

2.3-2.2 Placing in environment – theoretic principle

When we have to model a tooth from an image file, we try to extract from this file a certain number of information.

They are:

- the new finishing line or stump base line
- six basic points
- the vestibular point by interpolating the vestibular envelope of the theoretical right inferior arch
- the lingual point in the same manner with the lingual envelope
- the mesial and distal points respectively defined by the anterior and posterior teeth
- the vestibular and lingual occlusal points, respectively corresponding to the summits of the vestibular and lingual cusps defined with the help of the antagonist arch's teeth

Rapidly (after the Marseille demonstration in May 1986), we noticed that the number of points thus called weren't enough and that the obtained tooth wasn't the reflection of a "functional reality", particularly at the level of the occlusal points. We had to define better:

- the vestibular and lingual support line, very variable depending on the type of tooth
- the respect of the occlusal gutter notion
- the proposition of occlusal points corresponding to either the patient's actual occlusion or a therapeutic occlusion leaning on the great concepts recognised today and very well defined in Ph. JOURDAN's thesis (AIX MARSEILLE 1986).

This obliged us to know how to recognise automatically the data and propose them to the dentist for a possible interactive modification. WE can summarise today the action of placing in environment as 2 steps which are:

- application treating the automatic placing in environment and leaning on the recognition of previous points (figure 32, 33)
- interactive modification and deformation

The automatic placing in environment happens in two automatic steps separated by a possible modification of the centred points (figure 34)

2.3-2.3 Automatic placing in environment of bowl

The first step or automatic placement in environment happens in 5 stages and doesn't act on the surfaces but on the essential lines programmed in modified B-spline, such as described in introduction of the theoretical teeth. The five stages are:

- interpolation of the new finishing line which corresponds to the adjusting of the theoretical line on the real line of the preparation (approximation by the least square method)
- the theoretical crown is reduced so the barycentre of the finishing line of the crown corresponds to the barycentre of the new line. There is a general movement of the environment around the theoretical tooth (affinity with regards to the O_x, O_y and O_z points of the tooth).
- adjusting of this tooth to the environment with regards to the average affinities
- translation of basic points to establish a narrower correspondence with the environment
- replacement of the finishing line by the real preparation line (operation by translation and correspondence of each pole)

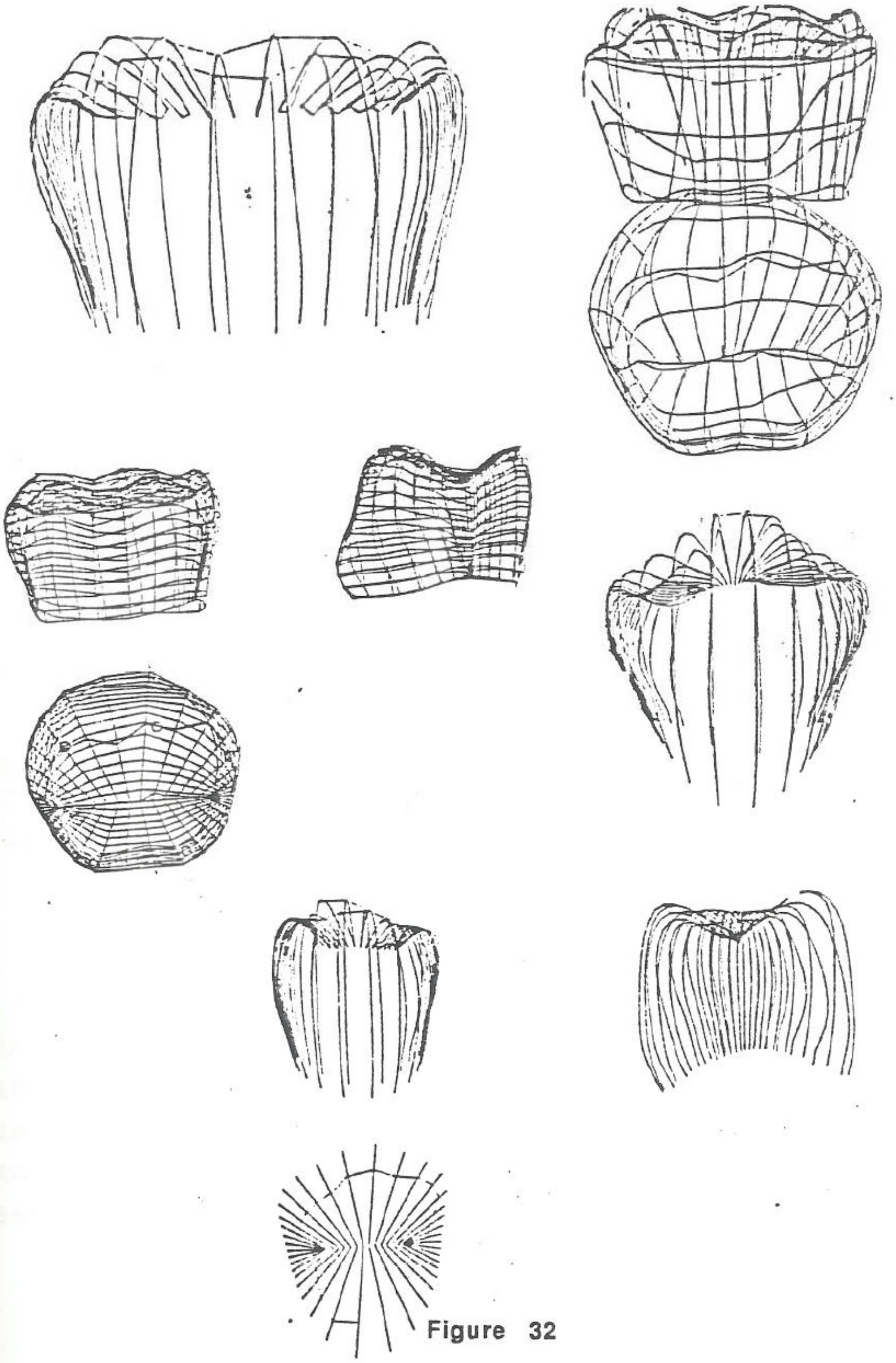


Figure 32

EXEMPLE D'EXTRACTION DE PARAMETRES
POUR LA MISE EN ENVIRONNEMENT

Rapport odontologique Confidentiel

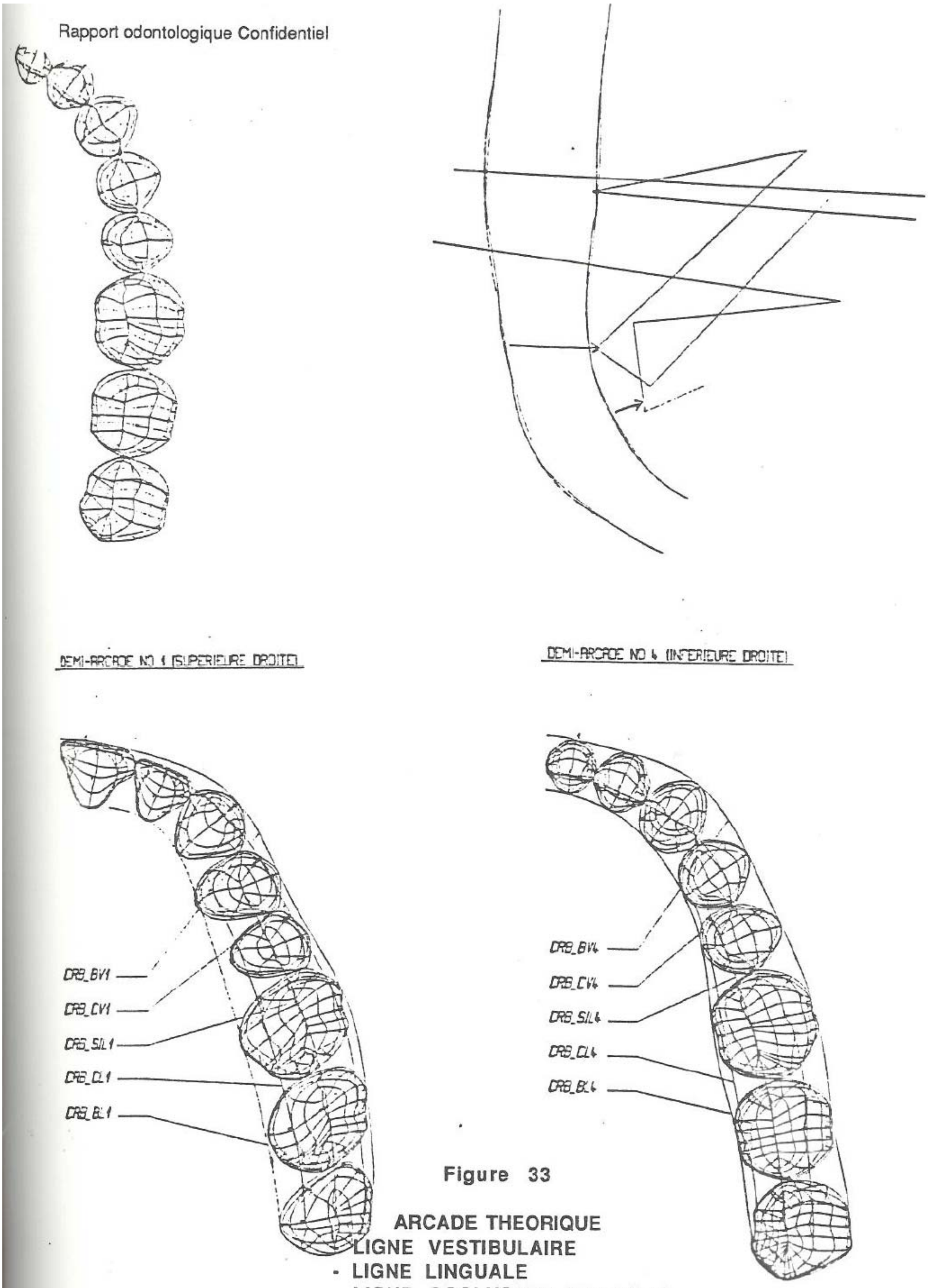


Figure 33

ARCADE THEORIQUE
- **LIGNE VESTIBULAIRE**
- **LIGNE LINGUALE**
- **LIGNE OCCLUSALE (Gouttière)**

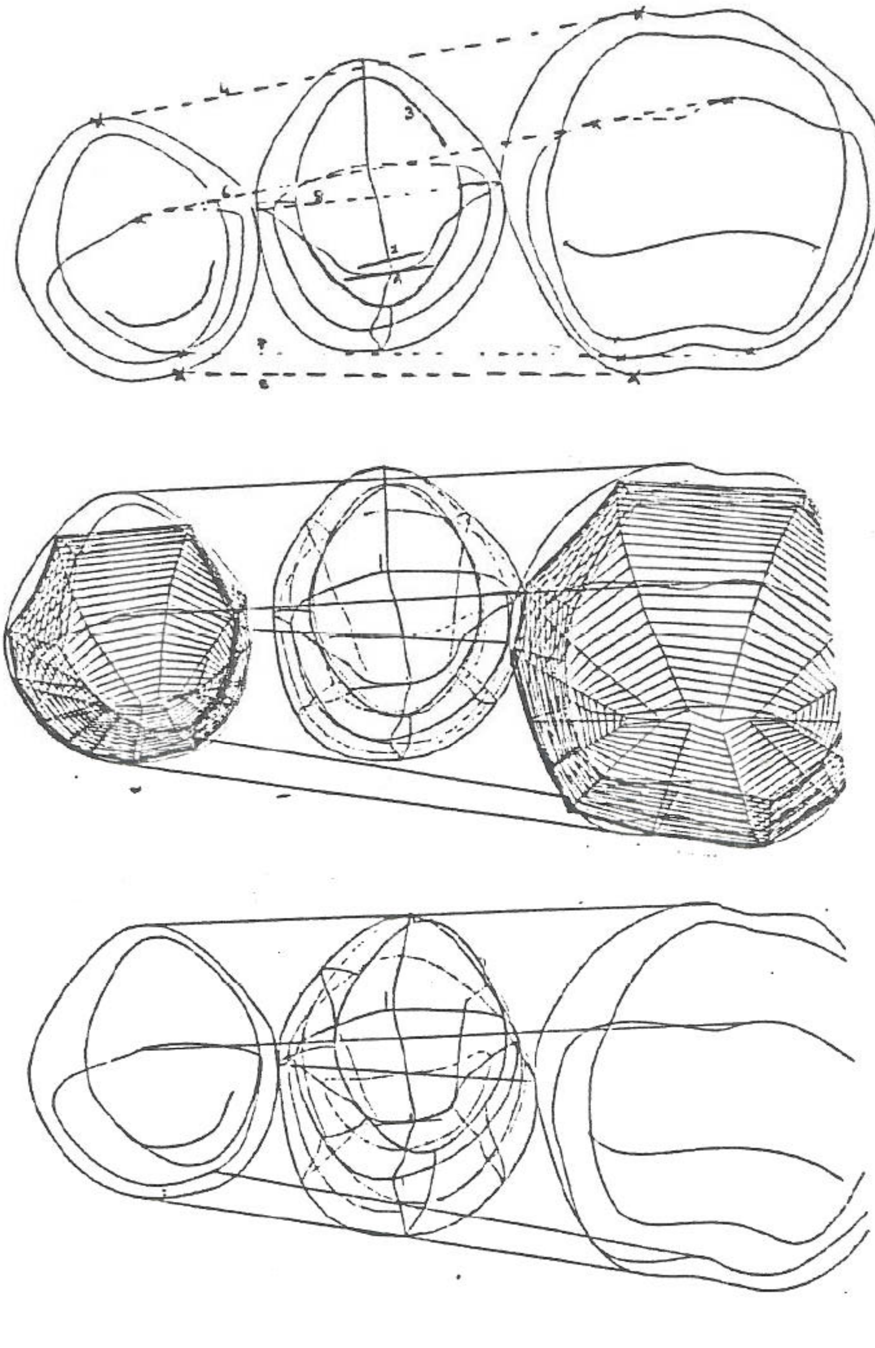


Figure 34

EXEMPLE DE MISE EN ENVIRONNEMENT AUTOMATIQUE

The neighbourhood has had transformations thanks to the translation, dilatation and rotation base functions with an action in certain cases of algorithmic “filter” in order not to give abnormal images. We apply, in this sense, the global automatic adjusting gesture of a crown such as defined in numerous publications and in Burch’s article JDP, 30, p454-458, 1963.

Summary if the dentist’s action:

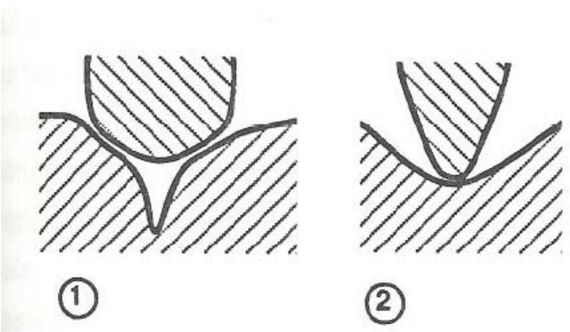
When the finishing line has been defined and accepted and when the dilator has been established, there is a minimum intervention of the dentist, which is:

- acceptation of the vestibular line
- acceptation of the lingual line
- acceptation of the occlusal gutter line
- acceptation of the line linking the contact zones
- or movement of one of the two extreme points.

This intervention can take up to one minute for a normally practiced practioner.

2.3-2.4 Adaptation of static occlusion

Placing itself, really, between the contact line determination process and the final orientation of the crown in its environment, it appeared more “dental” to explain it as a final and “fine” adaptation to the patient’s environment. The principle rests on a double modelling gnathologically or functionalistically possible. It is possible to obtain an inter dental contact depending on the following drawings:



Gnathologic theory

Functionalist theory

(Figure 39)

This corresponds to a modification in the modelling of the occlusal surface of the crown. The interactive operation will only have an effect on the choice of the number and place of implantation of each centre.

2.3-2.4.1 Global orientation of gutter

With the interactive action of the placing in environment at the level of the impression capture probe (definition of the furrows) and with the adjusting and acceptation of the placement in environment at the CAD level (acclusal gutter), we can suppose there will be a logical correspondence between the occlusal surface of the future crown and the antagonist tooth.

2.3-2.4.2 Contacts

Still we have to be certain that there is no supra contact surface or interferences and that the choice of contact zones respects

- either the patient's occlusal mode
- or the therapeutic occlusal relationship mode chosen by the practioner

With the absence of troubles and with the acceptation of a tolerance space for the occlusal factors, it is possible to find inside the mouth of a certain number of patients a intercuspidation position, and correct movements (laterality, propulsion and functional). In this case, we should position our contact points at an academic reference level (slightly modified if there is a natural lag) and with a combination between a pit cusp lodging or a peak cusp following the individual's class.

Historically, we have followed the following plan. Between 1982 and 1984, there was no question of treating the occlusion in a "centred point" sense. The inter dental relationships were global and the occlusal surfaces defined the antagonist surfaces without any subtlety. However at this time, a specific algorithm had enabled to model in "negative" on the crown what the antagonist tooth was, in order to create the future occlusal surface. We don't use any proper morphological criteria.

In November 1985, during the ADF congress, we have decided to follow a new rule which can be summarised as such: the morphology of a theoretical tooth expresses what is an occlusal surface. Taking into account the homothetic deformation of the tooth, in the placement in environment algorithm, the new obtained tooth is in harmony with its environment and the definition of several points is enough to obtain a tooth close to reality. Particularly, the definition of the furrow enables us to get a good relationship between the furrow and the cusp. To do this, we indicate it at the cusp summit's SPE level (or at least we try) or at the CAD level of the furrow on the antagonist teeth. The result wasn't really disappointing and we could notice that CAD could give some usable information such as contact types, their shape and localisation in the neighbouring teeth. The problem with this approach was the need to designate the cusps in a precise order (long and fastidious work) and mainly to define the "collision" zones, a very difficult action as it necessitates a great precision (figure 35 and 36).

From 1986, three works on occlusion really started and we particularly posed the rules we use today. We started from three different objects which are the stump impression and the neighbouring teeth impression and the antagonist teeth impression and an impression of the teeth in occlusion. It supposes that the occlusion chosen by the practioner will be correctly defined (concept). Then the creation of the occlusal surface will happen with regards to the antagonist, in several steps:

a) affectation of the theoretical centres:

the practioner must defined the centre of each tooth and check the correspondence inside the mouth. **To do this, he indicates to the computer the type of occlusion he defined and the type of theory adopted (gnatho-function and cusp pit-peak).** There is display of 6 teeth, three antagonists, and two teeth and the crown, in a theoretical arch fashion, simple, easily interpretable by a dentist with, as over information, the centres corresponding to the type of chosen theory (figure 39). **Facing this arch, the dentist accepts or moves the centres depending on the patient's case.**

We then stock the common data. We must signal that the dentist can stock as many centres as he wants for each tooth, move them or change their numbers. Are automatically stocked the position of the centre (cusp-pit…), the type of contact (monopodism, bi…), the number and types of arches. We have, at this stage, defined and controlled the type of inter-arch rapport.

b) attribution to teeth of defined centres:

There is a decoding of the preparation arch and a progressive construction until we get the characteristic lines (peaks, furrows, cusps…) (figures 37 and 38). Then the previously defined centres are positioned, this happens automatically as soon as the tooth is known in its characteristic lines (peak line, orientation of furrow, summit of cusps), it supposes successive steps of analysis which pass through new modelling developed by HENNSON.

The dentist can check, possibly through cuts, the quality of the established inter-dental contacts. The third cut joined here, at a times 30 scale, shows a superposition of 50µ, on the vestibule-lingual way and of less than 10µ in the mesio-distal way.

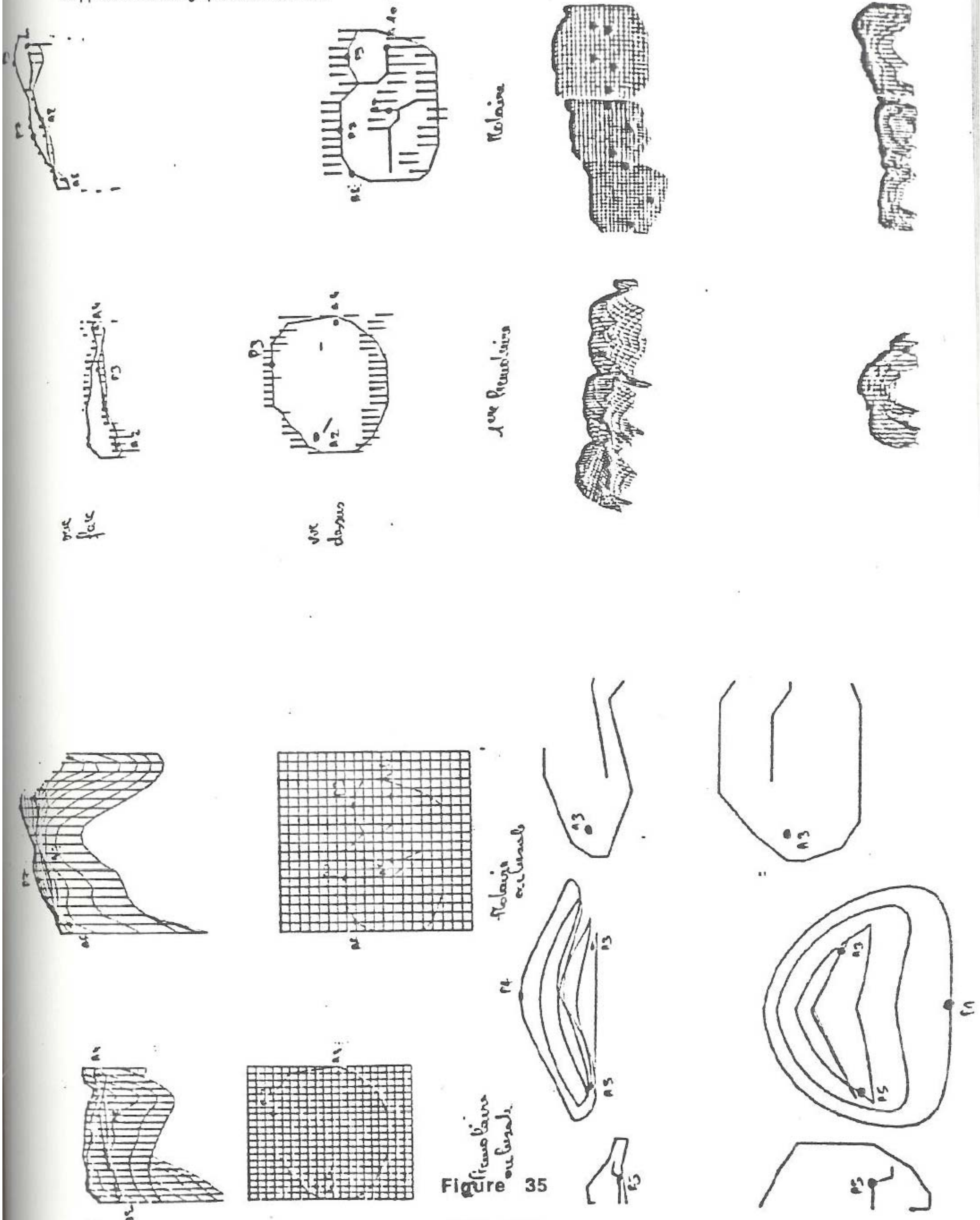


Figure 35

ADF 1985
RECHERCHE AUTOMATIQUE DES POINTS DE CENTRE

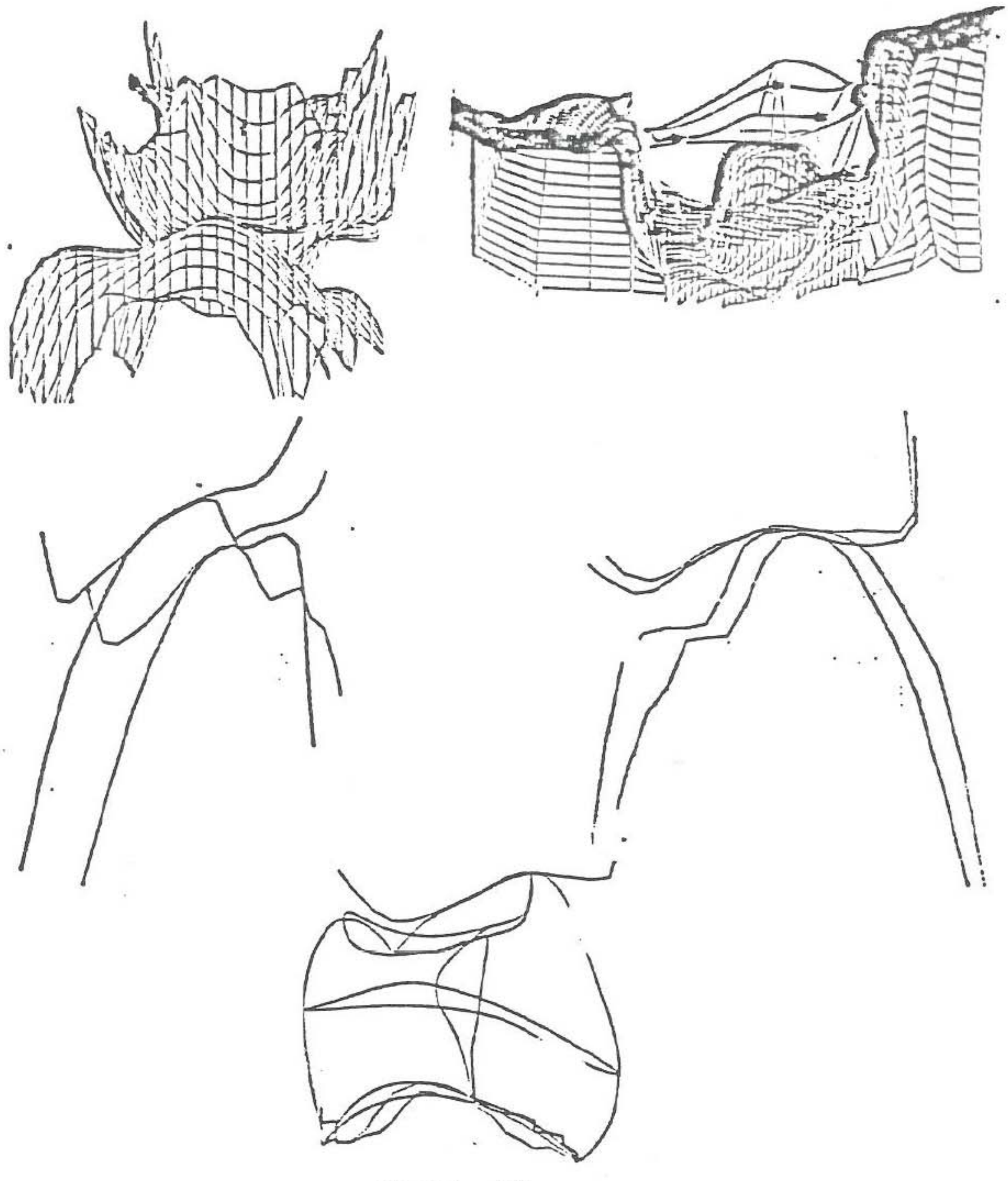


Figure 36

DEFORMATION DE LA COURONNE
DANS SON ENVIRONNEMENT,
ADAPTATION DE LA SURFACE OCCLUSALE
ET COUPE
1985/1986.

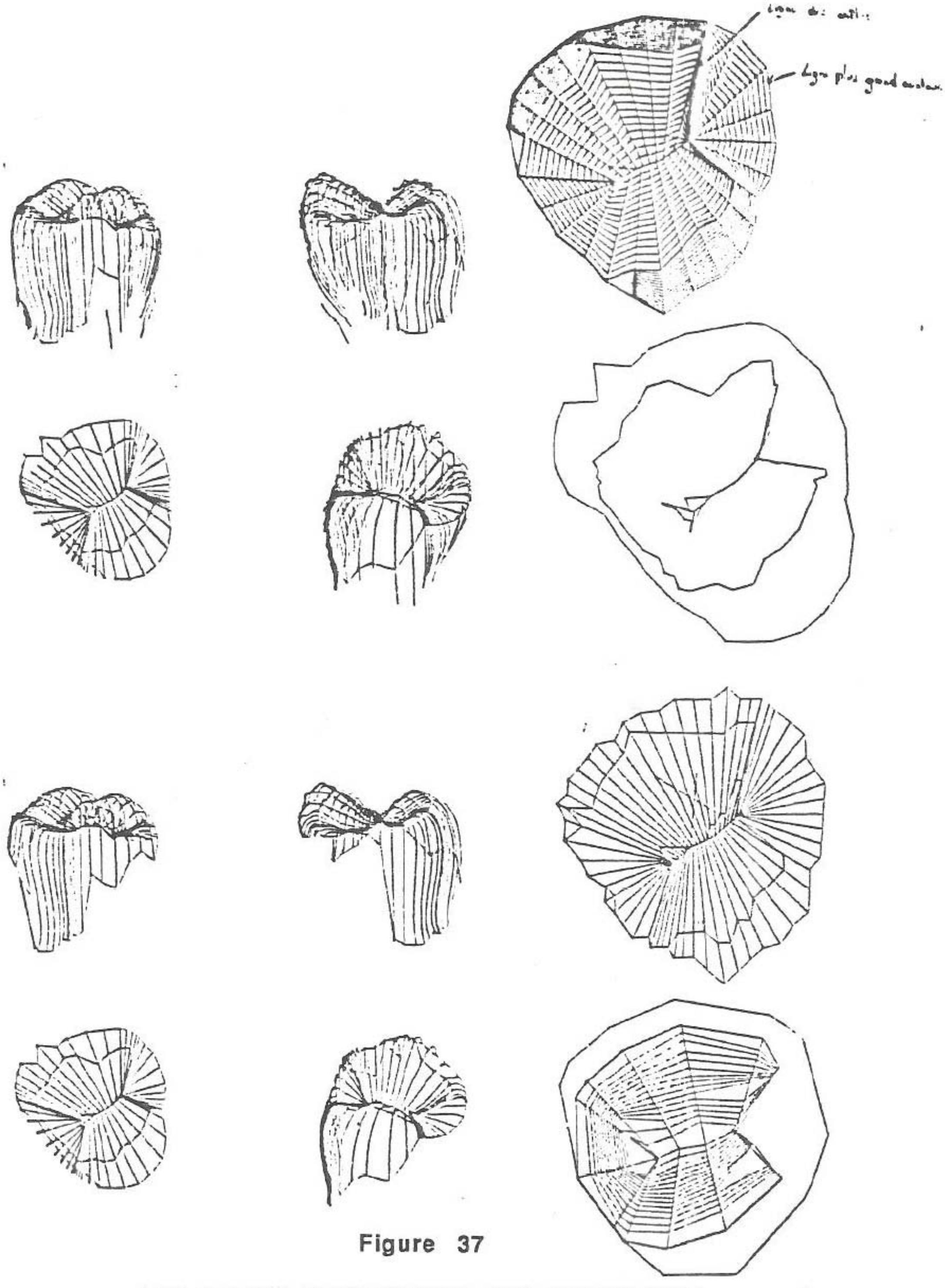


Figure 37

LES ETAPES D'EXTRACTION DES PARAMETRES CARACTERISTIQUES
1987

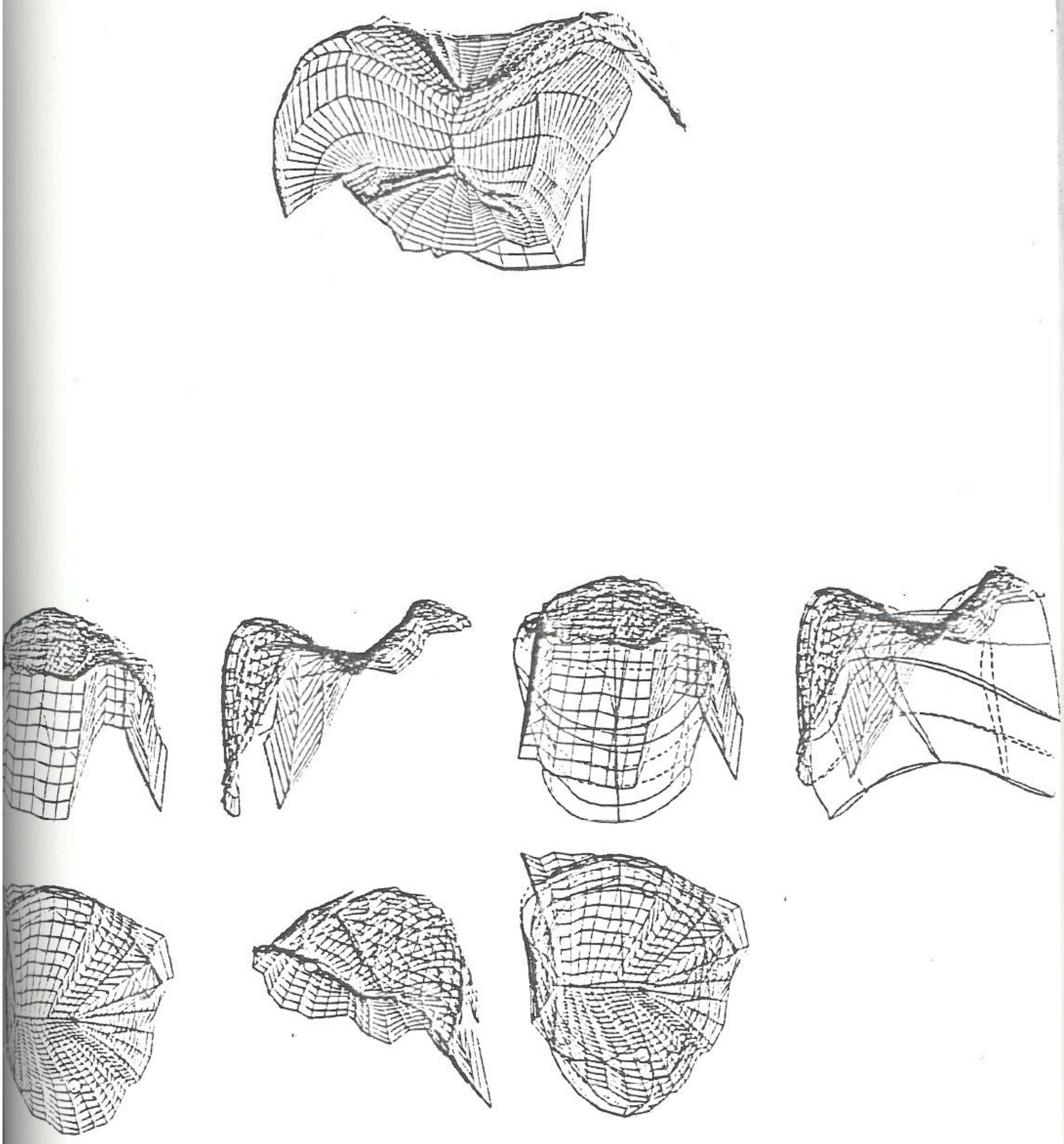


Figure 38

MODELISATION SURFACIQUE
ET EXTRACTION DES PARAMETRES OCCLUSAUX

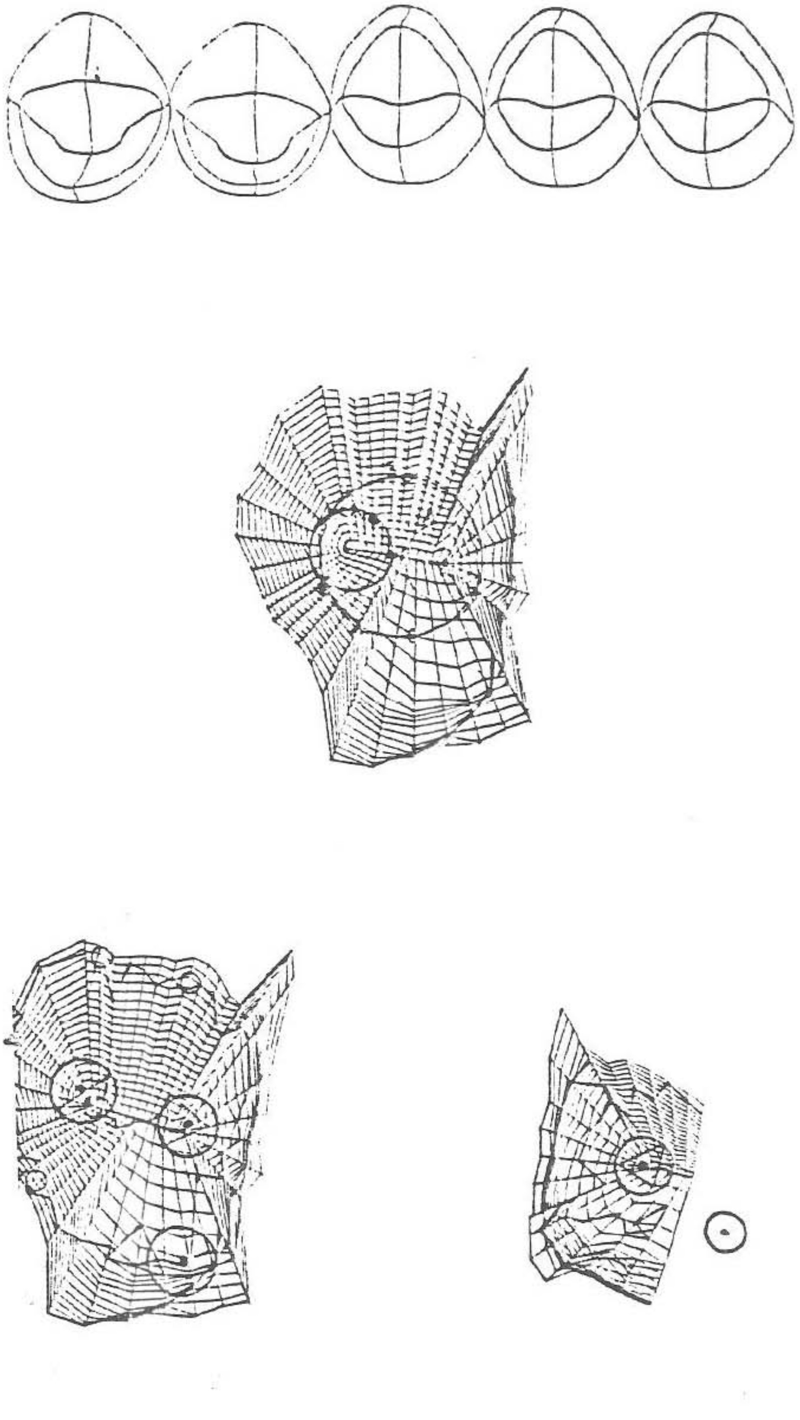


Figure 39

LES CENTRES EN GNATOLOGIE ET FONCTIONNALISTE

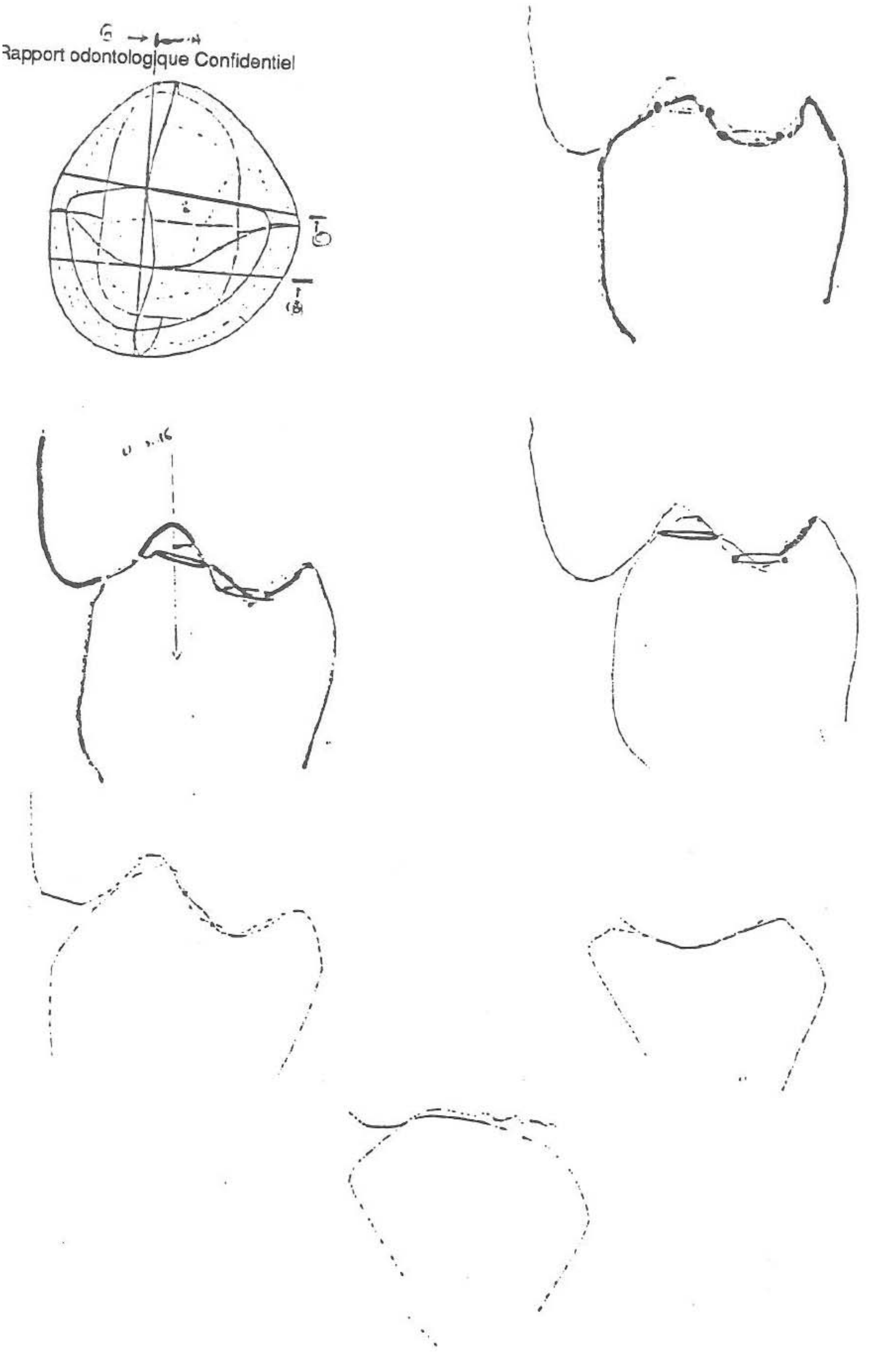


Figure 40

COUPE POUR SUIVRE L'ADAPTATION OCCLUSALE

2.3-2.5 Adaptation of dynamic occlusion

Although not indispensable for bridges of small size and unitary elements (F. LIGUER, C. KNELLESEN "Journal d'Art Dentaire" – n° 89 p1-8, 1979), it appears necessary to us to respect the thoughts of P. DAWSON or M. ASH and RAMFJORD, which are:

"There is a narrow relationship between the occlusal morphology and the mandibular movements. A functional occlusion, contrary to a centred or static one, is a reconstitution of the relief, founded on the mandibular movements determined by the patient."

For this reason, from 1982 (F. DURET "Tonus dentaire", 1982), we have envisaged to check if it was possible to visualise, in the CAD space, the movements of an arch with regards to the other (figure 40). At the Nice days, during the SOFREB in 1984, we presented our direct recording concept of the mouth's movements with an opto-electronic captor (figure 40). However with the ADF demonstrations approaching, we noticed that:

- this setting would be long to develop
- there were two devices that could satisfy this measurement, A. LEWIN's synograthograph and HOBO's C_3 Visitrainer.
- We had to quickly test the movements to check the coherence of our software

For this reason, we have in October 1985, modelled a semi-adaptable articulator in the CAD software, based on the Quickperfect and with which it was possible, thanks to a modified facial arch, to enter interactively the condylian slope, Bennet's angle and the inter-condylian (figure 42). Moreover, thanks to a specific marking, we managed to position our model in the environment of the modelled articulator. We thus managed to obtain in space the mandibular movements and pass them on the occlusal surface of our crown.

From 1986, and with the collaboration of Marseille's faculty, we have decided to completely study the dynamics of mandibular movements. For do this, we decided to know the parameters indispensable to any analysis of the type defined in 1982. We list seven:

- measurement of maximal opening
- variability of trajectory
- measurement of deduction movement
- measurement of lateral translation at beginning of movement
- analysis of masticatory cycle
- measurement of sliding angles, laterally and by propulsion.

- difference between PIM and ORC

Quickly, we understand that the C_3 Visitrainer can give us all of this data and decide to buy it. The first device in Europe of this kind, we had to go through, not without any difficulty, the French Japan Embassy to buy it. This device enables us today to know easily the existence of pathology and the choice of a prosthetic concept (automatable operation sooner or later).

We can today, as well as a diagnosis, situate the PIM at the time of the capture in closed arch, orientate the lateral furrows and define, in a frontal plan, the value of the cusp angle, modified depending on the antero-posterior position of the tooth and the codyilan slope, when the intercodylian distance and the arch's width, measurable with a compass, give us a precise idea of the cusps' height. As for the angle and Bennett's movement, they are given by the Visitrainer and enable the modification of the orientation of the furrows but also the concavity of the antero-posterior group.

The Visitrainer stays, according to us, a device which is too expensive (100 00FF) which obliges us to study it to replace it by a CAD peripheral. To do this, an engineer studies the device completely according to the following plan:

- study of the Visitrainer and the data given by the device
- transmission of this data to the CAD (directly)
- realisation of an opto-electronic captor simply using the computer and electronic support of the CAD

We think this ensemble will be ready for the commercialisation of the device.

To summarise the action in a practice, we will say that:

The dental surgeon will only have to set the measuring helmet with one position of the camera and make the patient do the mandibular movements, without any interactive action.

Firstly and if he measures the inter-condylian distance, the width of the arch and the antero-posterior position of the tooth with a compass, he will have all the necessary parameters. He will have all the determinants for the occlusion which will enable, with an estimation of the codylian slope by axiography or simple tomography, to know all the orientations of the furrows and the value of the cusp angle. The opto-electronic captor will give, with the compass measurement of the antero-posterior position of the tooth, the furrows and the cusp angle. Automatically reported on the crown's model, we will also automatically set the researched values.

Today, we can already know this value:

- by the averaging of the anterior and posterior teeth of the crown
- by the C_3 Visitrainer

2.3-2.6 Conclusion

The software placed the tooth in its environment by respecting the vestibular and lingual bumps, the peak line and the occlusal gutter. The practioner chooses his occlusal theory interactively and checks the position of the centres on the computer screen, depending on the theory. He measures with the Visitrainer the horizontal frontal and sagittal movements. Without having to intervene, the data is transmitted directly to the occlusal surface which is modified depending on the chosen theory and the movement vectors which are the patient's.

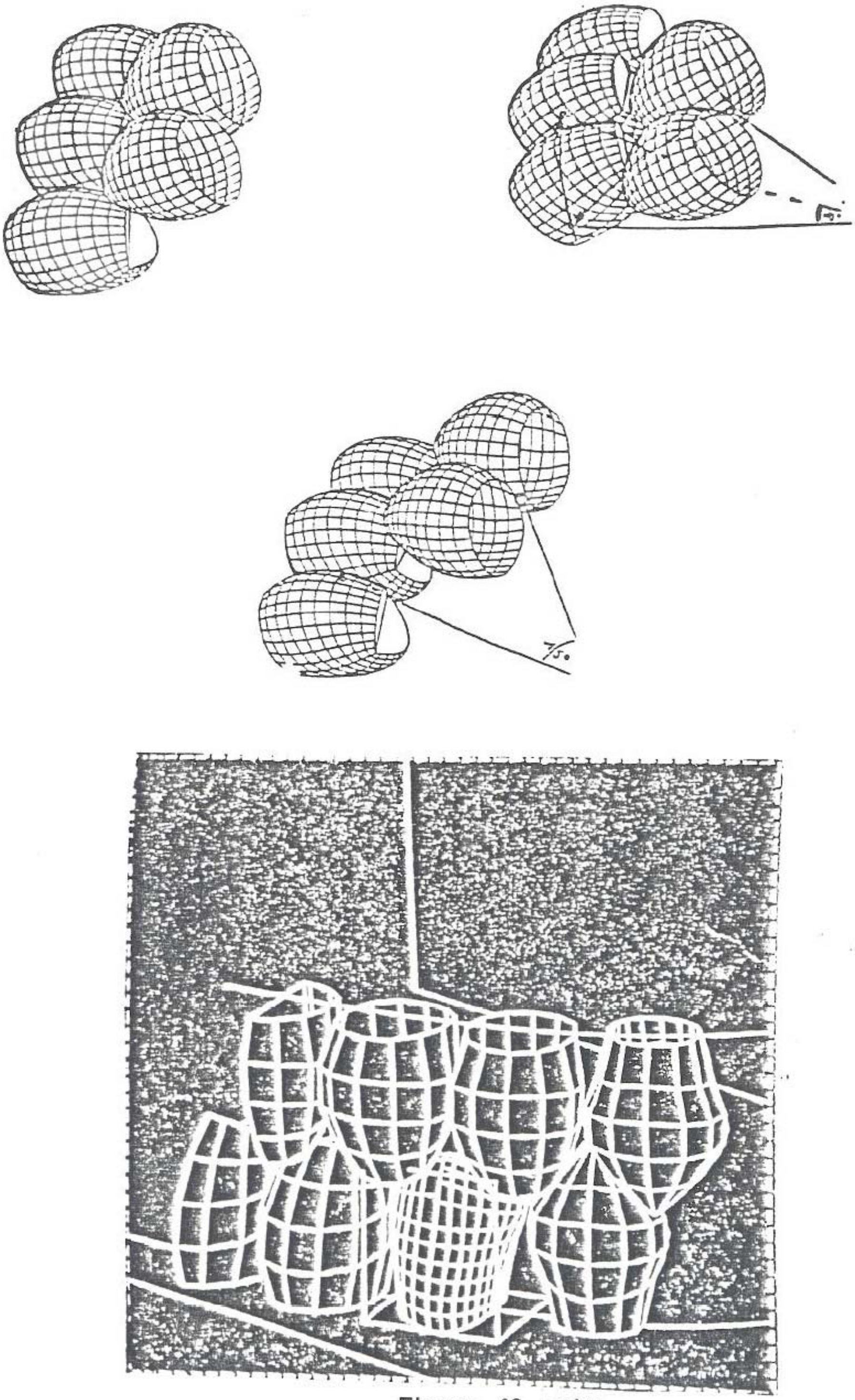


Figure 40 suite

OCCLUSION ET MOUVEMENT EN 1982

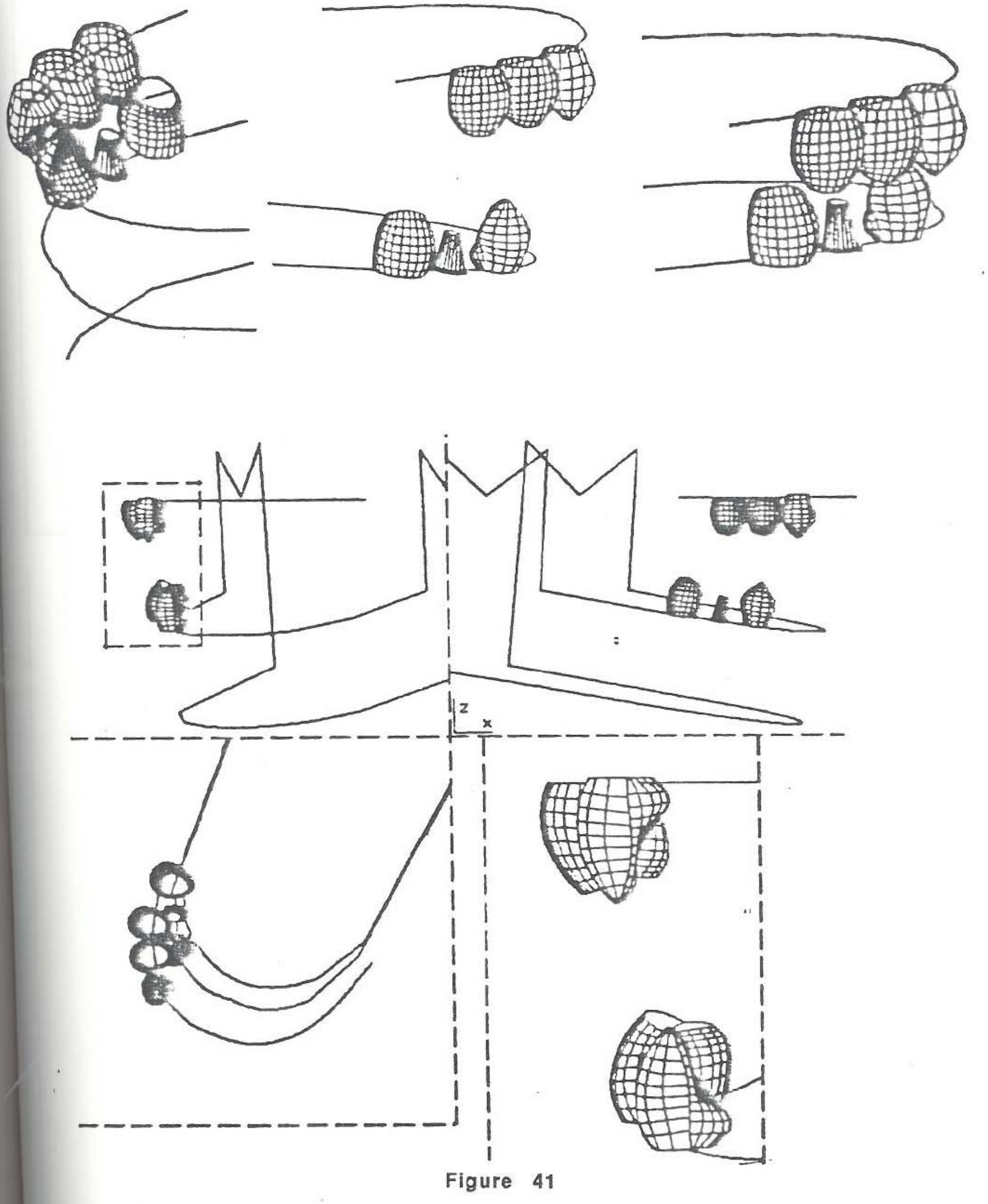
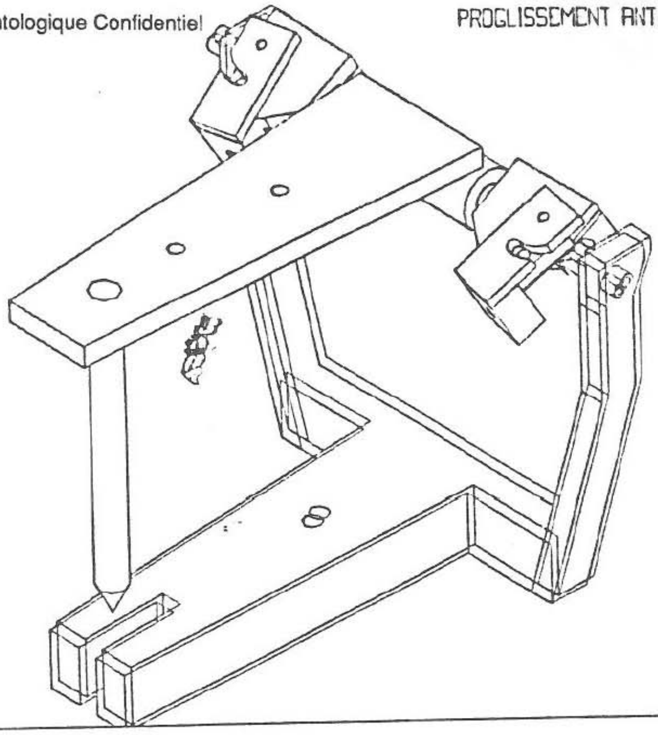


Figure 41

MOUVEMENTS EN 1984

PROGLISSEMENT ANTERIEUR: 3 MM



DISTANCE INTERCONDYLIENNE EXTERNE: 125 MM
ANGLE BENNET: 10 DEG.
PENTE CONDYLIENNE: 30. DEG

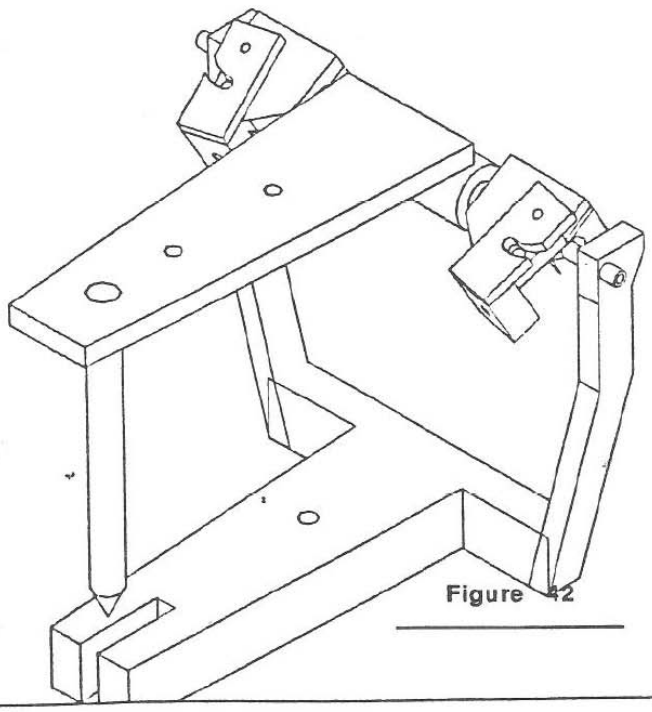
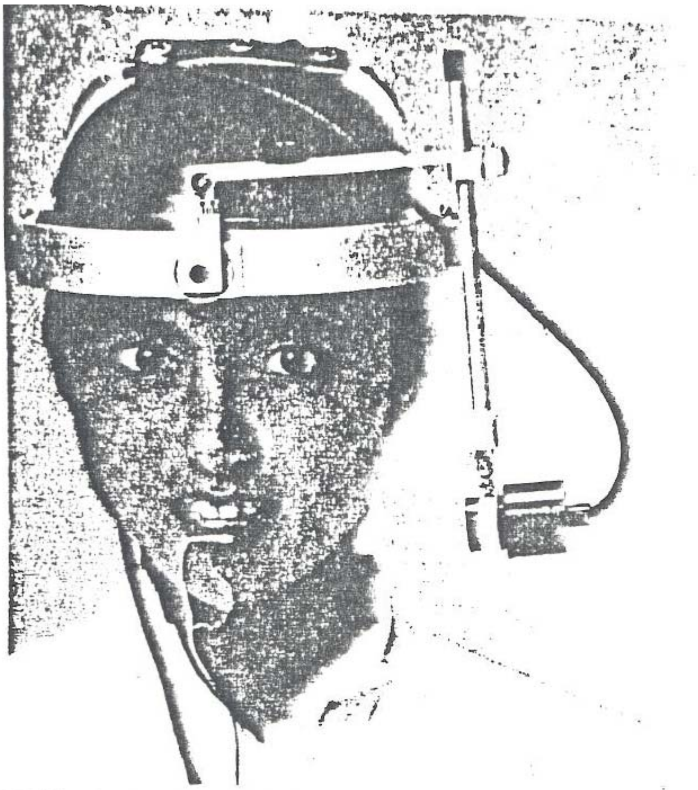


Figure 42

Rapport Odontologique Confidentiel



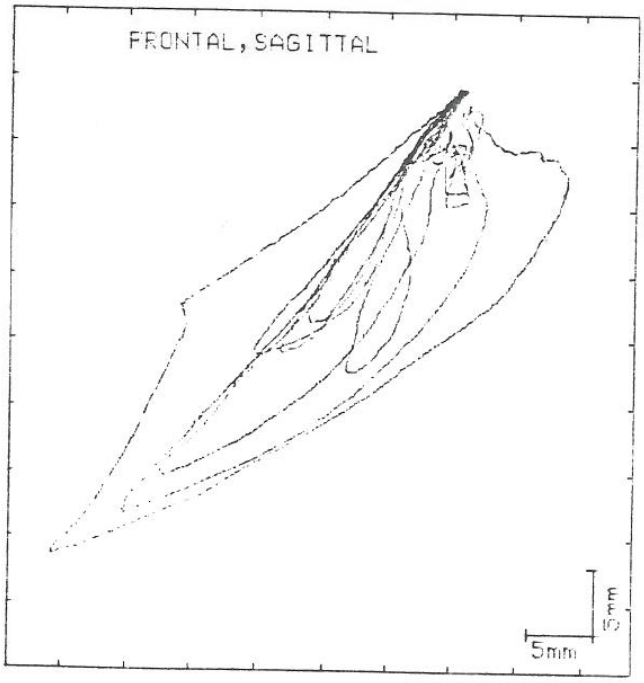


Figure 43

VISITRAINER

2.3-3 Interactive deformations (figure 44)

A certain number of deformation tools have been given to the dentist to deform the tooth. The language used is very simple and the actions are comparable to the removal or adjunction of wax on a crown to give it, for example, a particular shape more aesthetic and personalising the work of the dentist or the patient's mouth (cf. broken angle of an incisive). We find the following functions:

- material
- curve drawing
- wear
- cusp angle
- other (dilatation, rotation, curve, poaching)

We had:

- functional angle (internal – external)
- inter-cusp angle

2.3-3.1 Material

It enables the realisation on screen of a action identical to the addition or removal of matter on a base point of the wired structure of the tooth (slides). The modules is very simple to use as all you need to do is place a point in space by indicating the point you want to move. This action can help obtain bigger bumps or reduce the angles as you would with a spatula.

2.3-3.2 Curve drawing

This function enables, as its name indicates, the deformation of a curve of the wired structure of the tooth, to make it pass through one or several points. This action enables the drawing of a curve as if we added wax on one or more surfaces.

2.3-3.3 Wear

We can, with this module, simulate an occlusal wear. This wear is symmetrical and is done by diminishing the cusps' height. At the same time there is an opening of the cusp angle. This enables the obtainment of reliefs which are very "bruxomane" and the choice of any wear value between 1% and 100%, on a tbale of six values (1, 2, 5 – 10 – 20 -50).

2.3-3.4 Cusp angle

It enables the modification, interactively, of the cusp angle depending on the given value. If the previous actions generally act on the tooth, this function will be directly used for data from the Visitrainer of the dynamic occlusion.

2.3-3.5 Other

The dilatation, rotation, curve and poaching functions are useful functions for the conception of a theoretical tooth but they aren't usable by the dentist, as too complex (they won't be on the working menu).

2.3-3.6 Functions being studied

2.3-3.6.1 Angle

It can modify the functional internal and external angles and the inter-cusp angle. Contrary to the cusp angle case, there is no movement of the cusps but a more or less strong rounding of the shape.

2.3-3.6.2 To be defined after the clinical tests

2.3-4 Basic principle for all crowns

2.3-4.1 Introduction

The placement of the theoretical tooth in its adjacent environment and its automatic adaptation to this environment are the bases of any conception software of a crown. The existing algorithms have been founded on the premolar, the only modelled tooth in CAD at the time. Now, we dispose of all the theoretical teeth, we can model a complete arch and test the placement and adaptation algorithms on each type of tooth

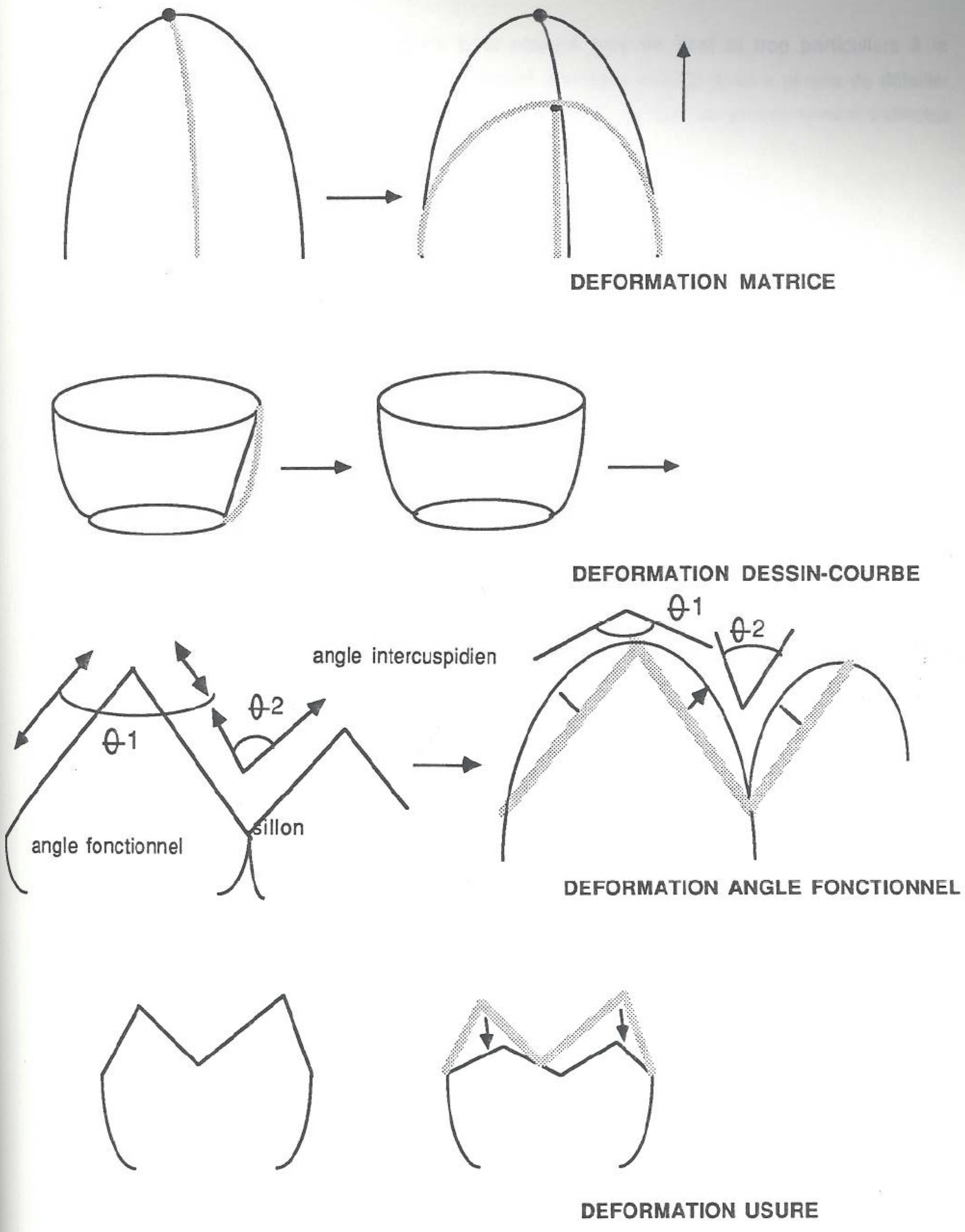

DEFORMATION MATRICE
DEFORMATION DESSIN-COURBE
angle intercuspidien
θ1
θ2
angle fonctionnel
sillon
θ1
θ2
DEFORMATION ANGLE FONCTIONNEL
DEFORMATION USURE

Figure 44

Those are shown incomplete for each type of tooth and too particular to the premolar to adapt to each case. A deep analysis work enabled us to detail for each type of tooth its placement and adaptation. The placement in environment is done in two steps:

2.3-4.2 The placement

We place the environment in the theoretical tooth's marking.

The image treatment transmits:

- a segment of the mesial adjacent tooth
- a segment of the distal adjacent tooth
- a perpendicular plan of the occlusal view

For posterior teeth this data materialises the position of the occlusal gutter and of the mesio-distal furrow of each tooth. For anterior teeth, they indicate the position of the free edge of each tooth. Let's remind that the placement in environment leans on the determination of the furrow, the alignment axis and the placement.

2.3-4.2.1 Determination of mesio-distal furrow (posterior teeth) or edge furrow (anterior teeth)

Having X and Y (occlusal views), the furrow segment or the free edge of the rown, we must determine the height of the extremities.

a) posterior teeth (premolars – molars)

There are either two adjacent furrows (mesial and distal tooth) or an adjacent furrow if a tooth is absent (mesial tooth or distal tooth) or no adjacent furrows (absent teeth)

If there are no teeth, we refer to the theoretical curve of the gutter of the theoretical tooth corresponding to the maxillary type, we can thus use the positioning done at the SPE level. In the case of two proximal teeth, we determine the vestibular points of the mesial and distal teeth to the crown. The theoretical teeth are placed on a theoretical arch have a natural curve; if we move them to put them in the same position as the patient's teeth, we can do an affined transformation enabling the knowledge of the patietn's real curve. For a proximal tooth, we will do similar operation by leaning on the gutter's line as well.

b) anterior teeth

The height of the free edge's extremities of the incisive is determined by simple geometric rules from the data calculated on the adjacent environment which are proper for each tooth. For the canines, we don't worry about the free edge since it is fixed more by the teeth's movement on the antagonist than by the adjacent shape.

This knowledge is given by the Visitrainer or simply by reading the symmetric or antagonist tooth.

2.3-4.2.2 Rotation axis, aligning axis

From the mesio-distal furrow's axis of the free edge of the crown given by the SPE, we determine:

a) the rotation axis

The rotation axis for the placement of posterior teeth is the mesio-distal furrow axis and for the incisive the axis deducts from the position of the free edge and other simple geometrical rules from elements of the environment. For canines, there is an exception: we take the axis joining the contact points to the crown.

Nota:

- the mesio-distal furrow of the posterior gives the direction of the occlusal gutter which helps the meshing of antagonist teeth
- this furrow becomes the cingulum at the anterior level, its detection isn't evident and its function in the meshing is reduced
- the free edge is a more representative criteria in the arch's harmony

On the other hand, its geometry on the frontal plan varies al lot from one individual to another. That is why we look for a rotation axis as independent as possible of these geometrical particularities.

b) The alignment axis

The alignment axis of the centres of gravity of the finishing line and that of the vestibular margin, in the vestibulo-lingual direction, is stocked for each type of tooth. It corresponds to the average axis of the neighbouring tooth of the vestibular margin line.

2.3-4.2.3 Placement (figure 45a)

We distinguish the following steps:

a) translation and rotation of the environment to bring the rotation axis of the environment back to the rotation axis of the theoretical tooth (having the same definition)
b) rotation of the environment around the rotation axis, in order to bring the centres of gravity of the finishing line on the vestibular margin's line and align them following the previously defined axis
c) translation following the rotation axis to adjust more precisely the alignment of the centres of gravity

An exception is to be signalled. It is the placement of the central incisive. We have defined the placement criteria as follows:

a) global homothety of the crown, so that the distances of the free edges, of the vestibular bumps of the central incisive symmetrical and of the crown be identical
b) placement in environment of the free edge
c) rotation of the free edge so the vestibular bump of the crown is placed on the curve of the vestibular bump deduced from the theoretical teeth

2.3-4.3 Adaptation of the crown to the adjacent environment

2.3-4.3.1 Homothety (figure 45b)

The global homothety of the crown is done so that the distances, seen from above the line joining the contact points and the line joining the mesio-dital points of the great contour line of the crown are equal.

2.3-4.3.2 Adaptation of vestibular margin to the finishing line

It's a substitution operation.

2.3-4.3.3 Adaptation of the crown's "bowl" to the environment (figure 45c)

It is the adaptation of the contact point and the vestibular and lingual bumps. We can find the movement of the **mesial** and **distal** points of the greatest contour line at given contacts points. Then the movement of points other than those of the vestibular margin line towards the mesio-distal direction, proportionally. We finish this phase with the movement of the vestibular and lingual points of the greatest contour line on the vestibular and lingual bumped curves previously calculated (figure 46a).

2.3-4.3.4 Adaptation of the crown's crest line to the adjacent crests

This operation insures a good regularity of the whole vestibular and lingual peaks of the arch. It is specific to each tooth.

a) posterior teeth (premolars/molars): there is a movement upwards and towards the vestibulo-lingual direction of the points of the crown situated on the free edge in harmony with the free edge direction, calculated when placing the adjacent teeth (figure 46b).

Incisive: there is movement upwards and towards the vestibulo-lingual direction of the points of the crown situated in the free edge in harmony in the direction of the free edge, calculated during the placement of the adjacent teeth.

Canines: there is movement upwards of the crown's free edge points, in harmony with the curve of the vestibular peak calculated for the crown. We have no movement on the lingual side.

Nota: for the mesial and distal peaks of each tooth we have (figure 46c):

- a movement upwards of the point of peak line and the crown, at the same level as the distal point of the peak of the mesial adjacent tooth
- same for the distal point of the peak line at the same level as the mesial point of the peak of the distal adjacent tooth

More or less.

For type of tooth, a complete process respects the real morphological data of the individual. This has enabled to proceed to a placement in environment practically specific for type of tooth which we have illustrated in figures 47 and 48 (real case).

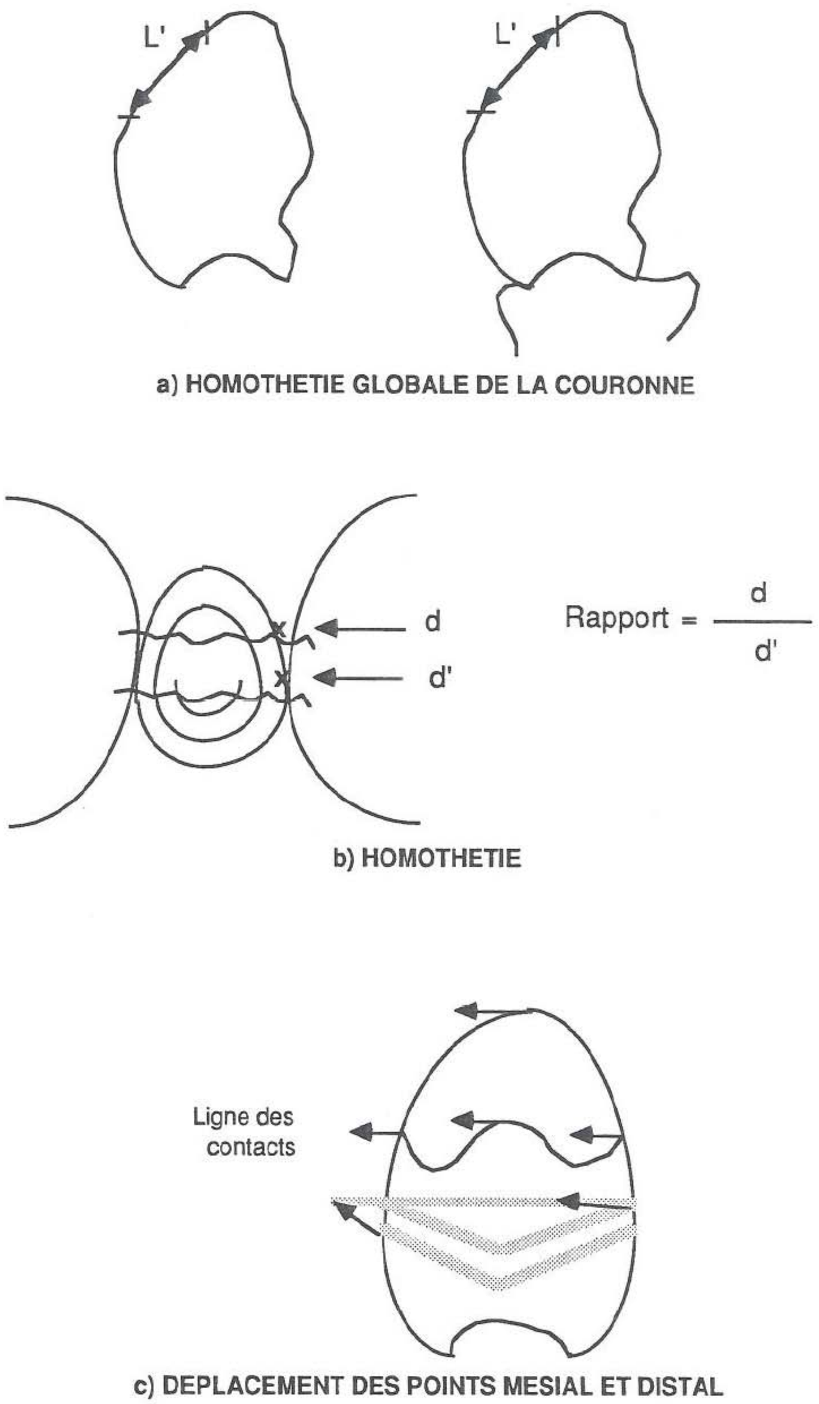
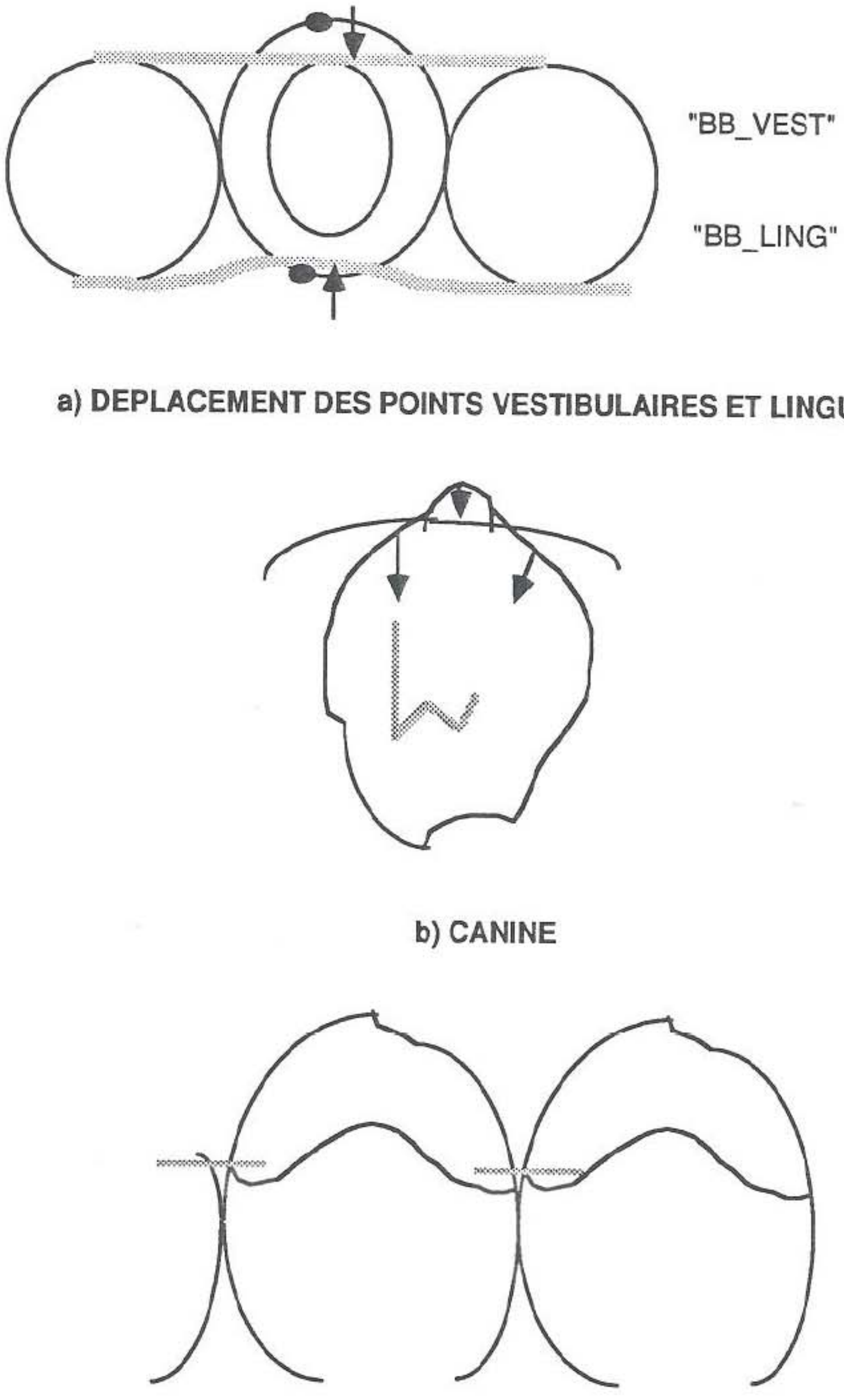

L'
L'
a) HOMOTHETIE GLOBALE DE LA COURONNE
d
d'
Rapport = d / d'
b) HOMOTHETIE
Ligne des contacts
c) DEPLACEMENT DES POINTS MESIAL ET DISTAL

FIGURE 45



a) DEPLACEMENT DES POINTS VESTIBULAIRES ET LINGUAUX

b) CANINE

c) CRETE MESIALE ET DISTALE (toutes dents)

Figure 46

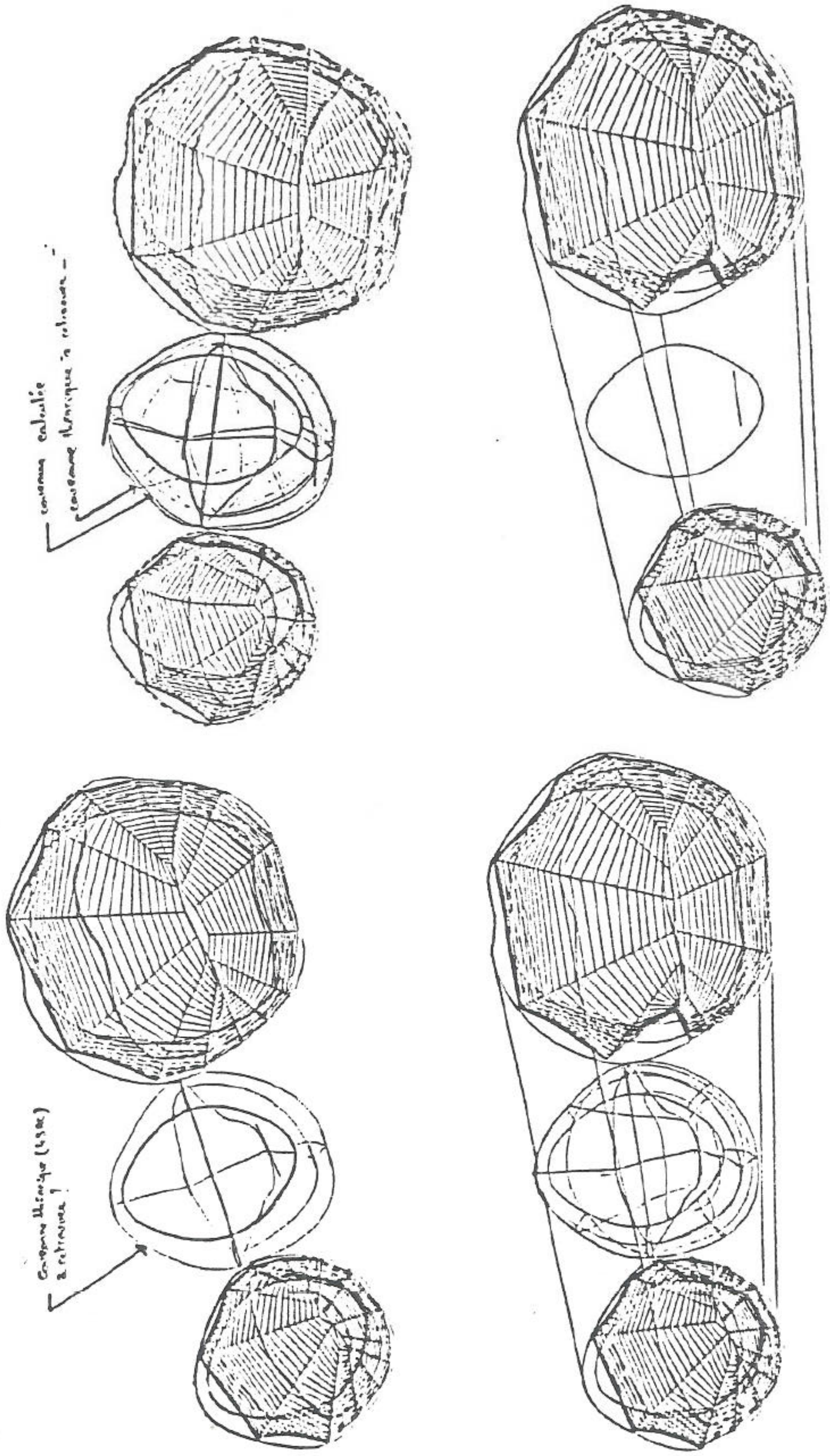


Figure 47

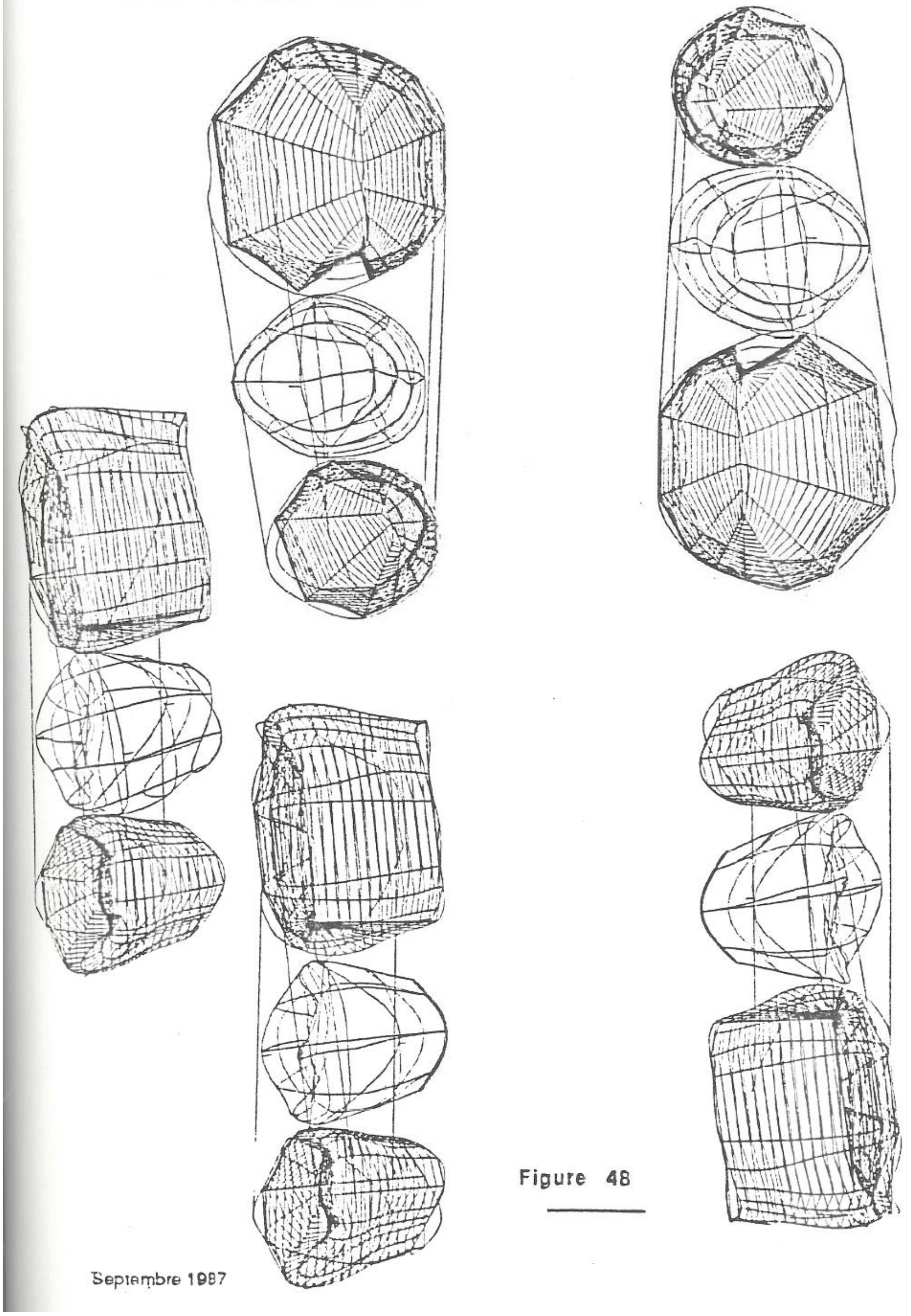


Figure 48

2.4 Realisation of bridges

"A bridge is a fixed (or conjoined) dental prosthesis, for the replacement of absent teeth by the aggregation of certain remaining teeth (BATAREC). What is most important in CAD is to use the acquisition of the crown to build the bridge, as we have defined it in our patent in 1982. It's best to do the positioning of the teeth with the bridge by firstly showing the whole theoretical arch then by determining the proximal plans, each proximal plan being determined as perpendicular to the line linking two contact points of the prosthesis with the teeth staying in the mouth, or as perpendicular to the line linking a contact point to another proximal plan depending on whether there are one or more pontic teeth. After the determination of the proximal plans, the process is to place the theoretical teeth against the proximal plans by, possibly, being deformed to respect the envelope available for each element. The cutting of the bridge will happen, if it is bigger than 5 teeth, in the posterior frame and 6 teeth in the anterior frame. In fact, the true rule of cutting had, there again, been defined in April 1982 and depended on the manufacturing possibilities brought by the digital command tool machine and the number of axes. Particularly the respect of a good embrasure must be the realisation trouble of a Bridge by CAD/CAM.

To realise the manufacturing of a prosthesis with several elements, it is interesting to section the arch to realise into a set of parts forming lines or arcs with a great radius. Each part is manufactured separately with an intermediary fixation system. The marking is done at the central element level, if the curve is regular. The cutting of an arch into a set of parts is done taking into account the angle of the manufacturing tool so that it can work in the best conditions possible, preferably according to three axes, maximum four for simplification reasons." (DURET – April 192 – Patent).

2.4-1 Realisation of a theoretic intrados library

As for theoretical teeth and by using the occlusal elements and the teeth's bowl previously described, it was possible to develop then model the intermediary bridges and adjoin them to the previous library (figures 49 and 50). This operation is more complex than it appears as the pontic no longer has a finishing line as we find it on the crown, but only one point. The operation consisted in January 1987 to reduce to one point the finishing line while keeping a good coherence in the BEZIERS' channels handled under the greatest contour line.

Moreover, by leaning on the different prosthesis book:

EMC – 5 A81 – 23 270 A[50]

TYLMAN – “Theory and practice of the Crown and Bridge” 1969
SHILLINGBURG – “Fundamental bases of fixed prosthesis” – CDP 1982
it was possible to know the morphology that the basis of this pontic must represent et the rules ruling its surface. We suppose that the occlusal morphology will respect the same rules than the dental crown. The pontics have been presented to R. Sheldon Stein, “BobStein” in February 1987 in Chicago (Professor in Boston). He stays today the specialist of Bridges’ pontic. Rather than describing the pontics, it appears more interesting to present them. You must know that the modelling rules are identical to those of the crown, on a mathematical plan and that it is possible to modify the part in contact with the mucous: it’s the adaptation of the “finishing line of the pontic”.

2.4-2 Realisation of a bridge

The realisation of a Bridge in CAD/CAM is identical to the realisation of a crown on a fundamental plan. With a great difference to the traditional method, the realisation of a Bridge is more complicated than that of a crown but not more in terms of Research and Development.

2.4-2.1 Definition of data from the image treatment

We must, as for a crown, isolate the pillars of the bridge. To do that, we transfer to the CAD the finishing line of the stumps as well as the furrows of the adjacent teeth. Seeing as the bridge represents more than 5 posterior teeth or 6 anterior teeth, it is necessary to adjoin to the “finishing line” and “furrow” data the “correlation point” instruction belonging to the common zone of the two continuous zones (at least) of the arch. It enables the CAD to reconstitute the hemi-arch of the bridge.

Moreover, are necessary:

- antagonist teeth
- occlusion teeth
- occlusal movements
- the gum given by the impression as are the teeth

To do that, a view of the antagonist teeth is transferred to the CAD with indication of the furrows and a view of the clenched teeth. Moreover, the movements and data of the antero-posterior movements (incisivo-canine lingual disposition) and the lateral movements (antero-posterior disposition of the molars) enable us to do an a priori positioning of the teeth.

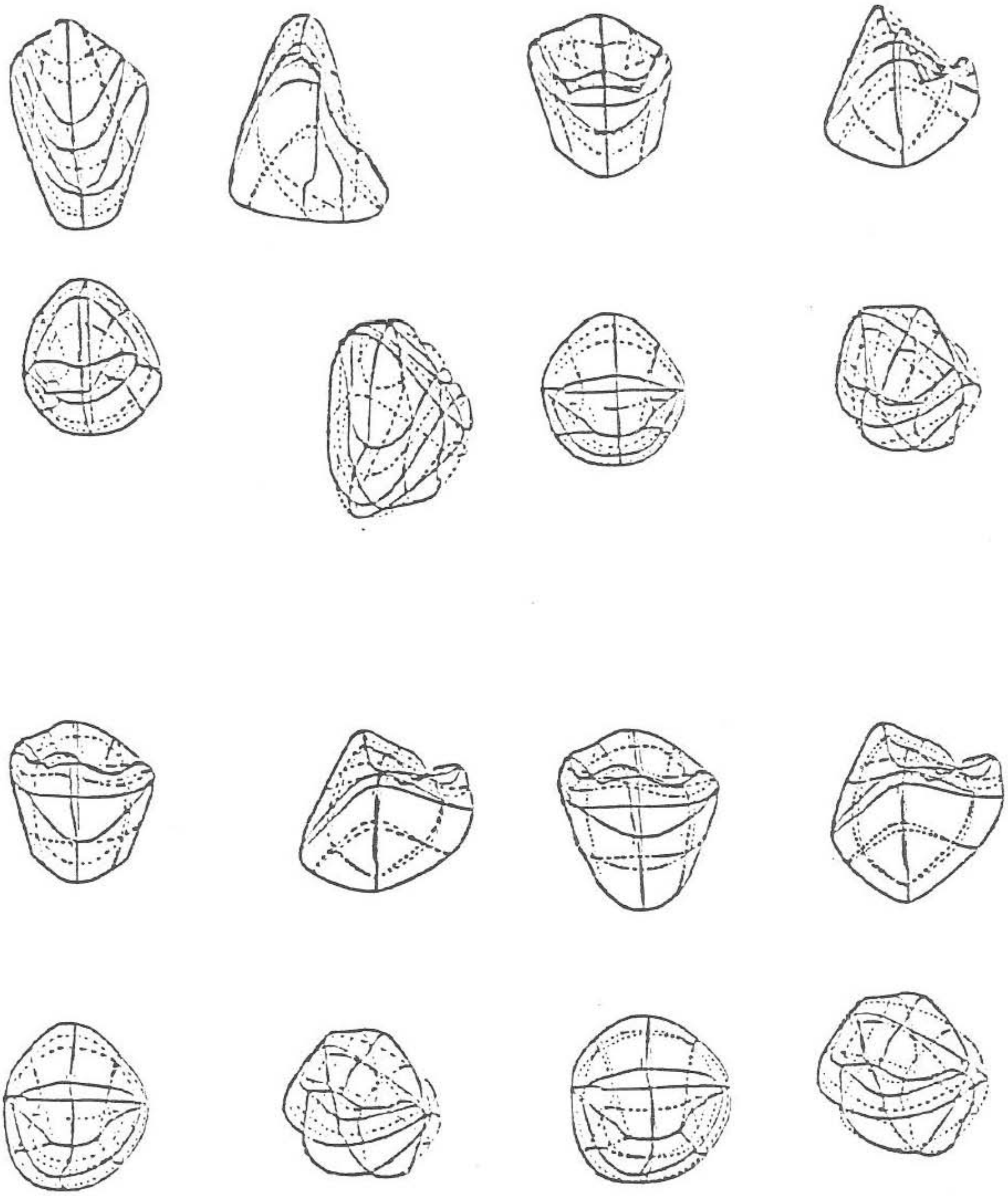


Figure 49

PONTIC DE BRIDGES
INCISIVE CANINE MOLAIRE

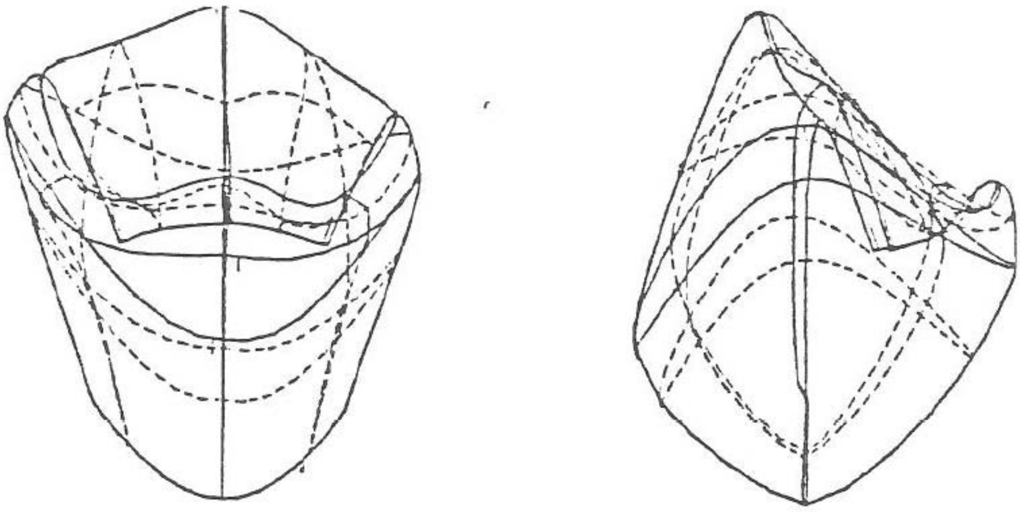


Figure 50

2.4-2.2 Definition of anterior shape

Its conception is identical to that of a crown. The only differences are the multiplication of the number of dilatation and possibly the correction of this dilatation depending on the insertion axis. A particular point of the bridge is that we had to develop from April 1987 a study of the insertion axis of the bridge, tooth by tooth, that is to say approach the parallelism problem. These examples have been presented in February 1987 in Chicago.

2.4-2.2.1 Parallelism control

The parallelism to be studied, even controlled, isn't rigorous. What it is necessary to have, it a "sense of remains" following the terms of de le Huche p23 (figure 50). The principal is to get an almost parallelism of the proximal faces, not of the preparations since we must rest on the principal that the cut is correct, by of the interior, of the intrados of each pillar.

The only way of resolving the problem of the intrados is to proceed as follows:

a) either research the average insertion axis and cute the axis with each other. We know is doesn't really have any sense
b) or offer a "diametric" mode, that is to say:
    - dilate the intrados as convened
    - divide in meridian each stump with the insertion axis as centre (figure 51)
    - check that the angle formed by the corresponding sides (proximal and distal) is situated under the finishing line for the face close and on this line for the far faces

This study has been presented in Chicago.

2.4-2.2.2 Influence of neighbouring teeth

It is necessary to check that the insertion axis reported to the contact point is done without meeting any obstacles on the proximal teeth. To answer this approach, we operate in several steps. We define the insertion axis of the cut which is the parallelism axis at the level of the frames situated on the contact zone. We report, in parallel, the insertion axis in question on the contact zone. We place the bridge at the level of the contact point 2 (figure 51) and check that the corresponding face (2) can be placed on the stump of the other pillar.

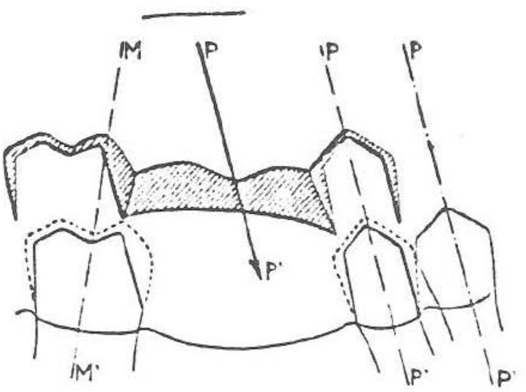


FIGURE 201.

Le bridge peut être placé parce que les faces proximales des deux dents piliers ont été taillées selon la direction PP' de la dent voisine d3. Mais il est indispensable que la dent de sagesse soit absente.

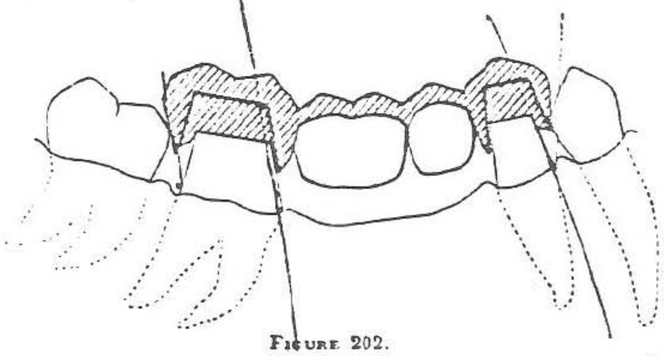


FIGURE 202.

Un cas relativement fréquent au maxillaire inférieur en raison de la courbe de Spee. La convergence des deux dents voisines des piliers du bridge fait que le bord des couronnes vient buter sur ces voisines, empêchant ainsi la mise en place du bridge.

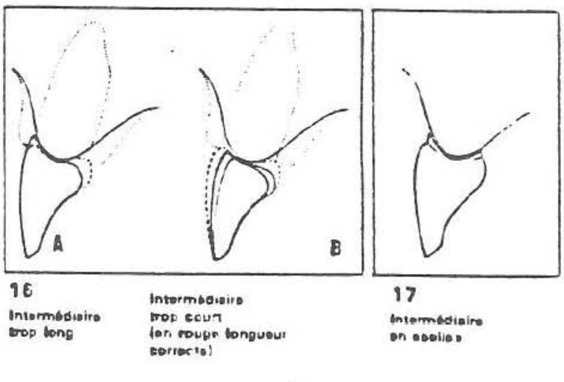


Figure 51

LE BRIDGE

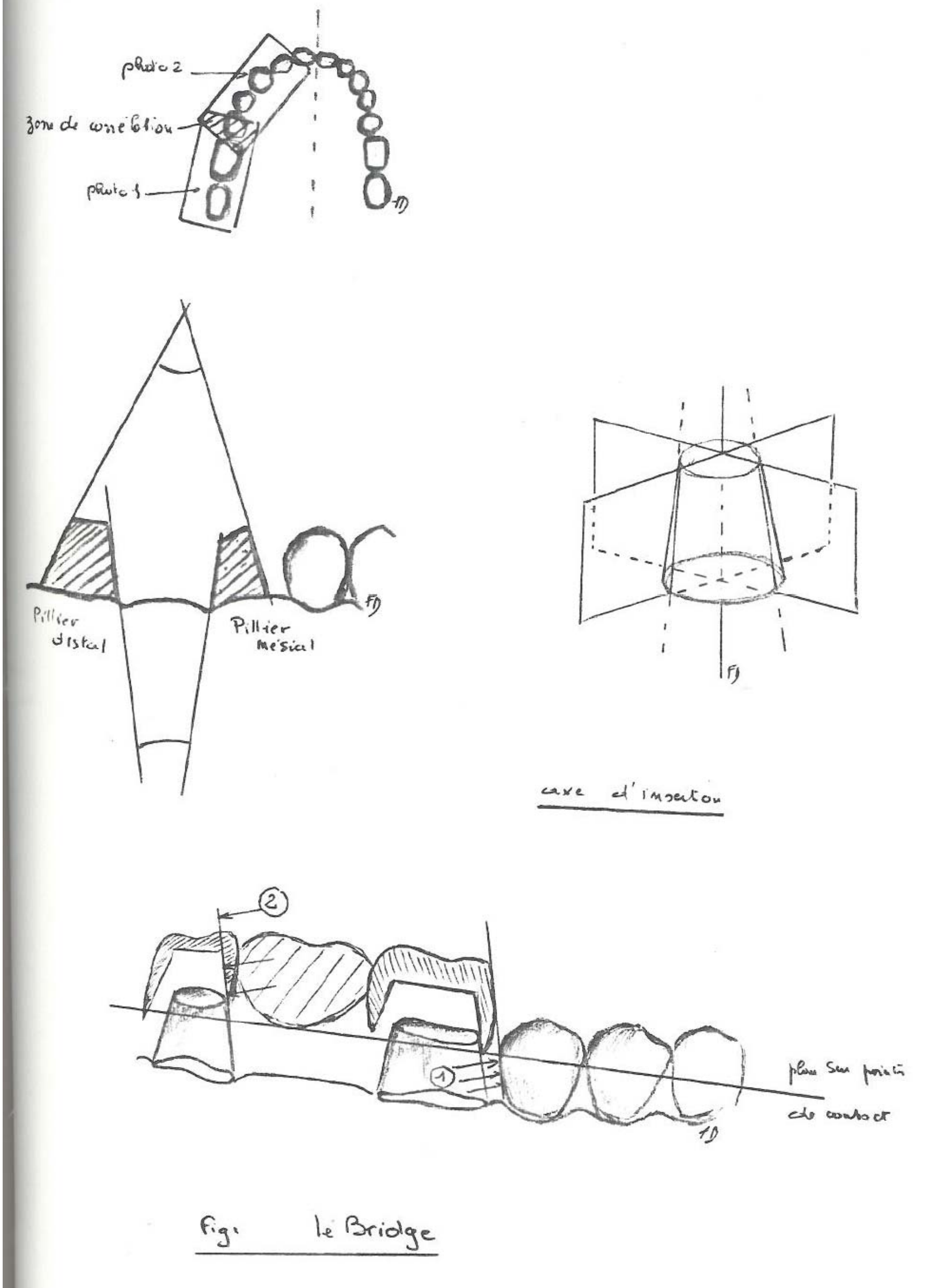


photo 2
photo 1
Pillier distal
Pillier mésial
axe d'insertion
2
1
de contact
Fig. le Bridge

2.4-2.2.3 Realisation of extrados

a) Modification of the finishing line

It follows the same rules as for the crown

b) Dilatation

It follows the same rules as for the crown. If there is a parallelism too narrow during operation 2.4-2.2.2, it is necessary to ass 100µ of dilatation.

The dentist has prepared his pillars. The study of the parallelisms, after the impression capture on the CAD, will enable the definition of whether the insertion is possible. This operation is transparent for the dentist (automatic). If an angle isn't correct between the faces, the meridian corresponding to the zone to touch up appears in another colour on the screen, enabling a correction before the study of the extrados.

It is the finishing line which enables the isolation of the stumps.

2.4-2.3 Realisation of the extrados

Are left to be reminded, the elements in presence.

2.4-2.3.1 Present elements

a) Gum

It is necessary to conserve the gum situated between the stumps; this zone is obtained thanks to the finishing lines knowing that the zone between two closest finishing lines has to be the gum (figure 50).

b) Antagonist teeth

The antagonist teeth being isolated, several parameters can be extracted in order to facilitate the placement in environment. There are the true furrow (not the one defined by the SPE), the cusps and the absent teeth.

c) Adjacent teeth

Come from the treatment previously described.

2.4-2.3.2 Placement in environment – theoretic principle

Note: seeing as there is no vestibular and lingual line at the maxillary and mandibular level, we refer to one of the three known arches as general and described by numerous authors and synthesised by MASSEN (Quintessence 18, P287-292, 1987).

We use two main elements of reasoning:

- the arch's lines
- the homothetic envelops according to the available space (figure 52)

The basic principle consists of respecting three successive steps which have for aim to bring the case of a bridge back to the one of a "multi crown".

1st step: is about knowing the curve to give to the bridge on a horizontal plan, that is to say to determine the vestibular and lingual curves which will be used to align the vestibular and lingual plans of the greatest contour lines of each tooth. To do that, we note the vestibular and lingual peak lines by using the specific modelling called spider's web of these same antagonist teeth. It enables us to define the exact curve of the arch in the horizontal plan. The SPEE and WILSON curve will be given by the occlusion plan of the antagonist teeth.

At this stage, it is obligatory to specify the number of each tooth that has been isolated to divide the arch into zones: molar and incisivo-canine. At the molar zone, we will associate the vestibular and the lingual peak lines. At the incisive, canines zone, we will associate the vestibular peek line corresponding to the free edge.

Note: The continuity of the vestibular peek line in both zones will have to be kept. It will specified during the interrogation, if the occlusion is of normal type or inversed in the molar/premolar zone and of normal type, tip to tip or inverted at the incisive level. We will find, at the preparation arch level, the same distribution.

The teeth's number will have to be specified here and the arch will be divided into molar zones and incisive and canine zones. The correspondence with the antagonist jaws is then possible. These great lines will already enable an opinion about the type of occlusion which will constitute the characteristic of the future prosthesis.

In case of normal occlusion, depending on the type of arch where the bridge will be placed, the rapports are as follows:

- preparation on inferior jaw
  vestibular peeks / antagonist furrow
  furrow / antagonist lingual peeks
- preparation on superior jaw
  lingual peeks / antagonist furrow
  furrow / vestibular peeks

In case of inverted occlusion, these rules are inverted. These rules enable us to have a precise idea of the position of the arch to reconstitute.

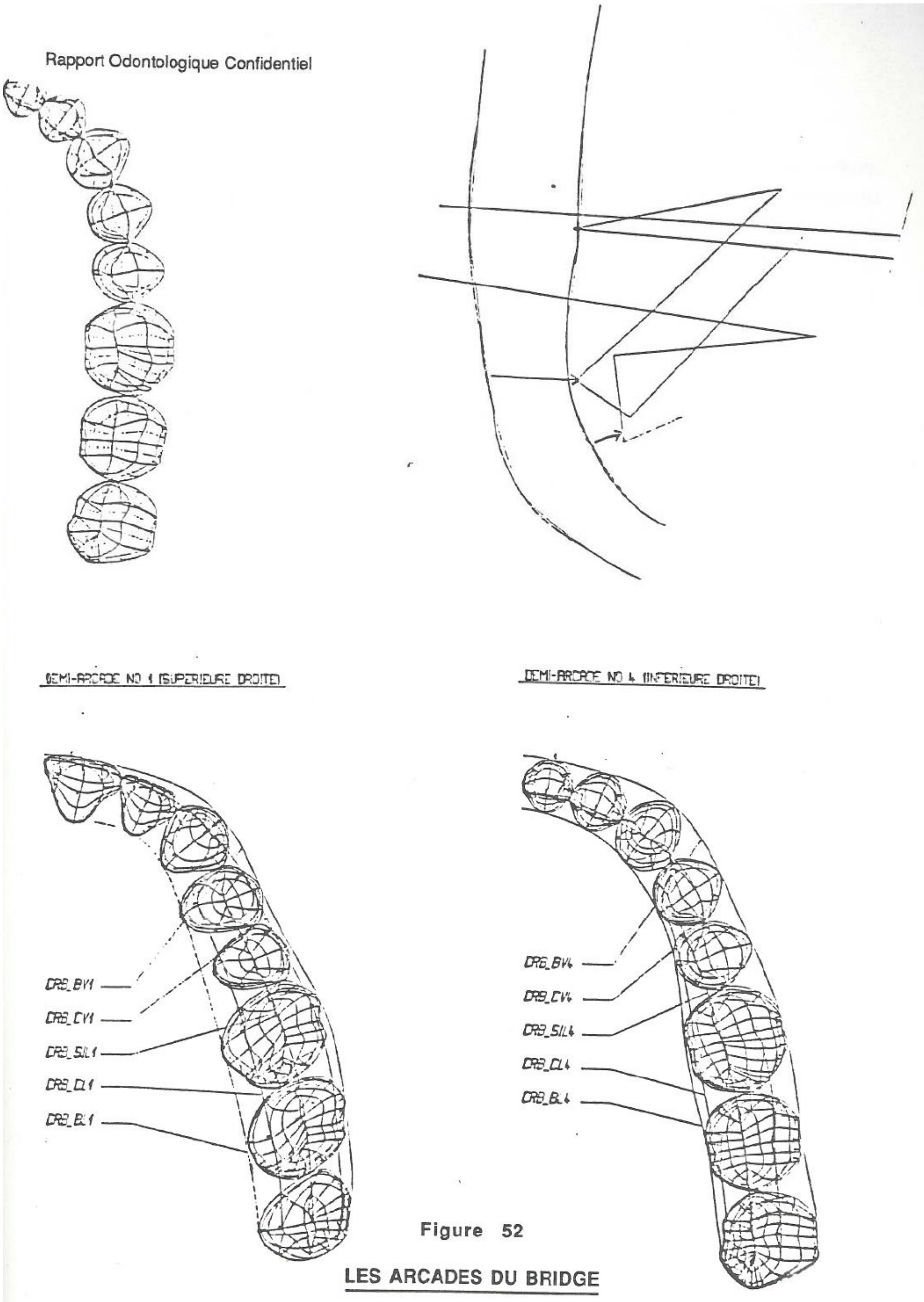


Figure 52

LES ARCADES DU BRIDGE

2nd step: it is about finding the place of each tooth constituting the bridge. The practioner has indicated the number of teeth for his reconstruction. Each tooth has a known mesio-distal dimension. With the exception of a mesialisation or a distalisation of a pillar (reduction of increase of the pontic space), will be applied an homothety rule on all the elements which will enable to "exactly define the position of their respective contact points". The vestibule-lingual position is given by the TYLMANN rules, automatically according to the position of the pillars among each other and on the arch.
3rd step: it corresponds to the placement in environment element by element and for that we will refer to the case described at the level of each crown. In this case, the occlusion is a less important factor and only the aesthetical factors will be predominant at this stage. We must take into account the OVER BITE and the OVER JET. The useful data are here the vestibular peeks and the constraints the crown will have to respect which are as follows:

- adaptation to the finishing line
- integration in the arch

Additional factors can be introduced from the theoretical arch, particularly to give the height of the anterior teeth. OVER BITE/OVER JET annex parameters enable the more or less slight inclination of the crown. Moreover, the gum will help the precise positioning of the pontics. The implementation of the pontics will be similar to the other crowns with less constraint of the finishing line and more constraint of the mesio-distal width.

2.4-2.3.3 Placing in environment of bowl

Identical to the crown, each element is individually brought to the positioning depending on the present necessary data which are the curve and the characteristic points.

2.4-2.3.4 Placing in environment of occlusal surface

Same remark as previously.

About the static and dynamic occlusions, the reduction of a pontic can make the use of a tooth instead of two or vice versa obligatory. In this case, we consider that the occlusion must be taken back to what the antagonist teeth impose and make sure the central ones are placed on the bridge according to the opposite teeth. The interactive action on the central ones can be very useful.

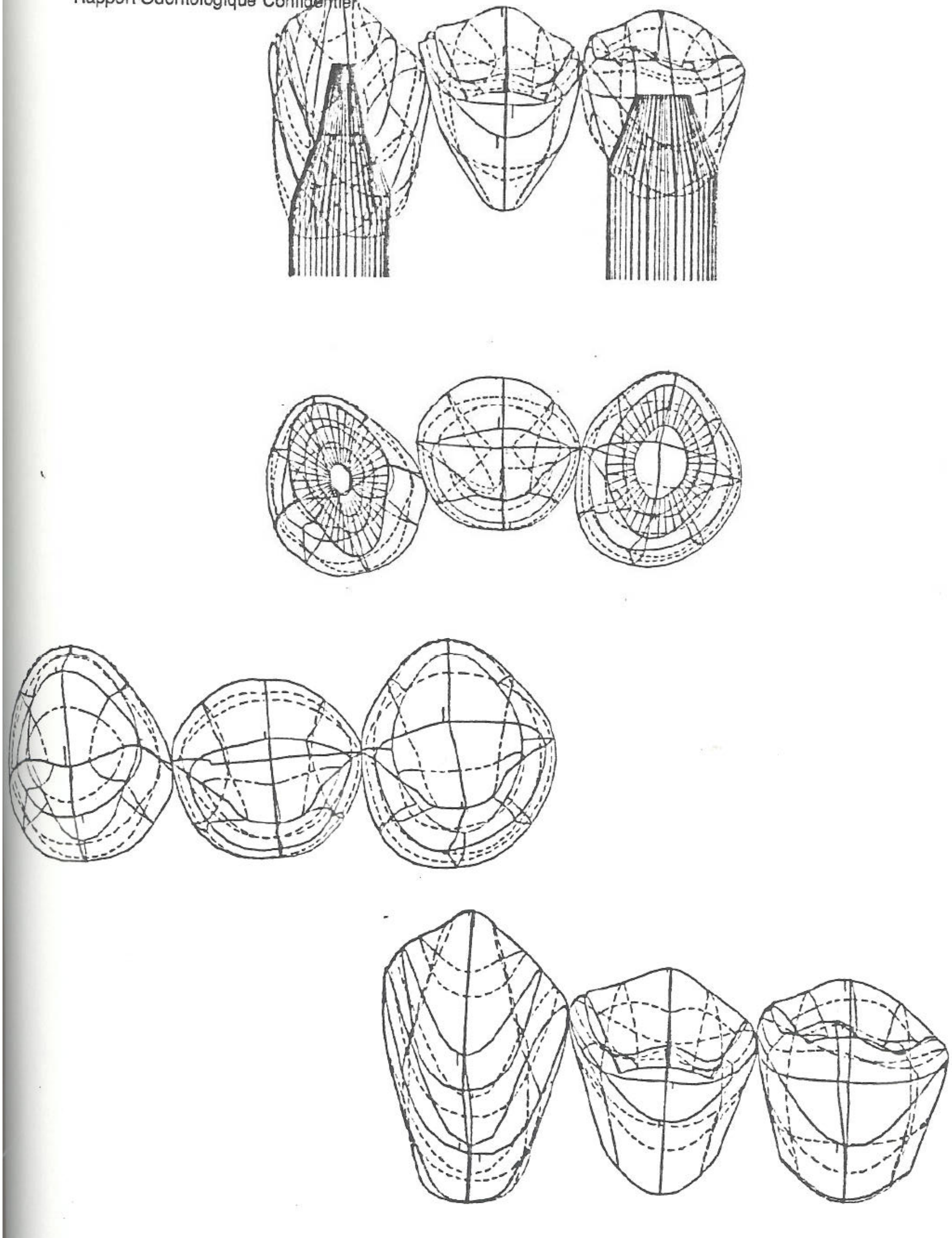


Figure 53

2.4-3 Interactive deformations

There are identical to those described for the crowns and don't affect the element during the modification like we showed in Chicago in February 1987.

2.4-4 Conclusion

Except for the definition of some extra elements, such as the morphological choice of the pontic base, we have strictly the same dialogue as for the crown which greatly simplifies training on the device.

2.5 Post teeth

INTRODUCTION

We have defined, in one of the previous specifications (1984), a crown on a premolar. It supposes the existence of a tooth in a relatively good state so that the practioner can find enough matter to get a solid and important stump. In the presence of a depulped tooth, maybe even destroyed, he will have to constitute the coronary part for it to serve as base to the future crown or the future bridge. We call fake stump a reconstitution coronnoradicular. It is a prosthetic piece with essentially radicular anchoring compensating the tissue loss and giving to a tooth a good resistance (figure 54). This prosthesis imposes itself if the classic methods of reconstitution aren't enough. They represent a non negligible activity of dental surgery (about 60% of reconstitutions) and must thus be solved in CAD as quick as possible. This here specifications book comes directly from those written for the crown. A certain number of chapters are thought to be acquired.

2.5-1 Odontological criteria for restoration

2.5-1.1 Restoration criteria

The dentist must respect a certain number of criteria which are:

2.5-1.1.1 Endodontic conditions

He must estimate whether the restoration of the root is correct. It will only be interesting in CAD after the development of the digital x-ray (programme being studied). At the moment, this operation is done manually with a retro-alveolar film.

2.5-1.1.2 Morphologic considerations (figure 54)

It is about doing the correct radicular preparation which is not too damageable in order not to weaken the root. The only elements to know for a CAD creation are:

- the rapport length of the post with regards to the total length
- the rapport diameter of the post with regards to the diameter of the preparation
- the angular orientation of the post with regards to the axis of the canal part.

2.5-1.1.3 Mechanical considerations (figure 54)

It is about having data on the retention value. This data is brought by different values and only represent little calculation: they are particularly the estimation of the contact surface (stump) with regards to the post's surface and the height of the post with regards to the height of the fake stump brought back to the finishing line (average value + or -).

2.5-1.1.4 Electro-chemical considerations

Not important for us given the used material.

2.5-1.2 Different clinical types

2.5-1.2.1 Monoradicules

We have several possibilities defined essentially by the position of the separation line between the fake stump and the tooth itself:

- either the fake stump will be entirely covered by the dressing (crown). In this case, the dento-prosthetic joint will be insured by the crown and the manufacturing will be cone shaped
- either the fake stump insures the dento-prosthetic joint. We must manufacture as well a shoulderin
- or the case is mixed and we will have to respect each zone (see further)

2.5-1.2.2 Pluriradicules

If the posts are parallel, we will be in the previous case but if the stumps are divergent, we will have to offer different solutions.

2.5-2 Coronnoradicular restoration in CAD

2.5-2.1 Total restoration

After the cut, the dentist will be confronted with a type of plateau with the post's hole. We know that it is impossible to do the impression of the post hole (figure 55). For this reason, a specific protocol of 4 steps has been devised.

Step 1

We do one (or 2) impression(s) of the fake stump with the post in place, cut at the desired height. We get the environment, the plateau (figure 55) and the post's axis. The practioner will have to trace the finishing line of this coronnoradicular restoration and indicate which clinical type is used. Also, it does the same verification as for the crown (see previously).

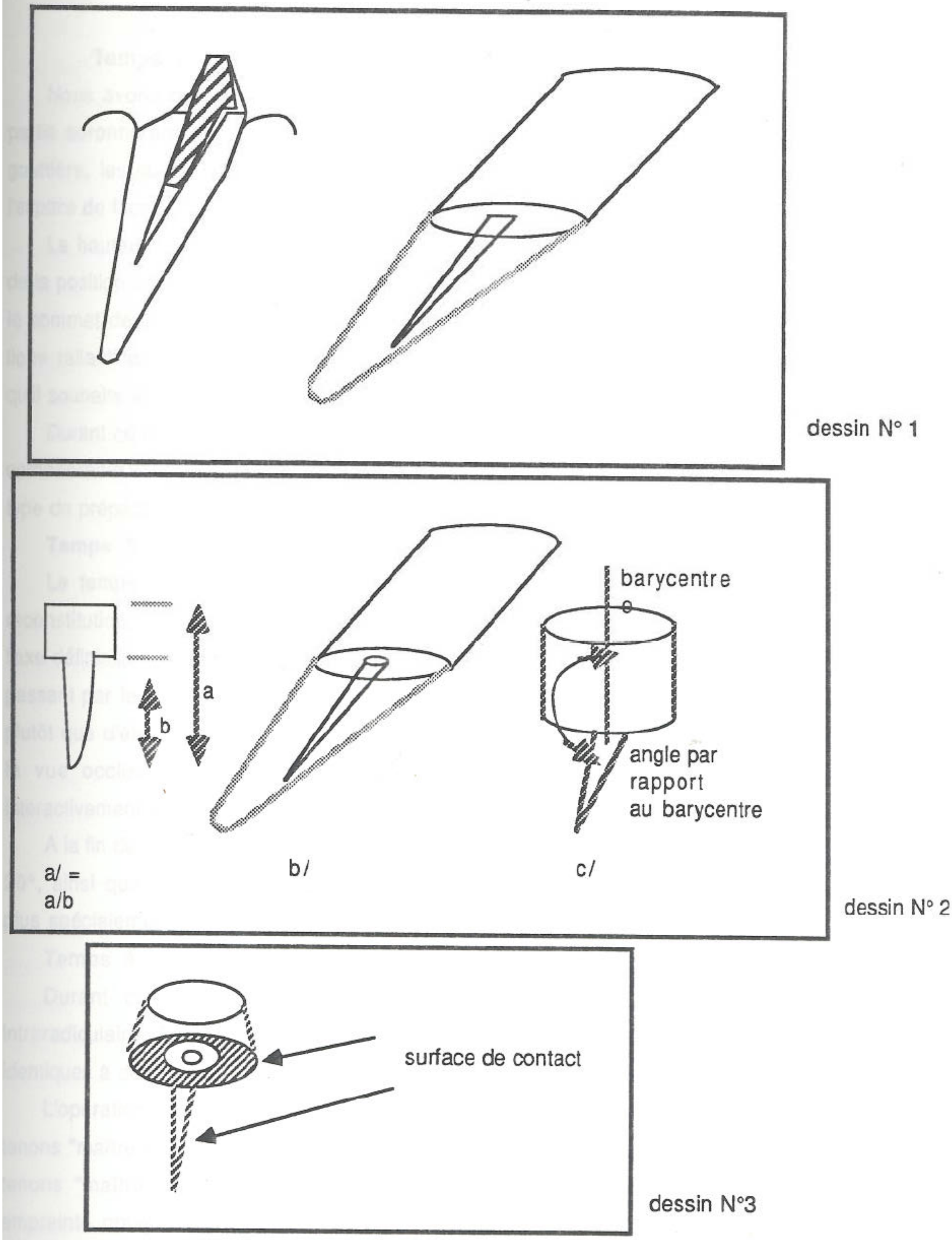


Figure 54

LE PIVOT, CRITERES DE RECONSTITUTION

Step 2

We have defined a certain number of elements which will enable us to build the coronnoradicular part of our fake stump. These elements are for example the gutter line, the cusps or the occlusion plan. The superior part of the cone will be place in the space in order to integrate harmoniously with these elements.

The height of this plateau (the top part) will have a z position directly deduced from the position of the antagonist teeth's surfaces. It will be at 1.5mm of a plan going through the top of the lowest cusp, a value which is interactively changeable and never lower than the line linking the contact points. The dentist keeps the possibility of defining the distance he wants to have between the plateau and the antagonist teeth.

During this second step we have defined the height of the stump of the coronnoradicular restoration when in the first step we had traced a finishing line as well as the type of restoration (with or without shouldering).

Step 3

The third step has the function of defining the exact position of the vertical wall of the restoration. The occlusal view enables us to know the virtual plan in x y going through the axis defining the height in z of the fake stump. We lower a perpendicular to this plan going through the centre of gravity of the left surface defined by the finishing line. Then, and instead of raising un cylinder from the plateau's surface to the superior plan (at the occlusal view plan), we raise a cone whose inclination varies from 5° to 20°, interactively chosen and depending on the frame.

At the end of the third step, we have the cervical limit of the fake stump, with slopes of 5 to 20° as well as 2 superior and inferior plateaus. All there is left to define is the radicular post, more specifically its intra-canal part.

Step 4

During this step, the length of the intro-coronnary post, intra-radicular, will be determined. For that we have taken care (figure 57) of memorising several posts identical to the standard posts present in a practioner's case.

The operation is as follows: we drill normally the canal and place one of the three "master model" posts corresponding to the 3 volumes known by the computer. At the top of these "master model" posts is an asymmetrical pyramid enabling the knowledge, in optical impression, of the spatial position of this pivot. Moreover, a graduation has been placed in the tooth, enabling the estimation of the post's length inside the canal hole. The post is placed in the tooth, the "pyramid" side emerging from the tooth. An impression is captured and enables the estimation of the part emerging from the canal and its orientation in the coronnoradicular restoration.

The software knowing the volume of the fake stump, the length of the emerging post and the position of the graduations, it will tell the dentist where to cut, no the master model pivot but an identical pivot with new materials. It will serve as definitive pivot.

Step 5

The chosen radicular post is cut where indicated by the computer. The fake stump is manufactured and a drill drills an axis corresponding to the emerging part of the post. The dentist has to glue the 2 pieces together. If the posts are divergent, the fake stump will be completely pierced (sliding post).

CONCLUSION:

The practioner's work for a post tooth is simple and is limited to:

- tracing the finishing line with the clinical type indication such as for a crown (3 possible cases to tick)
- possibly modifying the frame's angle for the fake stump
- cutting the post where indicated by the software
- indicating the existence or not of a shouldering and giving the value (250-500-750µ) par frame. This shouldering will be done parallel to the finishing line at a height interactively defined by CAD.

2.5-2.2 Partial restoration

It is done in an identical manner without taking into account the existence of a shouldering.

2.5-2.3 Mixed restoration

It supposes the existence on the tooth of a part of the shouldering. We trace the finishing line, interactively, we raise the cone as if there were no shouldering (automatic) then we trace interactively the limit of the shouldering by giving the desired value, which has for effect to reduce the size of the fake stump and to create a shouldering. The reduction must be homothetic.

2.5-3 Interactive deformations

We find the same deformations as we had for the crown with more possibility of simply playing on the angle of the fake stump and the depth of the post. This deformation happens on one point only and one view only (X_Y) horizontally.

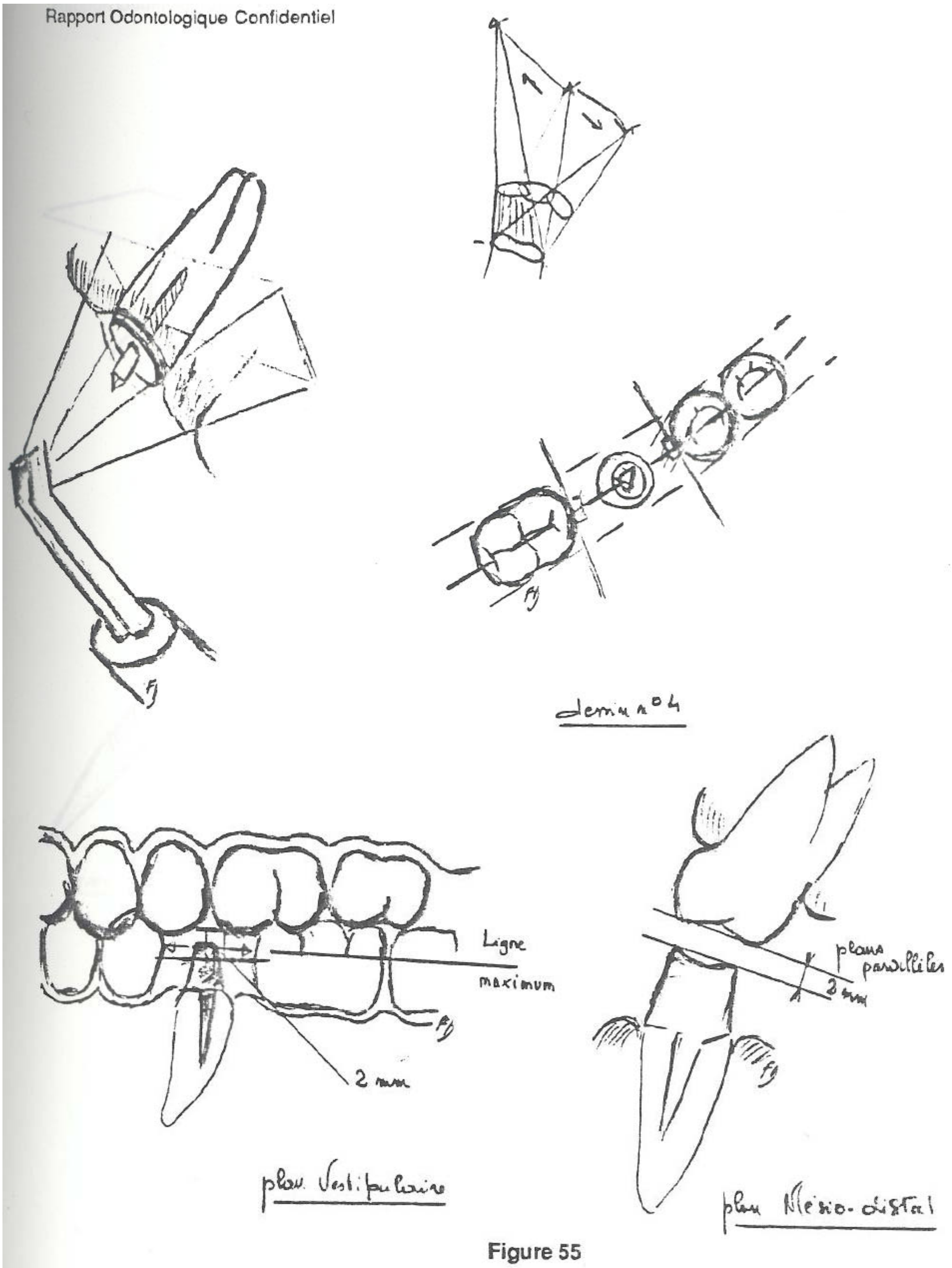


Figure 55
PREPARATION DES TENONS

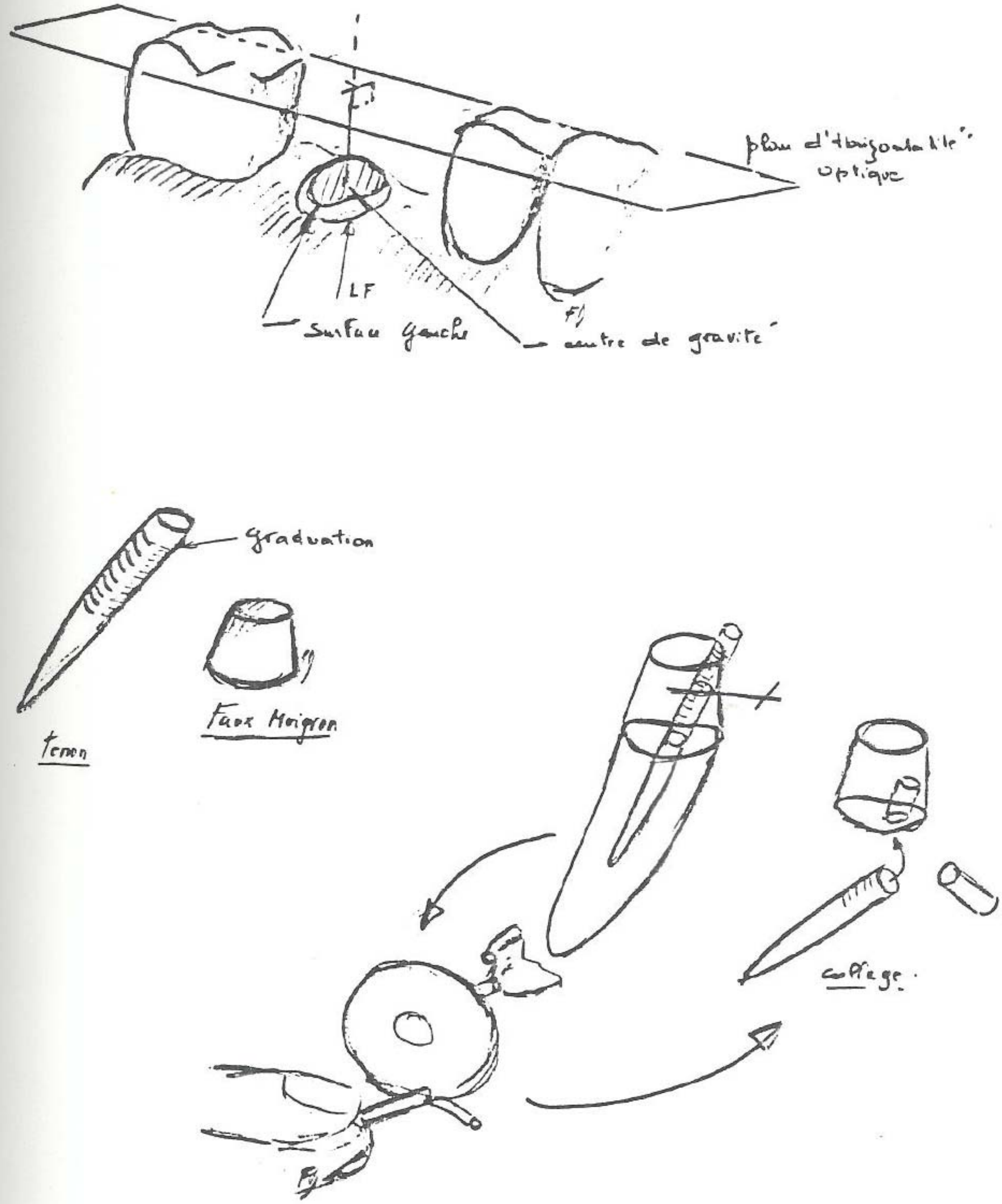


Figure 56
LE FAUX MOIGNON

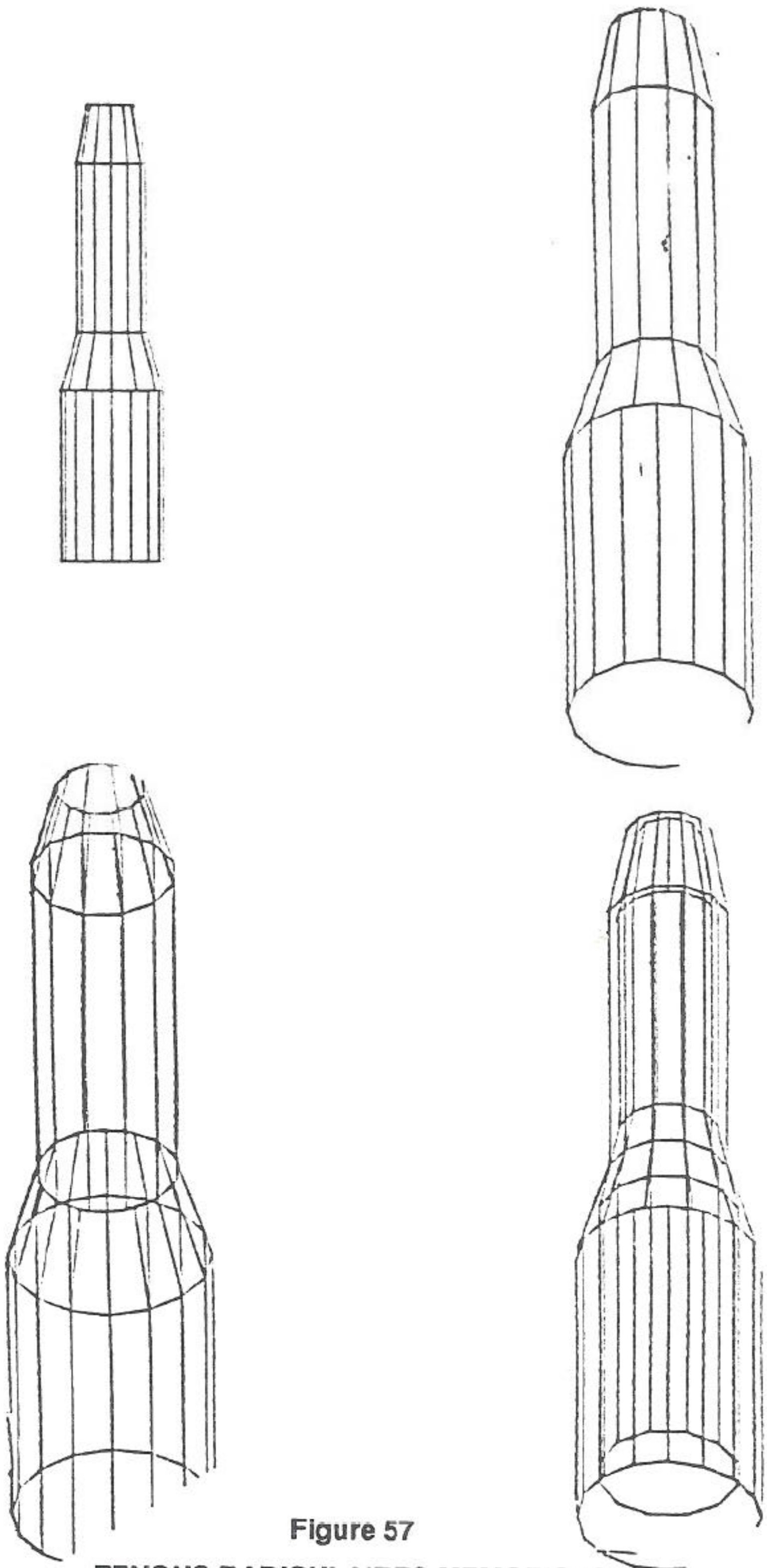


Figure 57

TENONS RADICULAIRES MEMORISES

2.6 Inlays and onlays

Numerous studies have been made on the fabrication of inlays in CAD/CAM. Aware of the effectiveness of this computer methodology in this domain, the first researches in the USA (Swindon) as in France (Duret) (figure 58), have led on the realisation of this type of restoration. We won't come back on the multitude of work between 1973 and 1987. We will simply cite the MORMANN and BRANDESTINI projects in Zurich (Quintessence Heft 3, March 1987, Ref. 6962) and the realisation of a device to manufacture inlays. As it appeared certain that the reader may confuse dental CAD/CAM and a simple reproduction tool machine as the one in Zurich, we wanted to remind the differences between both systems, the Zurich one and the Vienne one (HENNSON). These differences are found:

- at the impression level: with the MÖRMANN system, it is impossible of capturing more than one impression, which obliges us to use large cavities and no counter-remains. This restriction, forbids any use of the crown, bridge and other fixed prosthesis process. It isn't a little restriction when we know it takes more time to master the correlation than to do a tri dimensional reading. Moreover, the precision of the material stays to be demonstrated if we refer to articles published by this author.
- At the data treatment level: it appears that the software can't define automatically bumps and holes, an operation which is rather complex which obliges the dentist to trace inferior and superior limits of its preparation in the Zurich system.
- With the Swiss device there is no intervention of CAD, which stops the creation of space for cement and the modelling of the occlusal surface.
- The MÖRMANN manufacturing only happens in 2D1/2 with only 2 discs (today).
- No study of material or coloration has been done.

We understand that no comparison is possible between both systems (fifugre 59 and 60).

2.6-1 Theoretic principles

The realisation principle of the inlay joins the crown's principle. The difference being that the intrados, instead of being interior will be exterior and the manufacturing of the extrados will be limited to the worked zone and proposed by the dentist. Two protocols can be followed.

2.6-1.1 Protocol 1

It is directly issued from working on the crown. The practioner has limited, with the image treatment, the finishing line which corresponds to the superior part of the modelling (limited with bevel)

The principle consists of:

2.6-1.1.1 Applying the theoretical tooth corresponding to the prepared tooth

2.6-1.1.2 Making the cusps and furrows correspond of the theoretical tooth to the real tooth previously modelled in spider's web and of which we have extracted the characteristic lines. We won't take into account the possible microscopic differences of the surface but we will respect the cusp angle and the furrows line of the tooth modelled in spider's web if it is powerful and of the theoretical tooth is the Inlay/Onlay is important.

Note: The placement in environment must be based on the recognition of the cusps (peek) and the peek line, if the finishing line is occlusal, that is to say if we have a single-face inlay. However, it must be based on the greatest contour line on the vestibular and lingual faces in the case of big inlays or onlays as they are rarely worked on. The furrow can be used following the indication of the impression capture, before the cut (better) or after. The study of the isoplans and particularly an affinity effect between the isoplan of the theoretical tooth and the real tooth will enable a good adjustment of the elements.

2.6-1.1.3 Everything that is limited by the finishing line corresponds to the piece to be manufactured. We separate the extrados (portion of surface of the theoretical tooth) and the intrados in the shape of male or mixed male and female. The intrados will have similar contraction to the dilatation of the intrados of the crown but in negative value.

2.6-1.1.4 The manufacturing corresponds to the cut part of the theoretical tooth for the extrados and to the impression, the part closed by the finishing line for the intrados.

2.6-1.2 Protocol 2

The principle is to use a double impression of the same object by using correlation references described in protocol 1 (isoplan).

2.6-1.2.1 The practioner positions his marking points et reconstitutes the tooth with wax. We do an impression of the reconstituted theoretical tooth précising the finishing line (limit of the wax).

2.6-1.2.2 We prepare the cavity and indicate the finishing line on the second impression.

2.6-1.2.3 We do a mathematical difference between the first and second impression to get the piece.

2.6-1.2.4 We contract the internal part (corresponding to the second impression) for the space for the cement.

CONCLUSION

Two methods of handling extremely simple, the practioner can be contented with tracing the finishing line and the rest is automatic. A final impression enables him to apply the corrections already described for the crown, interactively.

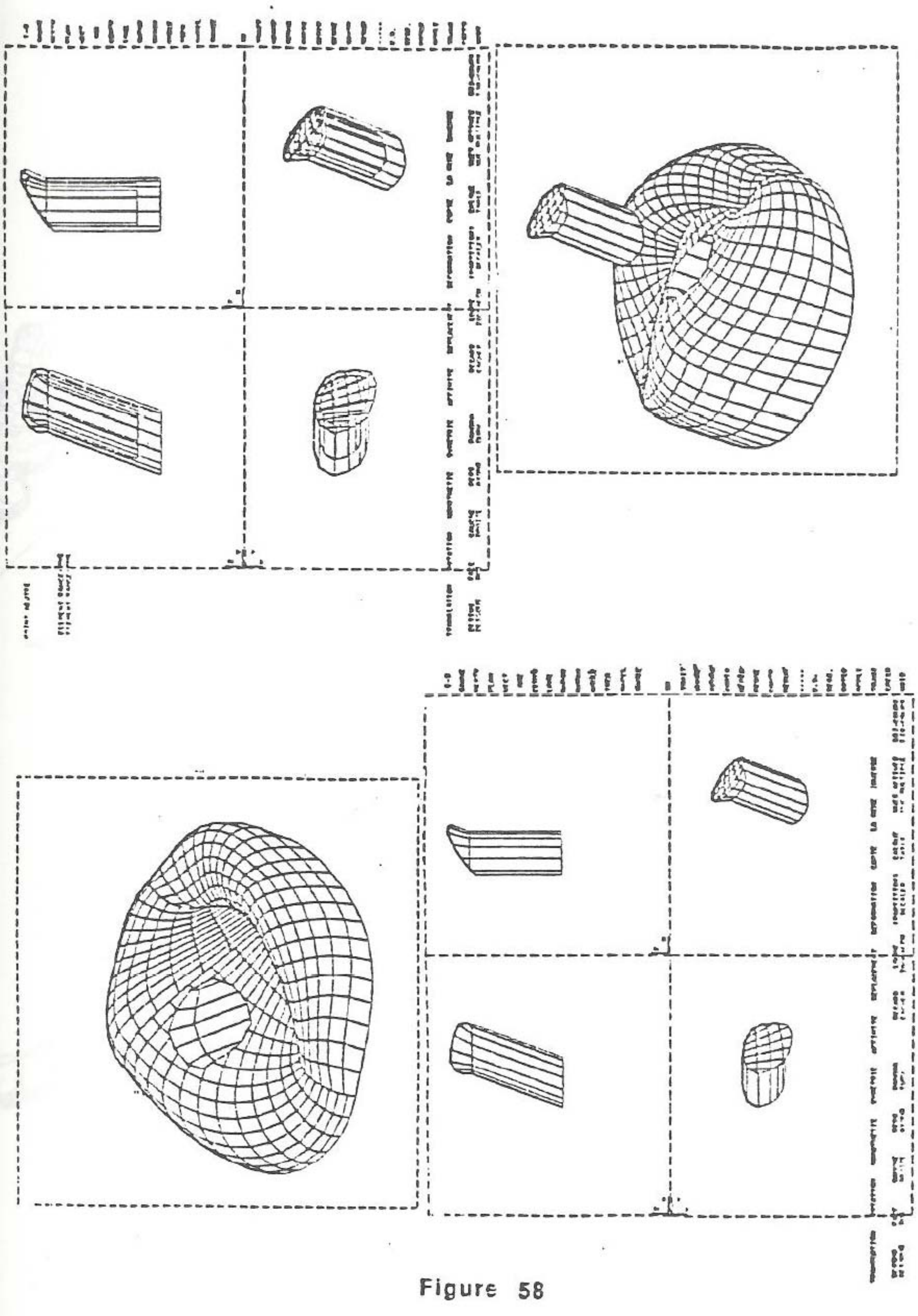


Figure 58

INLAY EN 1982

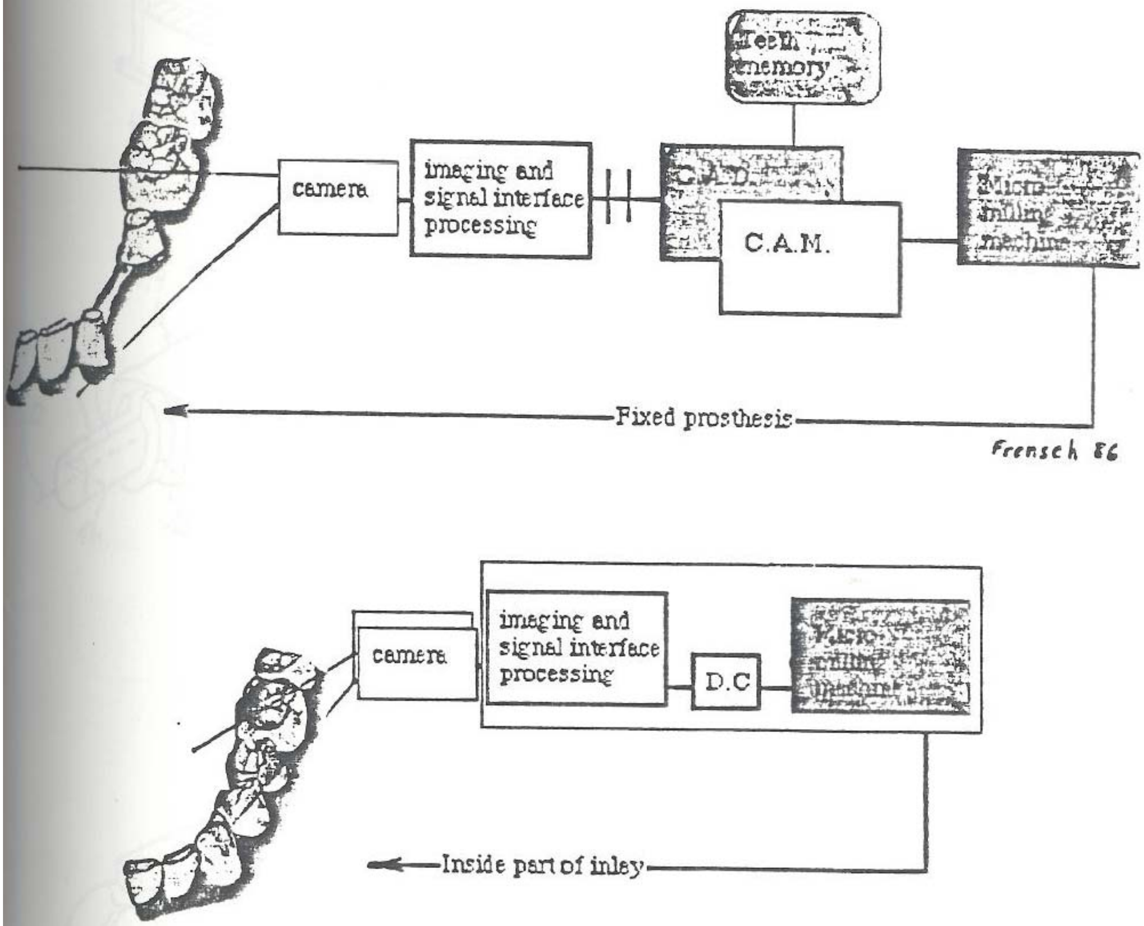

Teeth memory
C.A.D.
camera
imaging and signal interface processing
C.A.M.
Micro milling machine
Fixed prosthesis
Frensch 86
camera
imaging and signal interface processing
D.C
Inside part of inlay

Figure 59

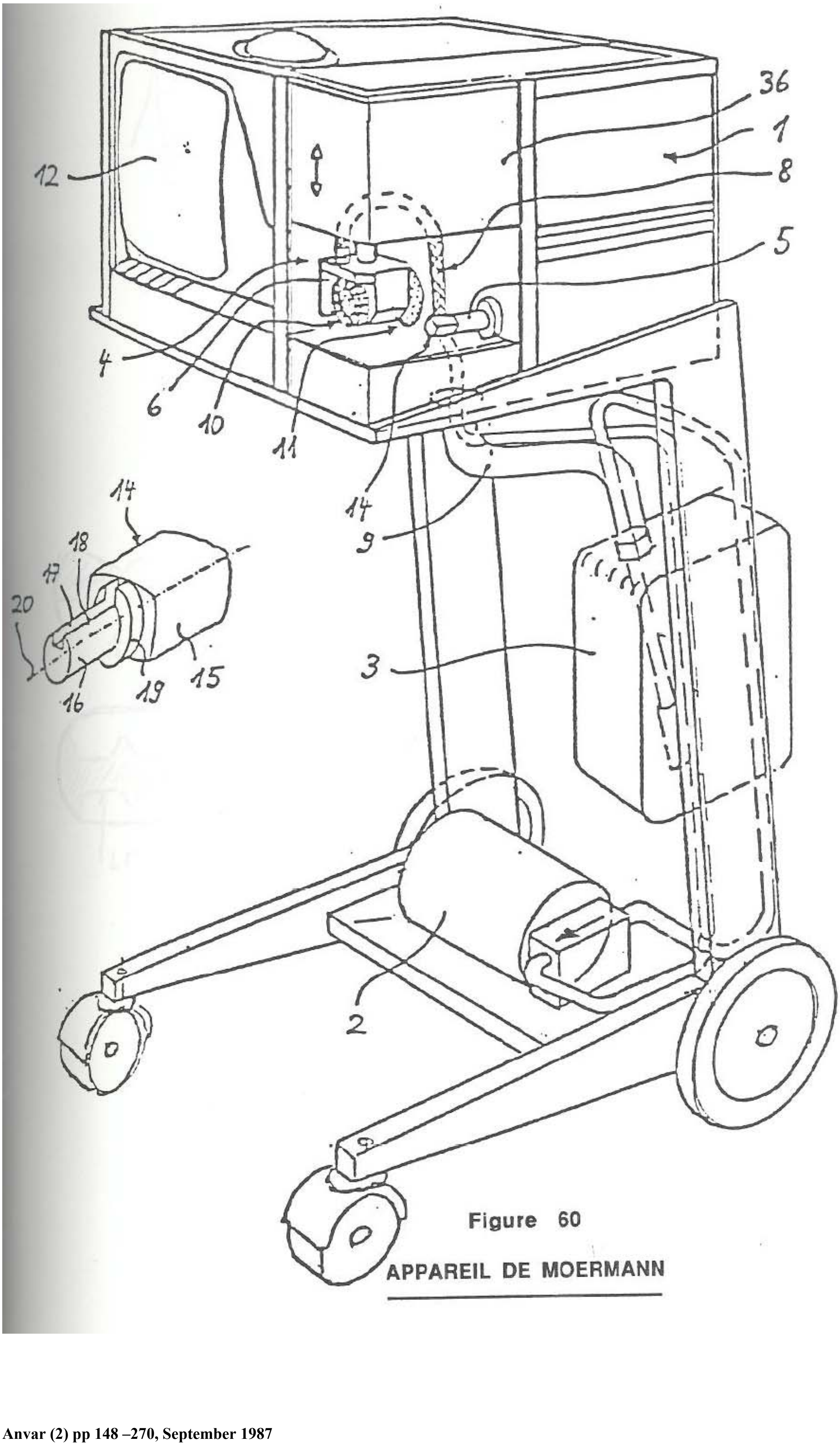


Figure 60

APPAREIL DE MOERMANN

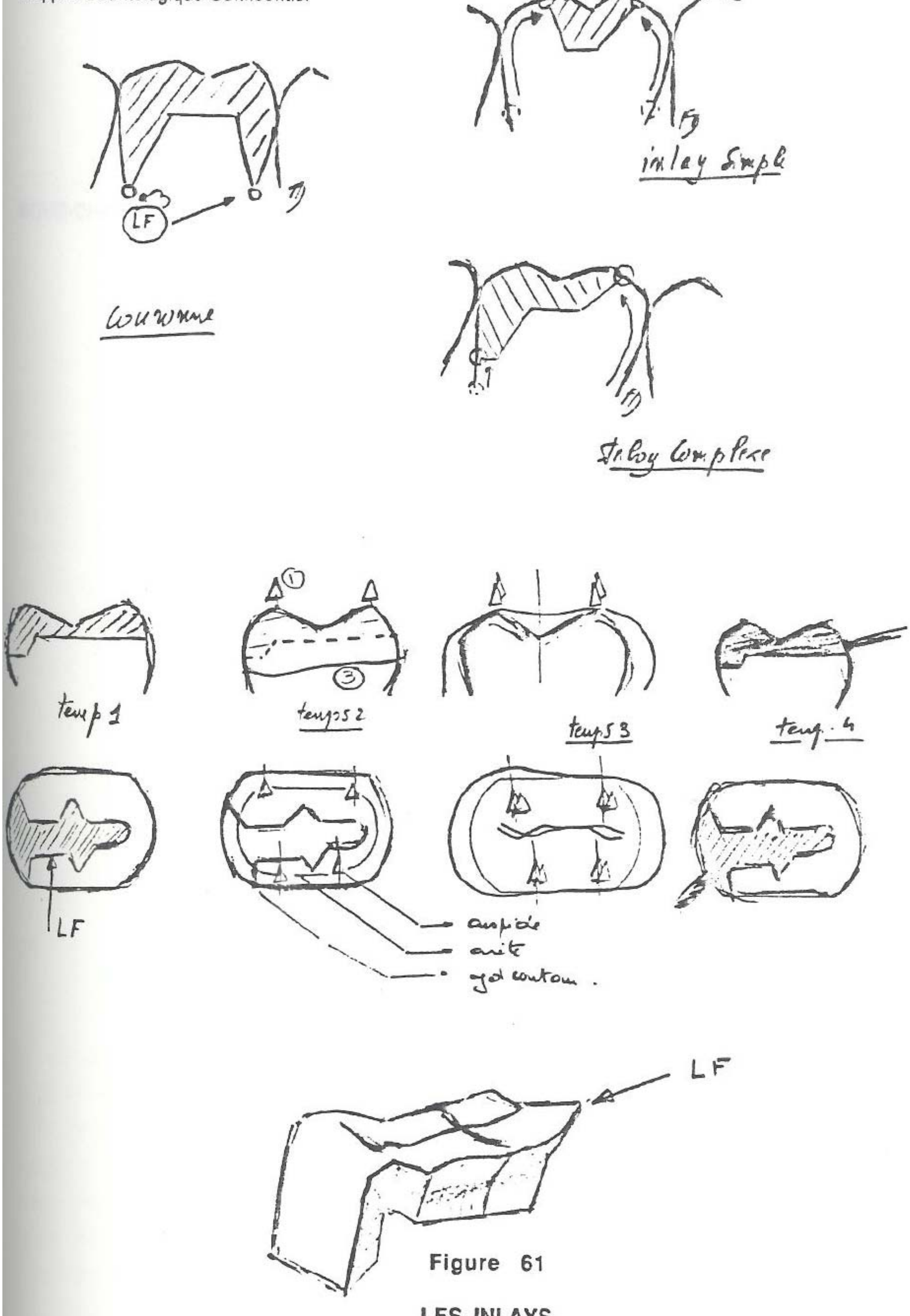


Figure 61

LES INLAYS

2.7 Attachments

The preparation mode of the attachments stays extremely simple if we admit the great basic theoretical principle announced in 1982 and which presents a respect of all the work previous to our research.

There are numerous publications on attachments. Let's signal in particular:

- DOUCET, ICBI, 210 pages, 1973
- PREISKEL, CDP, 315 pages, 1985

We won't come back on the automatic determination of place trace described in our Patents (1982) and in other articles as the recent part by Santoni et Coll (Industrie Dentaire, p47-50, 1986). They are part of an ulterior development easily integratable to our technology. It is important to define the rules of manufacturing to enable the insertion of attachments or the glueing of hooks on prostheses done by CAD/CAM. We proceed by following the rules of the excellent article by D. SEPULCRE and J. MIGOZZI in QQS, 8, p85-93, 1983. Two types of preparation must be envisaged:

- preparations by wedging and retention
- preparations insuring the fixation of attachments

2.7-1 Preparation of wedging and retention

All the prosthetic fixed elements have been studied and adapted in cAD/CAM, being unitary crowns or bridges, as we have previously described. If the CAD computer knows exactly the morphology of each prosthesis, the practioner knows where to position each of these elements necessary to the good stability of the mobile prosthesis. This determination will be manual as long as the automatic plaque determination software isn't precise enough.

2.7-1.1 Preparation of wedging (figure 60)

The practioner indicates which tooth will be used for the wedging. The wedging is present as a light flat suppressing the lingual bump destined to receive the wedge's arm of the removable prosthesis' hook. The drilling must be on the lingual face, respecting the contact zone and being maximum at 1/3 cervical of the crown. It is a drilling in 2D ½ with a large vacation (1mm), inclined at 130° or 90°. The thickness mustn't be over 2/3 of the thinnest part. In CAD/CAM, it consists of doing a bolean subtraction with a cylindrical tool, turning the lingual face of the indicated tooth. The dentist chooses:

- the beginning and the end of the trace (the line of the tool will be automatically traced)
- the tooth in question

The manufacturing axis will be a function of the chosen insertion axis. It will be common to the whole elements having the same treatment. It must be the same axis for any preparation by wedging. Without data, we apply a perpendicular movement to the average plan defined by the greatest contour line of the teeth supporting the wedging.

2.7-1.2 Preparation of retention (hooks and non prefabricated attachments)

There are several shapes of drilling to do. The function is very simple for CAD/CAM with the exception of the fact of the 100° inclination.

We can find 4 types of preparation to do at the contact zone level, on both sides of this zone and according to the vertical axis previously defined.

2.7-1.2.1 Wells (figure 62)

Vertical walls whose height is more important that the width (height and friction insure the retention of the piece). Retention is not the result of the right angle, a cylindrical drill with a 2D movement can be enough. For the bottom, we use a little cylindrical drill. The thickness, that is to say the width of the little stall, will depend on the width known by CAD at this point, of the crown between the intrados and the exterior shape. In no case it will be over 2/3s of the crown's width at the thinnest point (see SEPULCRE drawing). The practioner, using this work, will address CAD problems with wells to the technician realising the mobile plate and setting the temporary bridge (use of traditional impression).

2.7-1.2.2 Clips

They are important retentive elements completing the action of the hook. They are semi spherical, spherical or oval depressions situated on the proximal faces of the crowns or bridges. Not very deep, 1 to 2 mm, (specified interactively by the dentist), (the manufacturing movement and the drilling are identical to the wells by not as low).

2.7-1.2.3 Equipoise hooks

There are the wells associated to a wedging on the lingual face of the dent. All you need to do is combine the two manufacturing previously described.

2.7-1.2.4 THOMPSON attachments (figure 63)

Placed on the distal face, it is a well (see 2.7-1.2.1) but it has no mesio-distal retention perpendicular to the axis of the peek (parallel to the distal plan of the supporting teeth).

2.7-2 Preparation of attachments supports (figures 64 and 65)

It is about preparing the placement of the prefabricated attachment. Two possible cases can appear: either we manufacture the piece of the preparation defined by the laboratories (long and complex) or we impose to the laboratories an intermediary piece (long to get).

The estimation of the thickness of the prefabricated slide enables us, depending on the thickness of the cap, to choose a precise type of attachment. On each case, with the exception of soldered attachments, we must prepare a well as previously described. There are:

2.7-2.1 Rigid conjunctor

We must dig a larger well to place the slide corresponding to the type of attachment. We can find rigid conjunctors which are slides, braced or CSP systems.

We advance slowly with the study of the manufacturing of these little stalls as they are specific to each conjunctor. It will depend on the good will of the manufacturers as CAD manufacturing is simple (2D1/2 manufacturing) in every case, as the tool machine is the best parallelisor there is.

2.7-2.2 Articulated conjunctor

Same remarks as previously

2.7-2.3 Articulated bracing

We must manufacture a counter piece on which is welded the male part of the conjunctor. Simple even though a very precise study must be led.

The bars are for example placed with a slide glued in the wells (refer to the manufacturing of wells).

2.7-2.4 Strength distributor

For some we will need manufacturing of complementary wells and sealings and for others, wedging (external males).

2.7-2.5 Horizontal retentive units

Same remark

2.7-3 Conclusion

Even if today no study has been led on attachments, we know that the work isn't a major difficulty. Let's summarise the principle. The tooth which supports this very particular prosthesis is perfectly known by the software in its morphology and also its orientation. The preparation of an attachment in CAD is really only the determination of the 2D manufacturing, sometimes 2D1/2, of a reception site and only touches three faces. The tooth will be conceived as described in the crown and bridge chapter and will over-manufactured by one or some specific tools according to an axis which is the insertion axis of the mobile prosthesis.

We won't discuss here the insertion axis. It will be the object of a particular chapter but apparently, we can consider that this manufacturing will be in the perpendicular axis of the projected plan of the greatest contour line. Seeing as there are several attachments, this axis will be an average. The digging, that is to say the depth inside the crown in the proximal sense, will be defined at $2/3^{rd}$ of the thickness (but it can be different after the specification of the material). Its position will be developed in a software of specific study on the plates' contour. Finally, to answer to numerous cases, a specific study of welcome site for each attachment and a glue will be created to replace weldings.

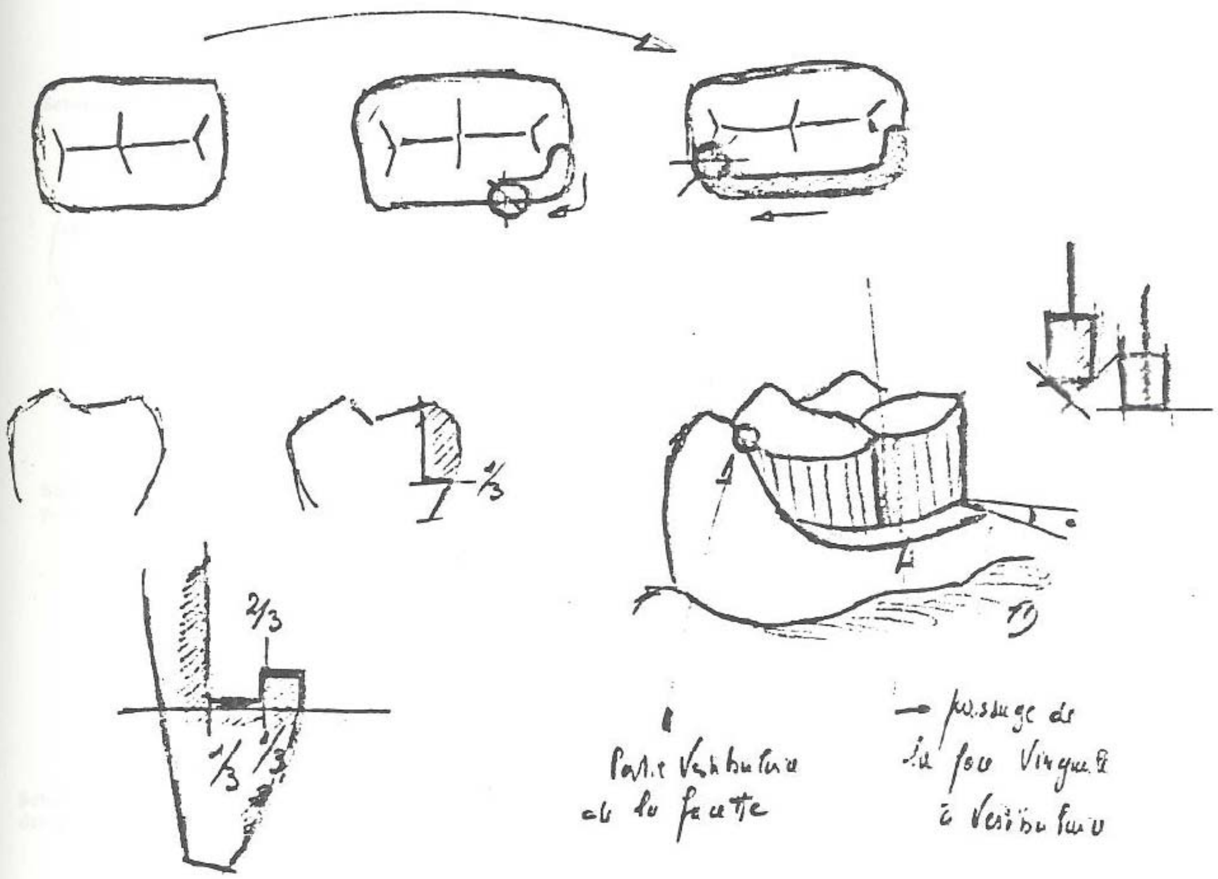


Figure 62

LES ATTACHEMENTS

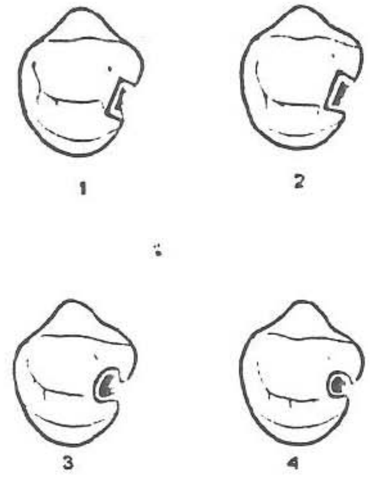
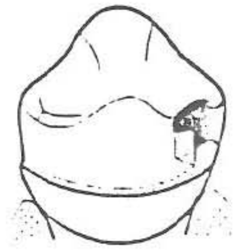


Schéma · Vue occlusale des différents puits.



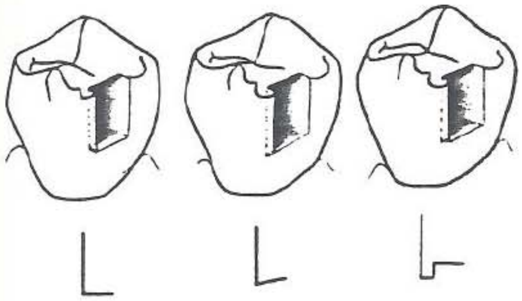


Schéma Les différentes formes du plancher des puits.

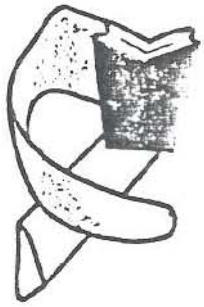


Schéma Le crochet Equipoise.

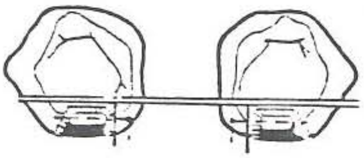


Schéma 9. L'attachement de Thompson. Vue occlusale des glissières.

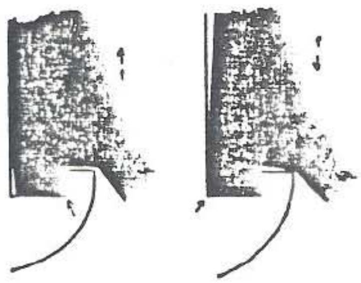


Schéma Rotation de la partie mâle dans la glissière de l'attachement sous l'effet d'une force occlusale.

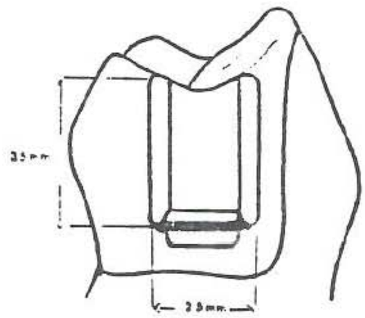


Schéma Vue proximale de la glissière.

Figure 63

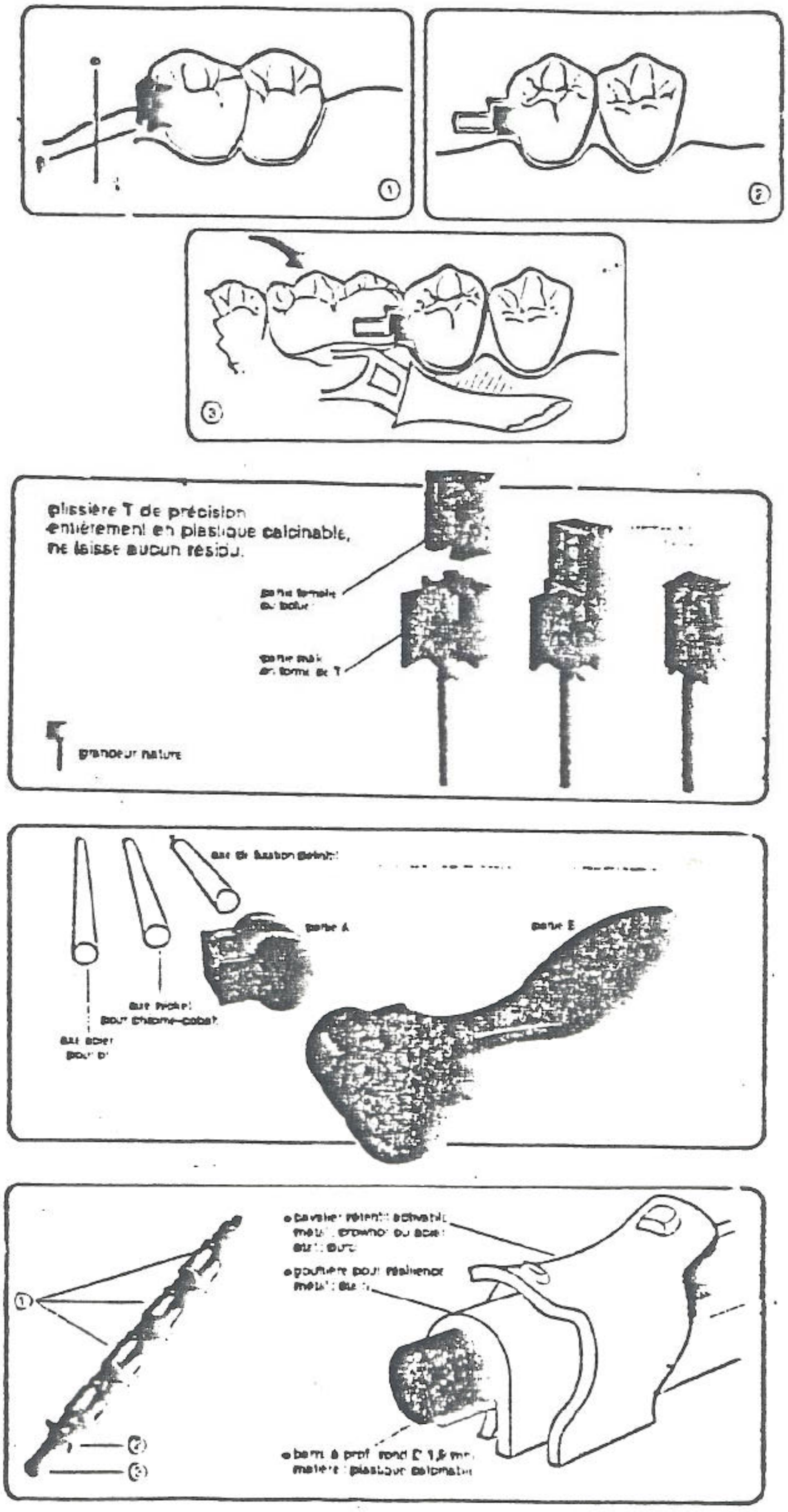

plissière T de précision
entièrement en plastique calcinable,
ne laisse aucun résidu.
grandeur nature

Figure 64

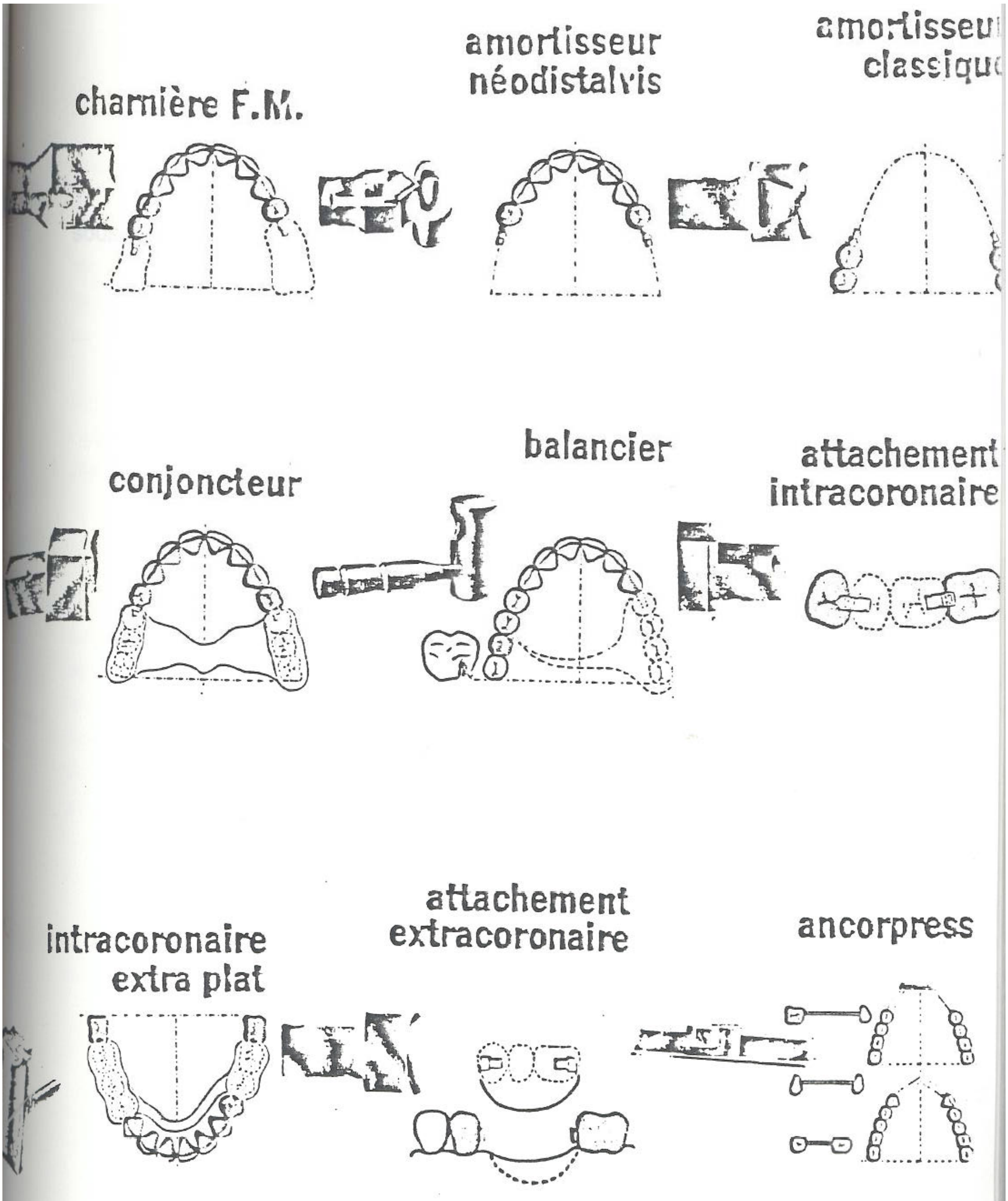

charnière F.M.
amortisseur
néodistalvis
conjoncteur
balancier
attachement
intracoronaire
intracoronaire
extra plat
attachement
extracoronaire
ancorpress

Figure 65

2.8 Orthodontics

Orthodontics, as Parodontology, is a complex science necessitating an extremely thorough analysis for diagnosis. It isn't HENNSON's work to redo what already exists but to use the competence of each specialist. There is today a certain number of very performing softwares around the world which can enable a complex and detailed analysis in each case. The ambition of HENNSON is to adapt these softwares to the Cad materials. From the diagnosis done by the software, the CAD/CAM executes orthodontic prostheses in accordance with the proposition of the therapeutics.

What is most flagrant is the apparent complexity for the dentist of the mastering of the tri dimensional movement of a tooth in a buccal space. Outside the mobile apparels which disappear more and more, the orthodontist uses brackets, where the forces are applied, to transmit a movement to the tooth depending on the wished direction. For that, he has two alternatives:

- torque the wire and place it in a narrow gorge
- place a "straight" wire in "pre-torqued" gorge

There is no question of CAD/CAM substituting to the first method as, on the one hand it is extremely complex for the generalist and on the other, the price of a bracket , even aesthetic, is to low to make CAD/CAM competitive. The straight wire technique is far more interesting. In this case, a non torqued wire is forced into a gorge which by its angulation, will get back to the alignment of the straight wire. The bracket being fixed to the tooth, it's the tooth that will move. RICKETTS, who is at the origin of this concept, opens all the big doors of orthodontics to CAD/CAM. If we know:

- the bone resistance
- the value of the pressure from the elasticity of the wire use

it is possible to preview the spatial angulation to give to a gorge so that when the gorge is aligned with the wire, the tooth is properly positioned. This principle will be used in our study.

2.8-1 Help with diagnosis

2.8-1.1 General information (figures 70, 74, 75)

They are brought by the traditional software.

2.8-1.2 Teleradiographics (figure 71, 72, 73)

The automatic digitalisation of the points and the measurement of the angles are proposed on a digitalisation table. To do that, we will place the teleradiography on our digitalisation table identical to the SPE one and will indicate the points according to a strict order. The angles will be automatically calculated.

2.8-1.3 Arches

This is an important point to study. The fact of been able to do a reading of each arch, to model the teeth and to know each furrow and each cusp, enables us to know: the reference points of diagnosis as the centres in occlusion and to see the mal-position by comparison to the theoretical arches known that we use for bridges.

If the first and second category of data give us the possibility of an automatic diagnosis, the third category goes much farther. If we admit the positioning of the bracket at a precise place on the crown, it is possible to define the path to run, through the tooth, from the mal-position to the chosen position, in 3D. If we start from a position in linguo-version of 30°, neglecting in theory the bone factor, all we need to have is a bracket with a 0° gorge to get at the end of the treatment a tooth in good position (figure 97, 69). With these movements, it is necessary, in order to respect the bone factor, to use progressive angulation. It is possible in CAD/CAM to choose these angulations. They enable a soft and progressive movement.

CAD/CAM, associated with bone diagnosis, enables the exact definition of angular values every x day. Of course, the examples described previously are simple in terms of movement. The great superiority of CAD/CAM is being able to define the movement of the tooth and to calculate the movement curves in space while respecting the targets, that is to say the progressive change of pressure on the bone. The definition of a movement in space and the report of this calculation in the angulation of the gorge can only be the result of a complex mathamtical study that only one system of CAD/CAM can solve. The comparison with the theoretical arch, particularly, enables the prevision of each case, the thickness depending on the real theoretical curve and for each tooth.

Since 1982, we have worked on the automatic definition of the angular values and the distances. Today, we look to master the value of this angle (figure 66).

2.8-2 Therapeutics

The therapeutics are summarised, if the diagnosis is precise enough on the angular plan, to executing a bracket by varying the fixation angle of the wire. We rapidly notice that the manufacturing of a bracket is relatively simple for a CAD/CAM machine in 301/2 axes. Truthfully, 2 ½ axes are enough and the third axis will eventually only serve to manufacture the glueing surface with regards to the patient's tooth. As well as personalising the angle, we personalise the wedging surface, thus rendering the bracket's action more precise to respect the ark's effort (figure 68). It supposes from the dentist an impression of the occlusal surface and of the vestibular face of all the arches.

Currently, we develop a program of manufacturing enabling the setting of the angulation in space. By working on typodont, it will be possible to check the analysis quality of the software.

2.8-3 Verification and prognosis

Given that the whole of the analysis elements in the diagnosis work, it is possible to simulate, before the therapy, the result step by step on the screen. It enables to explain clearly to the patient the becoming of his mouth. Moreover, by taking regular impressions, it is possible to control the evolution of the work and the stage at which we are. Moreover, an action error will be detected by confrontation with the theoretical simulation thus avoiding some catastrophies.

Conclusion:

CAD/CAM and orthodontics lean, certainly on the quality of the diagnosis but mainly on the automatic determination of the position of the tooth with regards to the theoretical position. The modelling of the teeth and the extraction of the characteristic parameters that we know are the proper of this method (see crown). It enables not to neglect the real orientation wished in the space. All of our efforts will be on this estimation and on the quantification of the difference between real and theoretical. From there, the rest is simple. All you need to do in CAD is to define the movement and report it on mechanical pieces which will be manufactured. The same goes to the verification of the quality of the work. The generalist will find in this tool the possibility to master a domain he often prefers to give to the specialist.

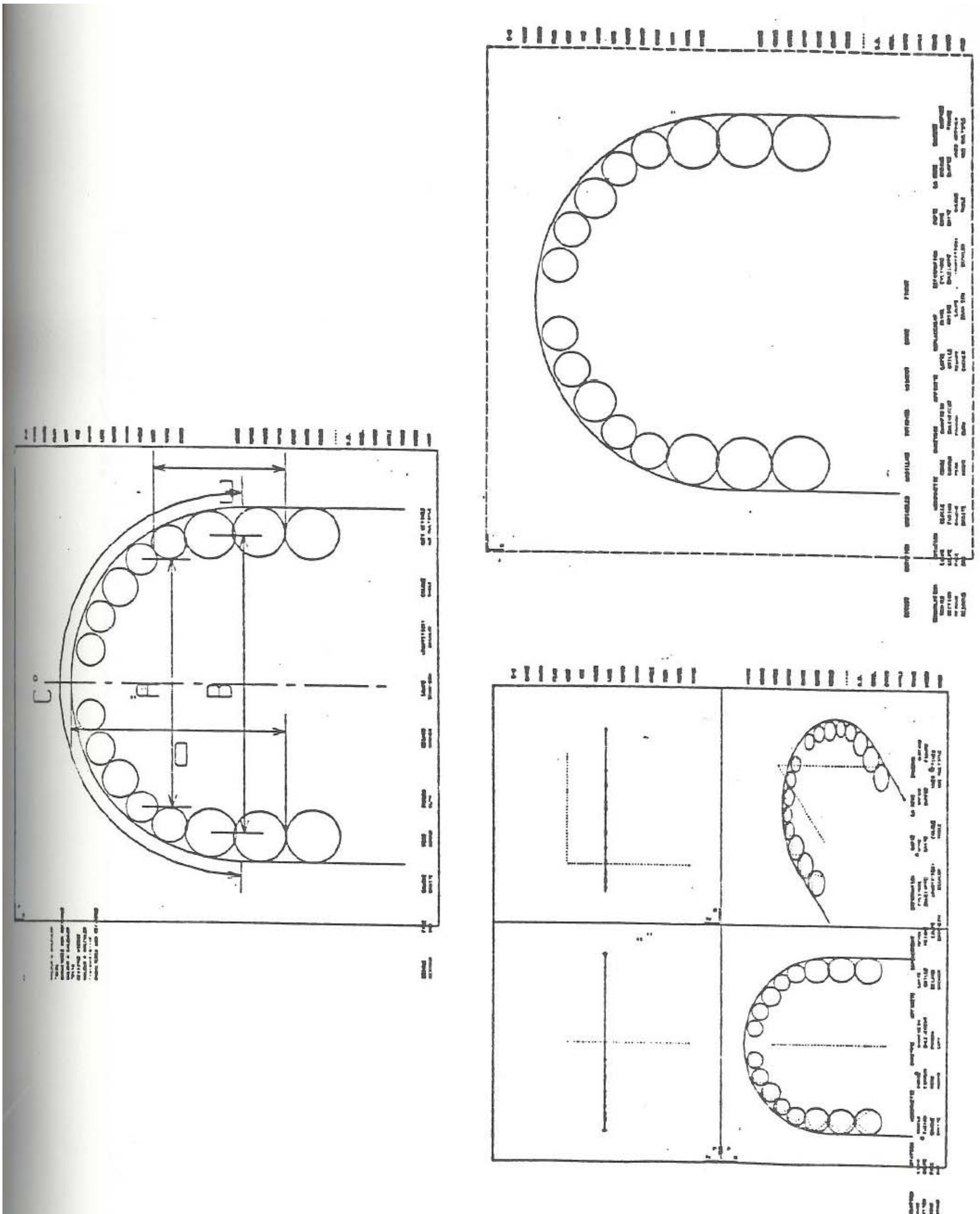
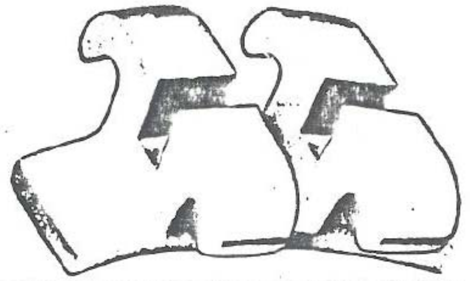


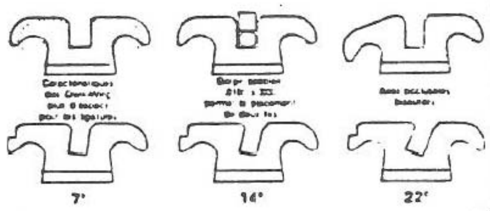
Figure 66



CARACTÉRISTIQUES

Le thérapeutique "Bioprogressive" (Ricketts) utilise des brackets à gorge de .0185 x .030 permettant un placement facile de l'arc et l'utilisation d'arcs et ressorts préfabriqués auxiliaires.

Les torques employés pour certaines dents sont de 7°, 14° et 22°.
Les angulations employées pour certaines dents sont de 5° et 8°.



BIOPROGRESSIVE STANDARD (RICKETTS)
Pour arc .0185 x .030 (0.470 x 0.762 mm)

SUPÉRIEUR

DENT	BRACKET	TYPE DOUBLE	ANG	PROFIL	DISTANCE GORGE/BASE	TORQUE	GORGE DROITE – AVEC PATTES POUR SOUDER SUR BAGUES – RÉFÉRENCE	GORGE DROITE – SANS PATTES SUR BASES POUR COLLAGE – RÉFÉRENCE	GORGE PRÉANGULÉE – AVEC PATTES POUR SOUDER SUR BAGUES – DROITE RÉFÉRENCE	GORGE PRÉANGULÉE – AVEC PATTES POUR SOUDER SUR BAGUES – GAUCHE RÉFÉRENCE	GORGE PRÉANGULÉE – SANS PATTES SUR BASES POUR COLLAGE – DROITE RÉFÉRENCE	GORGE PRÉANGULÉE – SANS PATTES SUR BASES POUR COLLAGE – GAUCHE RÉFÉRENCE
1|1 Centrales		Large	0°		0.7mm	+22°	A-69	A-5203	A-69		A-5203	
2|2 Latérales		Moyen	8°		0.7mm	+14°	A-213	A-5204	A-2000	A-2001	A-5230	A-5231
		Large					A-214	A-5205	A-2002	A-2003	A-5232	A-5233
3|3 Canines		Moyen	5°		0.7mm	+7°	A-468	A-5209	A-2006	A-2007	A-5236	A-5237
		Large					A-469	A-5210	A-2008	A-2009	A-5244	A-5245
4|4 1re Pré molaires		Moyen	0°		0.7mm	0°	A-996	A-5211	A-996		A-5211	
		Large					A-997	A-5212	A-997		A-5212	
5|5 2e Pré molaires		Moyen	0°		0.7mm	0°	A-996	A-5211	A-996		A-5211	
		Large					A-997	A-5212	A-997		A-5212	

INFÉRIEUR

DENT	BRACKET	TYPE DOUBLE	ANG	PROFIL	DISTANCE GORGE/BASE	TORQUE	RÉFÉRENCE	RÉFÉRENCE	DROITE RÉFÉRENCE	GAUCHE RÉFÉRENCE	DROITE RÉFÉRENCE	GAUCHE RÉFÉRENCE
1|1 Centrales		Simple	0°	1.9mm	0.7mm	0°	A-62	A-5214	A-62		A-5214	
2|2 Latérales		— ou — Moyen	0°	3.0mm	0.7mm	0°	A-66	A-5200	A-66		A-5200	
3|3 Canines		Moyen	5°		0.7mm	+7°	A-468	A-5220	A-2020	A-2021	A-5242	A-5243
		Large					A-469	A-5221	A-2022	A-2023	A-5246	A-5247
4|4 1re Pré molaires		Moyen	0°		0.7mm	0°	A-996	A-5228	A-996		A-5228	
		Large					A-997	A-5229	A-997		A-5229	
5|5 2e Pré molaires		Moyen	0°		0.7mm	0°	A-996	A-5228	A-996		A-5228	
		Large					A-997	A-5229	A-997		A-5229	

SACHET DE 10

Figure 67

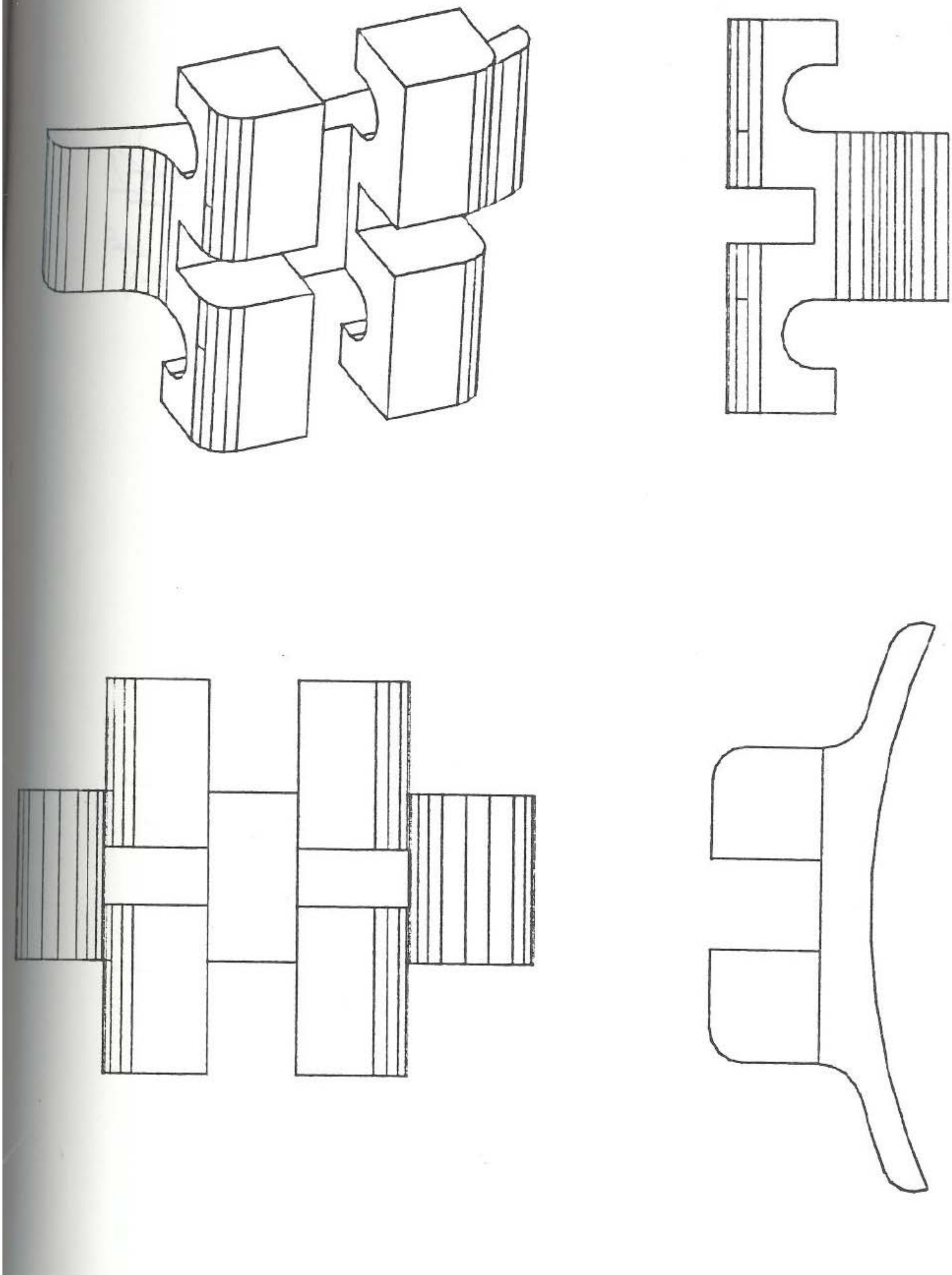


Figure 68

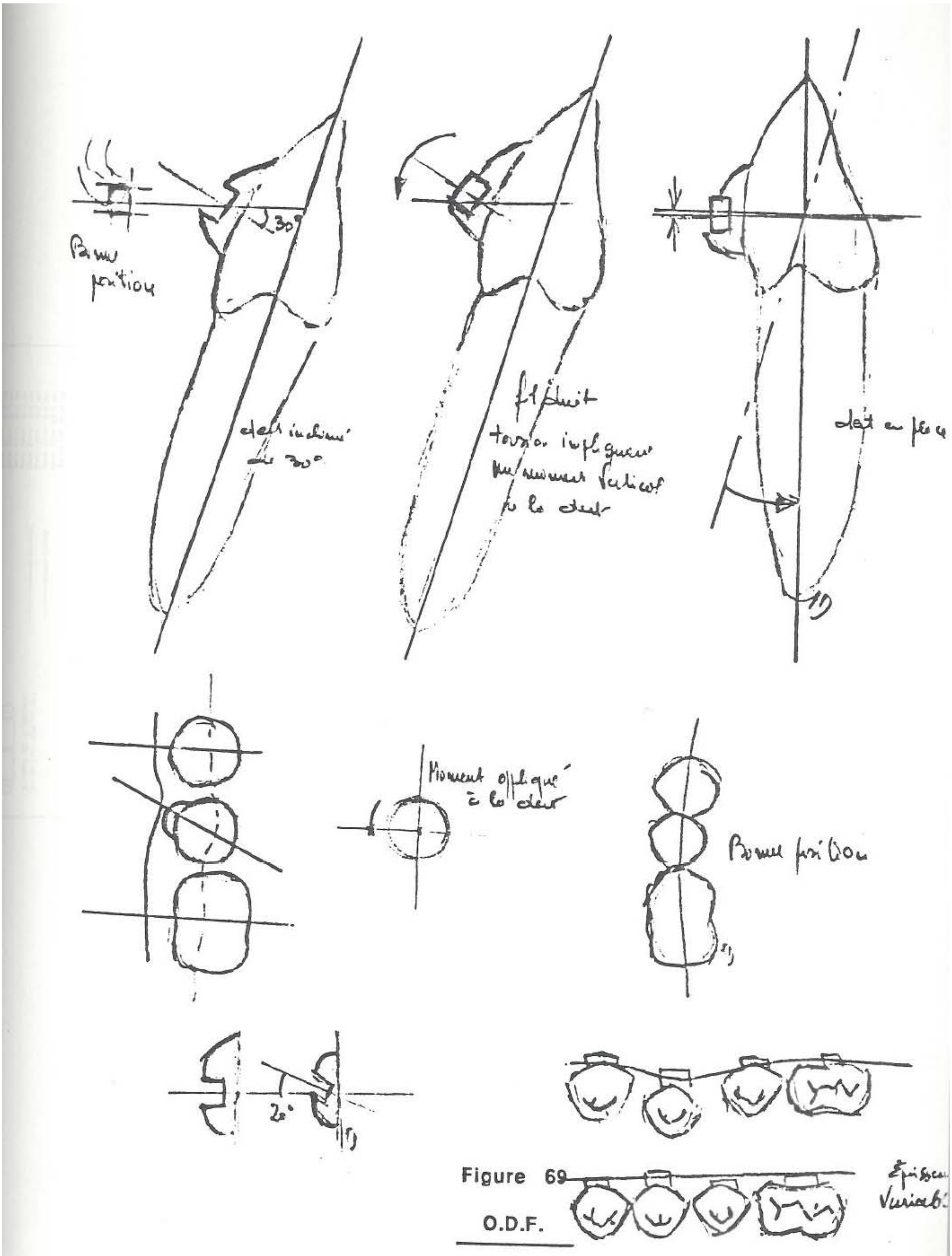
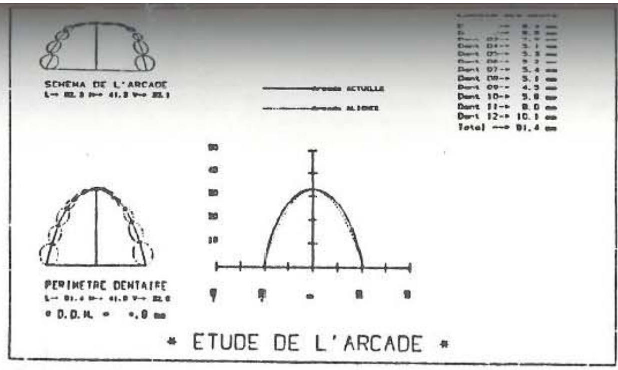


Figure 69

O.D.F.



CABINET D'ORTHODONTIE DE LA S.F.O.I.

VHE-INFORMATIQUE
5-7 LA CANEBIERE
13001 MARSEILLE
Tel: 91.11.12

ANALYSE DE RICKETTS

Pat : ROCHE SOPHIE
Age : 15.2 ANS (27/04/67) F

	ANALYSE DE FACE	Normes à l'âge (±écart)	22.11.76	13.09.79	07.06.82	06.05.83
	Axe facial	[illegible]	94.10	92.7	96.2	96.6
FACE	Angle facial	[illegible]	82.50	85.50	86.2	86.4
	Plan mandibulaire / Plan de Francfort	[illegible]	25.2	25.1	22.7	18.2
	Angle de convexité	[illegible]	71.70	71.00	76.8	75.3
	Convexité du point A	[illegible]	+4.30	+4.10	+2.1	+2.7
	Incisive inférieure à A-Po	[illegible]	-1.0	+1.0	+1.5	+1.5
DENTS	Première molaire supérieure à PTV	[illegible]	14.40	15.50	16.3	17.1
	Angle incisive inférieure à A-Po	[illegible]	9.60	22.9	16.7	16.2
PROFIL	Lèvre inférieure / ligne esthétique	[illegible]	-1.20	-2.20	-2.0	-4.2
	Overjet	[illegible]	+6.70	+6.60	+3.4	+4.0
DENTS	Overbite	[illegible]	+6.20	+4.9	+4.9	+4.0
	Extrusion incisive / plan d'occlusion	[illegible]	5.60	6.1	1.2	2.6
	Angle interincisif	[illegible]	108.60	123.5	122.2	124.5
[illegible]	Arc mandibulaire	[illegible]	28.10	27.30	31.5	36.2
[illegible]	Hauteur faciale inférieure	[illegible]	46.50	44.60	38.7	39.2

	ANALYSE DE PROFIL	Normes à l'âge (±écart)	[illegible]	[illegible]	[illegible]	[illegible]
	Protrusion incisive inférieure / A-Po	[illegible]	-1.9	1.4	1.3	1.5
	Protrusion incisive supérieure / A-Po	[illegible]	0.9	0.30	2.4	2.5
RELATIONS	Inclinaison incisive supérieure / A-Po	[illegible]	[illegible]	[illegible]	24.1	29.3
DENTS	Distance plan d'occlusion / mandibulaire	[illegible]	[illegible]	1.2	0.7	2.3
SQUELETTE	Angle plan d'occlusion / corpus	[illegible]	15.70	22.2	20.6	23.9
	Plan mandibulaire / Plan de Francfort	[illegible]	[illegible]	25.1	22.7	18.2
	Profondeur maxil. supérieur (Na.Ma.FH)	[illegible]	81.1	89.2	88.7	89.1
RELATIONS	Hauteur maxillaire (Na.CF.PTA)	[illegible]	54.1	53.2	55.3	57.9
CRANIO	SNA	[illegible]	81.60	[illegible]	81.2	81.2
FACIALE	SNB	[illegible]	75.20	75.20	79.1	78.6
	ANB	[illegible]	+5.10	+4.50	+2.10	+2.70
	Angle Francfort / plan palatin	[illegible]	[illegible]	[illegible]	2.9	0.7
	Longueur du crâne (CC.NA)	[illegible]	53.9	53.10	54.5	54.9
STRUCTURES	CF Gl	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
INTERNES	NA BA/FH	[illegible]	27.60	27.80	27.9	27.1
	FH CF BT	[illegible]	[illegible]	69.20	[illegible]	[illegible]
	Po à P.T.V	[illegible]	[illegible]	[illegible]	41.2	[illegible]
	Longueur du corpus (Xi Pm)	[illegible]	[illegible]	65.10	69.5	67.5

Figure 70

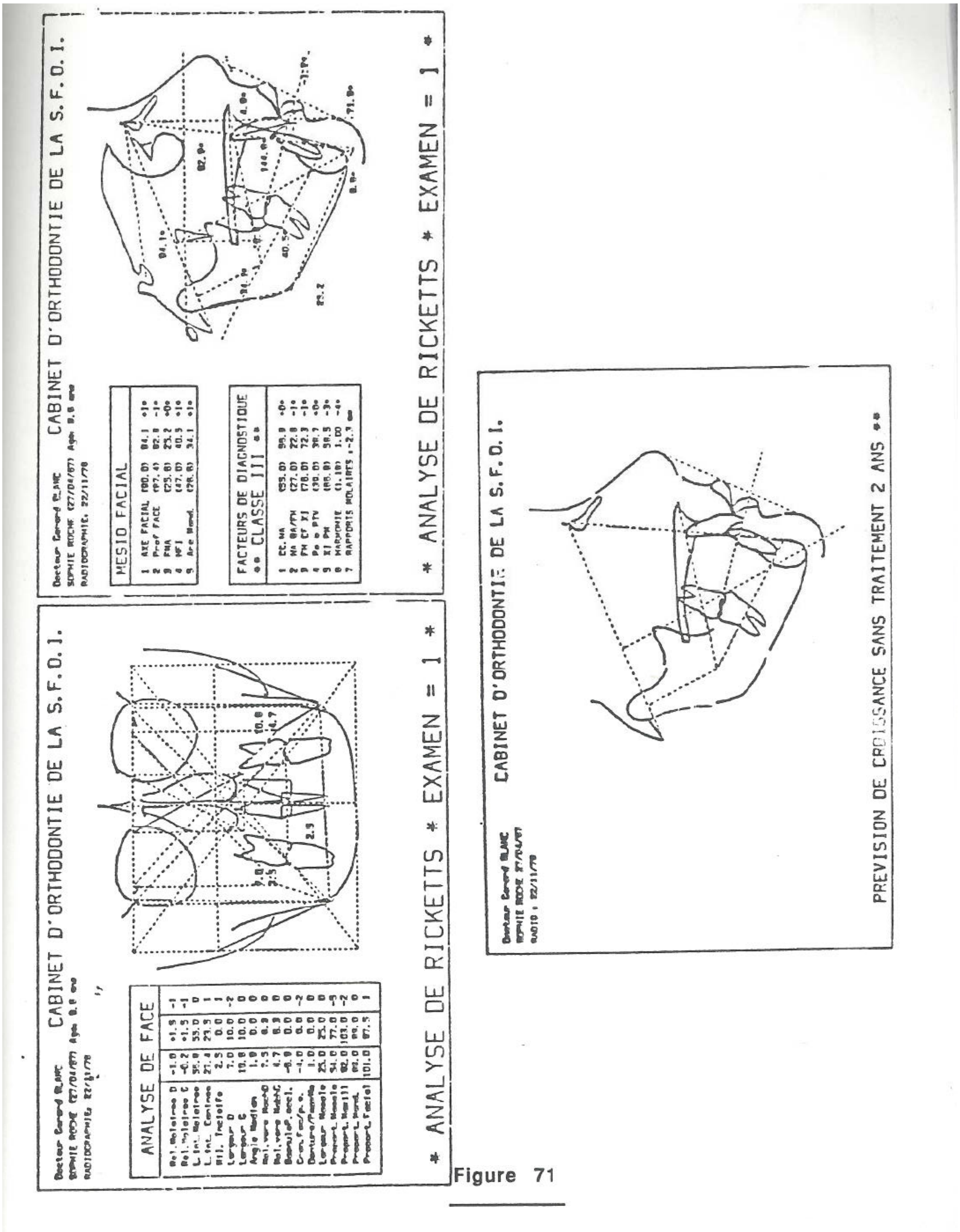

CABINET D'ORTHODONTIE DE LA S.F.D.I.
MESIO FACIAL
FACTEURS DE DIAGNOSTIQUE
** CLASSE III **
* ANALYSE DE RICKETTS * EXAMEN = 1 *
CABINET D'ORTHODONTIE DE LA S.F.D.I.
ANALYSE DE FACE
* ANALYSE DE RICKETTS * EXAMEN = 1 *
CABINET D'ORTHODONTIE DE LA S.F.D.I.
PREVISION DE CROISSANCE SANS TRAITEMENT 2 ANS **

Figure 71

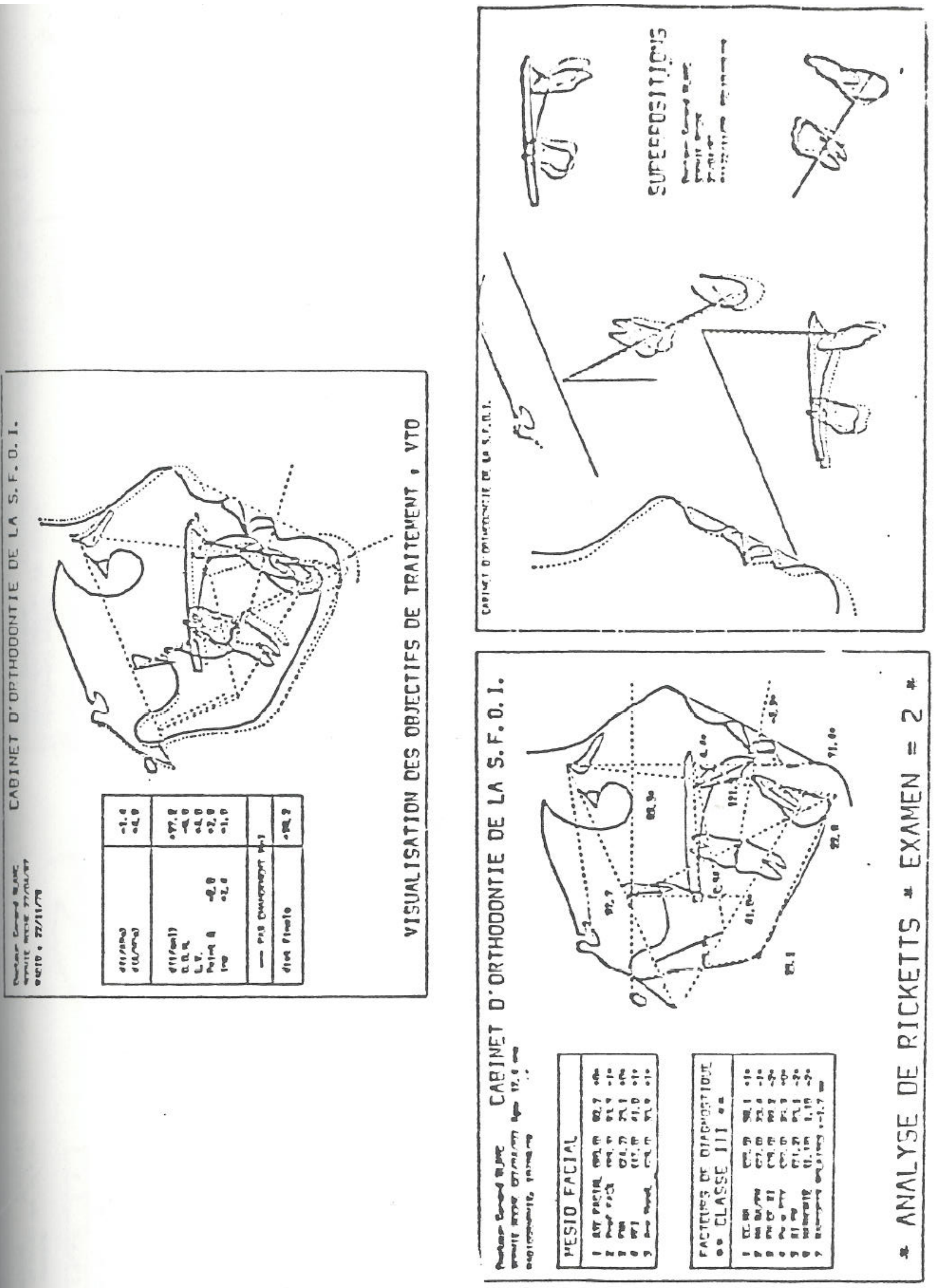

CABINET D'ORTHODONTIE DE LA S. F. O. I.
VISUALISATION DES OBJECTIFS DE TRAITEMENT , VTO
SUPERPOSITIONS
CABINET D'ORTHODONTIE DE LA S. F. O. I.
MESIO FACIAL
FACTEURS DE DIAGNOSTIQUE
CLASSE III
* ANALYSE DE RICKETTS * EXAMEN = 2 *

Figure 72

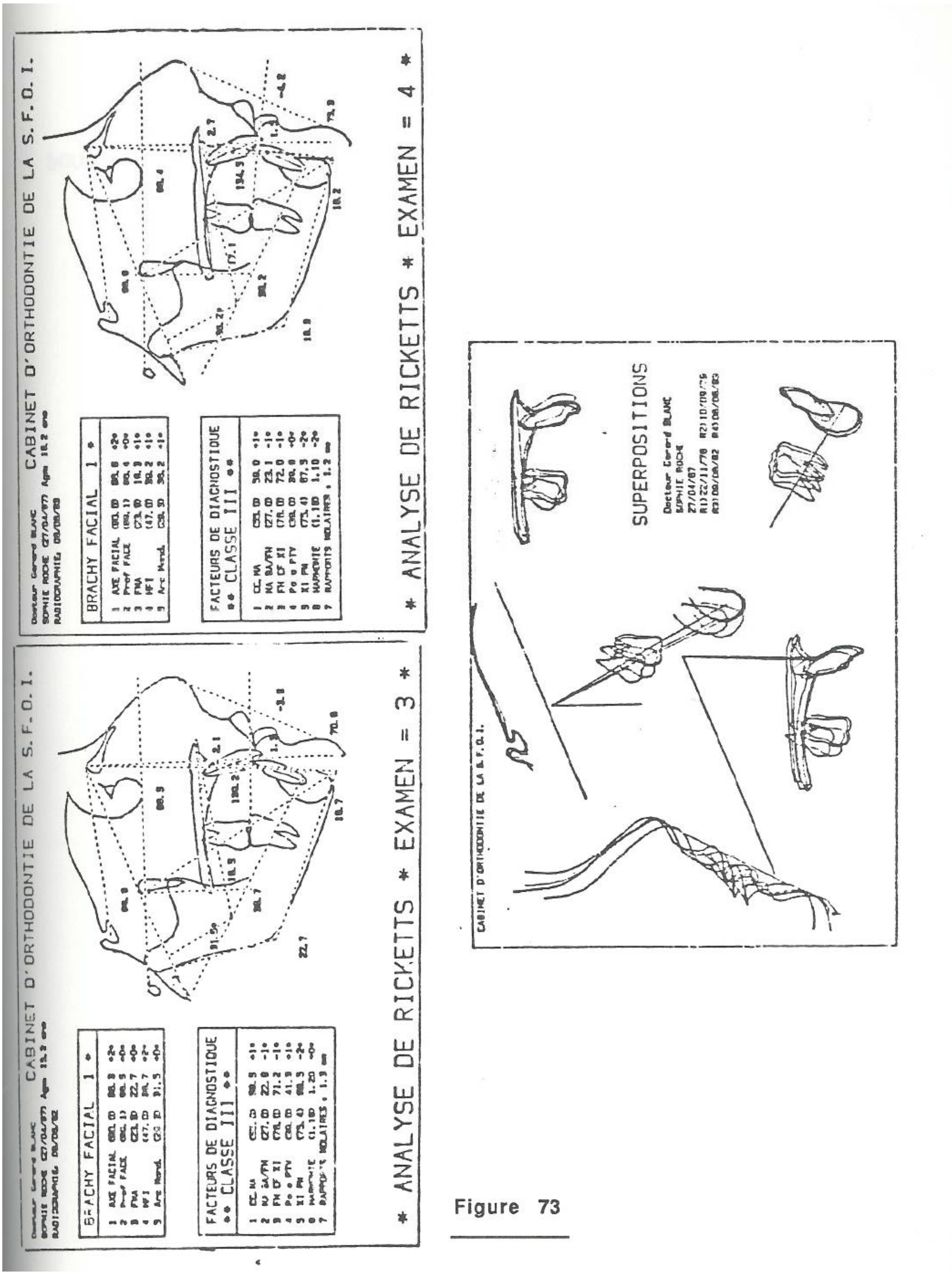

CABINET D'ORTHODONTIE DE LA S. F. O. I.
BRACHY FACIAL 1 *
FACTEURS DE DIAGNOSTIQUE
** CLASSE III **
* ANALYSE DE RICKETTS * EXAMEN = 3 *
CABINET D'ORTHODONTIE DE LA S. F. O. I.
BRACHY FACIAL 1 *
FACTEURS DE DIAGNOSTIQUE
** CLASSE III **
* ANALYSE DE RICKETTS * EXAMEN = 4 *
SUPERPOSITIONS
CABINET D'ORTHODONTIE DE LA S.F.O.I.

Figure 73

2.9 Precision

2.9-1 Correlation and modelling precision

We have spoken, in the previous chapter, about the precision of the relief measurement. We have seen that the optical probe could deliver, in certain measurement conditions, impressions in semi points having a certain imprecision, mainly coming from of, on the one hand, the phase measuring noises and on the other, uncertainties of the calibration procedures. The impressions are referenced to a plan which is linked to the probe and to its orientation; the **reference plan**. For each impression, we have a referential system which is associated to it. The modelling step consists of:

a- gathering the points from the different impression in a same referential, it is the **correlation**.
b- adapting the relief data thus obtained following a format which is compatible with CAD software, it's the **modelling**.

2.9-1.1 Correlation precision

The current principle of the correlation consists of placing the relief to be acquired, points which are easy to find. These points are interactively detected on each impression and are then used as base for the calculation of a referential common to each impression (system of axis associated with the marking points). For each impression, the coordinates of the points of the relief are transformed (rotation and translation) to refer to the marking points. We thus obtain several semi points with the same referential. The precision of this correlation is evidently linked to the precision of detection of the marking points but also to their positioning in space. With the current methods of detection, the precision of a point is around 30µ depending on the 3 axes. We use three points. If these three point are for example 20µ apart, the correlation error will be 20 times the marking error. We can summarise this leverage effect by the approaching formula that follows:

$$E_C = \frac{E_R \times D_P}{D_R}$$

With

E_C is the correlation error for a given P point

E_R is the marking error (around 30µ)

D_R is the average distance of three marking points to their barycentre

D_P is the distance of the studied point to the barycentre of the three marking points

We see that the more the marking points are far apart from each other and the closer they are of the studied object, the lower the correlation error is.

REMARK: to palliate this leverage effect, we have imagined the completion of this correlation method by a micro correlation step which, starting from the correlation results, detects by using the relief's curves, the zones effectively common to the two semi points and which deduces an adjusting transformation. This software is still at the development stage.

2.9-1.2 Modelling precision

Modelling has a double role:

a- eliminating the aberrant relief points
b- interpolate the semi points by function

The CAD softwares aren't generally done to receive a lot of points. It's even the contrary, with few captured points by man on screen, these softwares are capable of generating several million. For example, a circle will be defined by three points, a Beziers curve by a dozen maximum. However, the circle and the Beziers curve have an infinity of points! In our case, we must do the contrary: the probe delivers a very important quantity of points (around a million for a good impression capture). Evidently all these points aren't useful but they constitute a good statistic base. Their characteristics are as follows:

- their density isn't constant all over the relief
- they are ordinates
- some are wrong

With these processes of smoothing then skeletisation, we eliminate the aberrant points, ordinate the points and give a more or less density. Then we approximate the semi points with binomial functions or with z buffer functions, in order to reduce the number of parameters transferred to the CAD. In terms of precision, this modelling improves the global quality of the relief while generating smoothing effects on some small details. It is very difficult to quantify this grain but everything happens as if we selected the more precise semi points on the curve or on the surface (tendency and lesser square).

2.9-2 CAD software precision

In a general manner, the precision of the software is closely linked to the precision of the calculator. The codification of the numbers in a computer is obligatorily edged.

It means that each number can only be expressed with a certain number of figures after the comma. In the calculators we use, the coding of the digital data is done following a standard internationally recognised which is called "floating comma". With this mode, we have a precision of 7 numbers after the comma. Knowing that the unit we use is the millimetre, the precision of the calculation will be $10^{-4}\mu$. We must add to this hundreds of degradations which are proper to each calculation module.

2.9-2.1 Precision of CAD calculation

The calculations done by the software generally use interactive algorithms. On the other hand, several calculations using the results of the previous calculation can add to each other. The multiplication of these operations leads to a degradation of the precision and "edge effects". Fortunately, we have the means to limit this "inflation" by working on intermediary partial results with a more precise representation. This costs some time but avoids rapid degradation.

Let's take an example: let's suppose that the machine only accepts two numbers after the comma and that we must multiply 1.13 by 9.99. Seeing that these two numbers have each two number after the comma, and that the result will also have two, it will cut them by one number, 1.1 and 9.9 and will give 10.89 as a result. If, on the contrary, we program 10 x 1.13, then 10 x 9.99 and finally divide the result by 100, it will do:

10 x 1.13 = 11.3
10 x 9.99 = 99.9
11.3 x 99.9 = 1128.87
1128.87 / 100 = 11.23, which is more than 10.89.

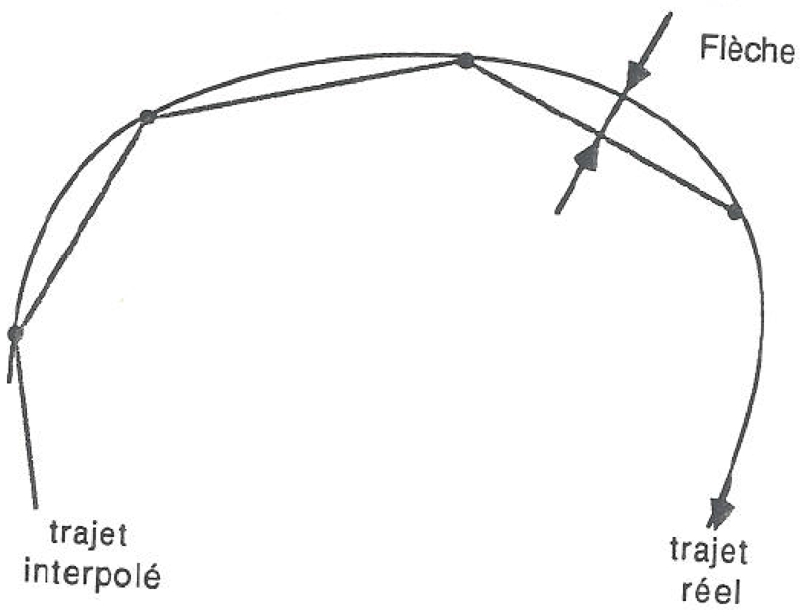
For the softwares we use, the precision for the final results is 10^{-6} x DIMEN, where DIMEN is the dimension of the working space which can be different depending on the work done (stump, crown, occlusion, bridge…). But even if we are placed in an unfavourable working case, for example 45 x 25 x 15 mm3, the error is only 0.045% in z, 0.025% in y and 0.015%in x.

2.9-2.2 Precision of interactive

We must distinguish here two very different cases. When the dentist captures a point already existing on the screen, the precision of capture is internal to the software, thanks to a particular procedure which goes to the closest point indicated by the practioner (readjustment on existing curves). When the dentist captures a point that doesn't exist already on the screen, the precision of the pointing is the pixel. Thanks to the "magnifier effect", it can become important. Let's suppose a 10mm high curve. For a screen of 1000 by 1000 points, the capture precision will be 10µ. But if we take a part of the curve, for example 1mm of it and we do a "magnifier effect" on it, we still have 1000 by 1000 points which leads to a 1µ precision. We see that we can get an adapted practice of the visualisation screen, a very important precision of the capture of points.

2.9-2.3 Precision of manufacturing movements

After having generated the prosthesis, the calculator launches a particular procedure which enables the calculation of parameters to be sent to the tool machine. It only knows how to execute linear movements. We are going to approximate the shapes found by a succession of segments of a line. We could do this infinitively but the limit is imposed by the speed of transmission of the coordinates to the digital command on the one hand and the speed of execution of the order on the other. If we generated too many points, the manufacturing time would become prohibitive and the movements would be interrupted during the waiting of the transmission. To limit ourselves and to keep a certain precision of the manufacturing movement, we have determined an acceptable maximal arrow. This arrow corresponds to the maximal distance between the real curve and the segment of line joining two points sent to the digital command. It corresponds typically to the precision of the manufacturing movements and is 20µ today.



3-MANAGEMENT SOFTWARE

3.1 Generalities

Management must be a constitutional element of CAD/CAM. Particularly each practioner possessing this device must have a logic management capacity, quick and organised, given the power of the used material. It is particularly interesting to note that a practioner who invests 100000FF of management material pays 1/5th (20%) of the CAD/CAM and who wanted to computerise his management will pay his CAD/CAM 20% less. It is also a marketing operation as well as a medical operation (with the difference to other sectors).

There are today around 80 softwares of dental management and only a dozen are really operational (figure 74). For CAD/CAM, we have preselected 10 following these conditions:

- software tested by numerous colleagues , as, if this software was to be sold in numerous copies, it means it corresponds to a good analysis of the dentist's needs. Moreover, it's a pledge of achievement for the company that commercialises it
- multi-practioner's software, as the market aimed at by CAD/CAM is oriented towards grouped practices
- a software recognised by the A.N.E.R.I.O., which guarantees a certain quality of the software
- a software representing a technological advance as we must be on top today to be ready tomorrow…

PRELIMINARY REMARKS:

The pre-selected softwares are recognised at a national level by a group of colleague fans of computer science and impartial. Then, we have eliminated the doubtful ones because of the reliability of the companies who support them and those whose analysis banality isn't compensated by the number of sold systems.

The kept softwares are as follows (first analysis):

- AGATHA
- ALPHADIS
- APOLLINE
- DENTILOG
- DENTPRO
- GESDENT
- JULIE
- PAROLOG
- PRODENT
- VISIODENT

Each software enables, after study:

a) The management of patients
An identity sheet with management of birth dates and management of homonyms.
Patients clustering
Medical questionnaire
Treatment plan
Colour graphic dental drawings
Quotes
Orders and counter indications
Care sheet with both sides printing
Prior agreement with both sides printing
Management of non payment, reminder letters
Management of private insurance
Appointment management

b) Accounting
Receipt book
Expenditure book
Depreciation book
Big book
2035 declaration

c) Other
Salary
Stock management
Statistics (actions, time, etc…)

We must insist on the shyness of our colleagues, in front of computers (less than 1500 practices are equipped out of 37000 dentists, which means around 4% of dentists and 7 to 8% of practices) (figure 74).

3.2 Current study

Two softwares have been chosen. They are PRODENT from CERILOR and ALPHADIS from ALPHAMET.

3.2-1 HENNSON's policy

As we have defined previously, the HENNSON Company doesn't have a vocation of recreating a management software but to offer one or more software already written to his buyers and for free. The company responsible for the software will install it and insure the maintenance. The market in the first place concerns mono-posts but will be increased to multi-posts. CAD/CAM won't have a printer, a slight over cost will have to be planned.

3.2-2 Prodent (CERILOR company) – Doctor DESPREZ in Maxeville

The PRODENT software uses UNIX which seems incompatible with VMS and is in C Microsoft. We need to transfer all of PRODENT under VMS and rewrite the entry and exit routines (hard drive, screen). What are the problems being solved? (PRODENT on CAD/CAM must be presented in November 1987).

3.2-2.1 Problems linked with translation

The C Microsoft is an on-set of the KERNIGAN RITCHIE norm. The C Vax is under the same on-set. At first, two compilers are able to translate the "norm". Practically, the on-set doesn't exist (simple adjunction of identification key words). If the translators are close, the pre processors are different. IT leads to recognition problems for the implantation the objects done by the compiler.

3.2-2.2 Problems linked with links edition libraries

PRODENT uses 60 functions planned or not by the Vax library.

3.2-2.3 Problems with installed configuration

PRODENT needs 640 KO of RAM.
1.5 MO for programs and tables
7 KO per sheet (5 MO for a lifetime)

This conforms with CAD/CAM but there is still the connection problem. We are transferring PRODENT under BERKELEY 4.2, from Unix thanks to Vax 750 available. From October we will transfer on VMS with availability of a Vax for 2 to 3 months (analysis and tests).

3.2-3 Alphadis (ALPHAMET company)

The ALPHADIS software is written under RSX to use Microvax PDP II. The language is written under RPL whose license is 50 000FF for each user! This cancels all possibility of use. The principle would be, here again, to rewrite the software in Basic Plus for which the license price is null. We have decided to help M. VIDAL with this work and have charged an engineer to do this. To do this, a study has been made:

- working tools at our disposal (for both companies)
- licensing costs for the softwares (use)

We noticed that:

- the unavailability of Basic Plus 2 on Micro Vax, replaced by Vax Bass
- the licenses are very expensive

  35 920FF for DATATRIEVE

  15 120FF for TDMS

  7 235FF for CDD

If it is possible to have a software quickly, unofficially, we can't beneficiate of the documentation (!) and the logistical support. There would not be a fee to pay for the final user (dentist) for the programming languages but a Run-Time (use rights) license for TDMS of 6 006FF would still be obligatory. Unfortunately, the absence of competence for these transcription softwares and the high cost of the official versions will oblige ALPHAMED to abandon this way in July (23/07/87).

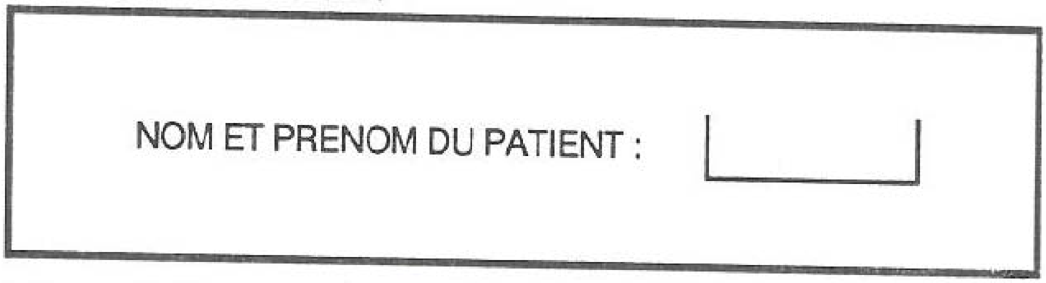
Recently (August), DIGITAL has offered a special Multi-use license of 25 427FF. Even if this price varies from Station 2000 to Micro Vax (reduction of 50%), the price stays too high. Moreover, DIGITAL is amazed if the use if CDD and DATATRIEVE as a management software as, according to them, these are very greedy and not adapted to Micro Vax. A more thorough study of the ALPHADIS software showed that this software was very powerful and needed lots of space on the hard drive. Moreover, the multi-use causes a certain number of problems and the providing of the license for Micro-VMS 2 Users with our PCs seems insufficient for our management software.

Finally, ALPHAMED has decide that, after seeing DIGITAL's prices, abandoning the CDD environment and so TDMS and DATATRIEVE was the best solution and the rewriting of the whole software in Basic would be done. This increases the development phase but it has started end of July and should be finished in November.

3.3 Particular interactive development by HENNSON

From April to June 1986, HENNSON has received an intern, Christiane ACHARD, in order to develop an interaction of management of prosthetic data in CAD/CAM. This software enables the management of the patient's sheet to whom we are doing a prosthesis and possibly transmit the data to a management file in a dental practice. This work was the subject of an internship dissertation and numerous clinical trials. The software was written under FORTRAN 77 with EUCLID (MATRA DATAVISION).

During the launch of the software, a capture of the name and surname of the patient runs. We have the first screen (see below):



Two cases can happen:

1ST CASE: the concerned patient is already in the database of the general CLIENTS file and has a care sheet
In this case, the program will display the VT 220.

2ND CASE: the patient is a new client of the dentist and not yet entered in the database. We must create his care sheet and insert a new recording in the general CLIENTS file.

We will send the data on the VT 220 but the menu of restrained command with three commands which are F for END, V for VALIDATION and M for MODIFICATION. Before sending to the VT 220, the treatment of homonyms will occur, that is to say the program will "sweep" the whole general CLIENTS file to see if there is already a patient with the same name and surname and the current patient. Two cases can logically occur:

- there are no homonyms. We go directly to the second VT 220 screen and create a new patient (figure 75).
- there is one or more homonyms, the program will send a list of this or those homonyms and ask to capture the chosen patient's number or will enable by typing on the keyboard a special N° (sent to the screen) to create a new patient (or new homonym). For the dentist to make a choice in the list, we had to send a screen line per patient with the minimum identification criteria.

We have chosen to put on this screen line:

- the patient's number
- the surname + name
- the complete address
- the social security number

In the 2nd case, only the Name and Surname and Number zones will be sent by the program, the others have to be captured. At the end of the display or the capture, the user will type the command of his choice on the keyboard (I…). All the commands have very precise functions that can be read on the screen.

We then have the following question on the screen:

DO YOU WANT TO START THE CAD WORK? [_]

(O = Yes / N = No)

If the answer is "N", we exit the program.

If the answer is "O", we will have the following question on the screen:

NUMBER OF THE TOOTH TO BE TREATED: [_]

This number must be between 11 and 48 for adult patients. There will then be an update of the last visit in the CLIENTS file. If the archive date isn't null, we will restore the patient's backup file otherwise we will do no treatment. That's when we start the CAD phase and the 5th screen appears. If the answer is "N", the program will add a recording in the care sheet file with the date, the number of the treated tooth and the nature/intervention/blank zone. If the answer is "O", a menu offering different types of prostheses appears on the screen. All the dentist has to do is choose and type the first two letters of the chosen name.

If his choice is = "CO" which means CROWN, another menu is displayed offering possible types of crowns. In this case also, the dentist will only have to type on t he keyboard the first two letters of the chosen type.

If his choice is = 3BR" which is BRIDGE, the dentist will have to answer the following question:

NUMBER OF ELEMENTS: [ ]

(=2, 3, 4 or 5)

Then the program will send him back to the types of crowns menu (see treatment for the choice = "CO").

If his choice = "IN", that is to say INLAY, the dentist will have to answer:

NUMBER OF FACES: [_]

(= 1, 2 or 3).

Whatever the choice of the dentist, the program will add a recording to the care sheet file.

This last phase finally concerns the handling to the users of the management database EUCLID. We will have on the screen the following question.

SAVE CAD WORK?: [_]

(O= YES / N = No).

If the answer is "N", there will be no saving of the work done with the CAD software

If the answer is “O”, the main software will launch the DCL command file: SAUVEGD.COM which will be immediately executed under EUCLID. The binary saving file will be under the form:

PATIENT N°.DAT

We will also have an update of the last backup date for the concerned patient in the CLIENTS file. In both cases, the database will be emptied or “cleaned” to initialise at the next working session. It is the end of the program. The work has be built in order to establish solid links with the ALPHADIS software.

3.4 Conclusion

Two softwares are being used. The HENNSON software will have to, in the first instance, work in parallel with the management softwares and in the second instance, a link will be built for interactivity with only one processor.

REPERTOIRE DES PROGRAMMES LE 27 JANVIER 86

DOS	NOM DU PROGRAMME	VENDEUR	ADRESSE	CODE POSTAL ET VILLE	TELEPHONE
CANON X07	INFORMATIQUE CDP	DOCTEUR LABOUZE	61 RUE DULONG	75017 PARIS	47-63-08-02
COMMODORE	DENTEX TRG	DOCTEUR TOLLET	EUDAL DE BAS URVILLE	50460 NACQUEVILLE	33-03-97-09
COMMODORE	SEMIDENT	MR MUHLA	69 RUE DE MAREVILLE	54520 LAXOU	83-40-43-38
CP/M	ARDION	MR VINCENTI	18 AVENUE BEAU PLAN	13013 MARSEILLE	91-66-12-40
CP/M	CIDENT	SILMM	B.P. 39	56530 QUEVEN	97-05-24-34
CP/M	MICRODENT	MR FOIX	21 BIS AVENUE SAINTE MARIE	94160 SAINT MANDE	43-65-25-30
CP/M	NC DENT	NORD CONCEPT DIFFUSION	5 RUE DU COLIBRI	59650 VILLENEUVE D'ASCQ	20-05-42-02
DOS 3.3	AGATHA	DOCTEUR GAUSSEN	59 BIS RUE DE LA BICHE	30000 NIMES	66-76-04-75
DOS 3.3	AGCODEM	MR PEREZ	22 RUE DE LA VICTOIRE	75009 PARIS	48-78-27-66
DOS 3.3	CHIRDENT DPR	DPR FRANCE	103 BD NATIONAL BP 44	92502 RUEIL MALMAISON	47-08-36-10
DOS 3.3	COMPODENT	MR AZOULAY	181 RUE TRIAIRE	92500 NANTERRES	42-04-03-95
DOS 3.3	CORRESPOND-DENT	DOCTEUR ESKENAZI	68 Bd MIREILLE-LAUZE	13010 MARSEILLE	91-79-85-82
DOS 3.3	DENTISET	SANTE SET	TOUR ORION 5 RUE KLEBER	93100 MONTREUIL	48-51-91-00
DOS 3.3	MAI DISK	A.G.D.	48 BD ALEXANDRE MARTIN	45000 ORLEANS	38-54-45-13
DOS 3.3	ODONTO-LOGIC	MR LETOURNEUR	32 RUE DE LA VICTOIRE	75009 PARIS	48-74-79-96
DOS 3.3	PRODAVIER DISK	MR ANDRE AMAR	5 RUE JEANNE D'ARC	94160 SAINT-MANDE	48-08-64-35
DOS 3.3	SGCD	MR VERSLUYSEN	6 RUE DE CHATEAUDUN	75009 PARIS	48-78-80-63
HP 150	DIGIDENT		11 RUE TRONCHET	75009 PARIS	42-66-40-34
HP 150	EVI-DENT	VHE INFORMATIQUE	5 LA CANEBIERE	13001 MARSEILLE	91-90-67-50
ITT 3030	DIALOG	MR BRAULT	38 BOULEVARD DU CHATEAU	92200 NEUILLY SUR SEINE	42-42-00-37
MAC	GESDENT	LOGI 27	73 RUE TURBIGO	75003 PARIS	42-74-70-55
MAC	MAC DENT	DAG INFORMATIQUE	38 BIS RUE DES GRANGES	69005 LYON	78-36-48-19
MS-DOS	ABSOLU	MR LATAPI	209 RUE DE BERCY	75012 PARIS	43-46-13-95
MS-DOS	ADENT	PROMOTEC	113 AVENUE APOLLINAIRE	69009 LYON	78-64-16-66
MS-DOS	APOGE	DOCTEUR GARIN	17 RUE AUGUSTE	30000 NIMES	66-21-00-88
MS-DOS	ARTHUR	MR VELU	IMMEUBLE LA TRAMONTANE	84300 CAVAILLON	90-71-42-45
MS-DOS	BASEDENT	DOCTEUR BERCY	5 RUE DU 4 SEPTEMBRE	13100 AIX EN PROVENCE	42-38-54-46
MS-DOS	BIBLO	VAO COMMUNICATION	41 RUE MARIUS AUFRAN	92300 LEVALLOIS PERRET	47-58-40-67
MS-DOS	CERG DENTAL	PROMODATA	10 AV. DE LA GRANDE ARMEE	75017 PARIS	45-01-54-13
MS-DOS	CIT DENT	MR THAHERALY	8 BOULEVARD DES ARENES	30000 NIMES	66-76-07-72
MS-DOS	DENTISYS	MR NGUYEN KHANH	OCFD 7 BD DE L'EUROPE	21800 QUETIGNY	80-46-01-25
MS-DOS	DENTPRO	MR RAOUIDEL	21 RUE CHAPTAL	75009 PARIS	48-74-60-64
MS-DOS	FMI DENTAIRE	MR JEAN-MARIE KURT	2 RUE CURNONSKY	75017 PARIS	47-58-12-72
MS-DOS	GID	DOCTEUR MEDIONI	41 RUE GUERSANT	75017 PARIS	47-33-30-03
MS-DOS	INFODENT	MR MICHEL DEMANGEON	23 RUE DE BREST	69002 LYON	78-42-49-27
MS-DOS	INFORM ET SANTE	MR CHIROUZE	46 RUE LAFAYETTE	75009 PARIS	42-85-12-88
MS-DOS	IVOIRE 2	PARTNER INFORMATIQUE	33 AVENUE DE GRAVELLE	94220 CHARENTON	48-93-23-87
MS-DOS	JULIE	CENTRE INFORMATIQUE	4 RUE DE LA MADELEINE	45140 ST JEAN DELARUELLE	38-43-27-27
MS-DOS	KARIANE	DAI	166 AVENUE DE HAMBOURG	13008 MARSEILLE	91-72-23-56
MS-DOS	ODUS	MR GEHIN	13 RUE MOLIERE	75001 PARIS	42-96-05-52
MS-DOS	PRODENTIS	MR BORG	4 RUE FOUCROY	75017 PARIS	42-67-74-57
MS-DOS	STADENT	MR CARO	53 AV. PHILIPPE AUGUSTE	75011 PARIS	43-72-21-66
MS-DOS	VISIODENT	DENTAL COMPUTER	94 RUE LAFAYETTE	75010 PARIS	42-46-81-05
OASIS	DENTILOG	MR TSIRANANA	46 RUE SAINT ANTOINE	75004 PARIS	42-78-26-64
OASIS	DENTILOR	MR LAMOTTE	35 AVENUE DE L'OPERA	75002 PARIS	42-96-63-59
OASIS	DENTILOV	MR CHEVALLIER	26 RUE DE BERRY	75008 PARIS	45-62-50-15
PROLOGUE	ITTIDENT	DOCTEUR BEUGNET	23 RUE DE LA NOUILLERE	25000 BESANCON	81-50-42-67
PROLOGUE	MANDIBULE	OGI NORMANDIE	21 RUE GUY DE MAUPASSANT	27000 EVREUX	32-31-16-77
RAINBOW	DENTO	MR COLLARD PLM	46 RUE DE LA THIBAUDIERE	69007 LYON	78-69-38-70
SANCO	ALLIANCE	MICRO 89	10 ALLEE DES ALOUETTES	89100 SAINT CLEMENT	86-64-35-74
SANCO 700	ISH	ISH	6 RUE GOETHE	75016 PARIS	47-23-31-05
SORD M23	GOLD	S.E.S. INFORMATIQUE	18 AVENUE DES CHAMPS-ELYSEES	75008 PARIS	47-23-78-20
UNIX	PRODENT	DOCTEUR J DESPREZ	17 RUE GAMBETTA	54000 NANCY	83-35-13-61
	ALPHAMET	J-M VIDAL	1 RUE HOCHE	83000 TOULON	94-92-98-18
	AFOLLINE	MR MONTILLOT	6 RUE BEONEGNE	21000 FREMYOT DIJON	80-41-67-4

Figure 74

```
DOCTEUR : [----------]
PATIENT : [-------------]
   DATE : [------]
DENT N° : [--]
```

```
OBSERVATIONS INTERVENTION : [__]
      (O=OUI/N=NON)
```

```
      FICHE DE SOINS DU PATIENT

   NOM ET PRENOM :  [-------------]
          NUMERO :  [-----]
  DATE NAISSANCE :  [----------]
    DATE DU JOUR :  [----------]
         ADRESSE :  [------------------]
 N° DE TELEPHONE :  [------------]
        N° DE SS :  [---------------]
    OBSERVATIONS :  [------------------]

    COMMANDE : I pour LIRE INTERVENTIONS
               A pour ANNULER LE CLIENT
               D pour LIRE DONNEES
                      ANATOMIQUES
               M pour MODIFIER
               F pour FIN
               V pour VALIDATION

       CHOIX ? : [__]
```

Figure 75

4-MANUFACTURING

4.1 Launching of digital command tool machine

4.1-1 Introduction

It is absolutely necessary that a dentist has no specific intervention to do when launching the machine. For that reason, from May 1982, we decided to use a direct correction command, through CAD and from June 1985, the launching of the machine was automatic. By semi automatic, we mean:

- verification of the mechanical characteristics
- resetting to zero of the working axes
- calculation of the automatic tools movements
- library of stocked tools
- choice of tool

During the ADF, all these operations, even they didn't really need a great control, were manually started. It meant:

- that the dentist had to possess a specific terminal for the tool machine
- that he had to command the starting of these instructions by direct manual action at each step and for each tool. From mid 1986, a library of tools, applicable to any type of prosthesis was defined, and only in March 1987 did we manage to develop the automatic launching of the machine.

4.1-2 Current state

The launching of the digital command and control of the tool machine process was entirely automated. It is a detached process to do in parallel the resetting of the axes of the machine, the calculation of the movements, the manufacturing of the pre shape and the manufacturing of the tooth. The CAD post is available for calculation of a new prosthesis or other things.

4.1-2.1 Launch

When a practioner has finished is interactive or automatic action, all he has to do is indicate "manufacturing". The application launches under process to take the manufacturing in charge. The process, commanded by a DCL procedure, launches the calculation of the movements in BATCH mode which insures at the same time:

- the resetting of the axes of the machine before the calculation
- the manufacturing of the pre shape as soon as we know its dimension
- the manufacturing of the crown at the end of the calculations.

Batch means "hidden".

4.1-2.2 Movements calculation

The program could be interactively used. To avoid any mistake, this calculation is blind to the dentist. After the dentist has accepted the manufacturing, it happens in two steps, first a pre manufacture of the pre shape to get to a state closer to reality, then a specific manufacture of the crown.

4.1-2.3 Intervention

It is possible to stop in emergency, to stop between each tool or when one or the case has been done. The flipping of the piece is used to observe the different stages.

4.1-3 Conclusion

The dentist having defined his prosthesis, the software knowing the volume of the pre shapes indicates which pre shape to place (1, 2 or3) so that the dentist can launch the manufacturing. It frees the post as the process is automatic. Some interventions can help control his work.

4.2 Manufacturing

The manufacturing must be divided, in its study, into two distinct parts which are:

- digital command
- tool machine

If the first element insures the positioning of the brooch, the control of the movement and of the speed (and other things), the second element is an executive organ. In the first case, it will be a question of studying the functioning choice whereas in the second case, it will be more the quality in a larger sense of the execution of the work.

4.2-1 The digital command

4.2-1.1 Definition

As we have summarised previously, a digital command insures the control of the position and of the speed of movement of the mobile parts of the machine. It insures as well a certain number of accessory chores of the manufacturing cycle enabling for example the lubrication and change of tool.

Traditionally, it is composed of:

- an instruction of the programs and their stocking zone
- a system of data treatment and amplification of the movement's command
- a certain number of control of the quality of order's execution organs
- management of the annex program, as the tool change

The digital command receives a manufacturing program under a coded form (APT, CP/M…) completed with specific manufacturing, reference for the control captors and logical signals for the peripherals signals.

It analyses the manufacturing program it receives from EUCLID and organises the values into functional categories (sizes, speed, tools, flipping…). It doesn't have to take into account the manufacturing parameters as they have already been prepared (generation of movement depending on the BEZIERS surfaces respecting the geometrics of the tool). It has to queue them, the thus prepared values so they are executed according to a logical sequence with the data necessary to a good execution.

The first function of the digital command action is the creation of the movement of each tool depending on the known position in space of the tool and the pre shape. This step is realised with EUCLID. The second function of the command, at the CN card level, is the coordination of the axes of the machine to execute the movement addressed to the calculator. After having prepared the data (treatment logic), the program is directed towards the interpolators.

They elaborate the movement the axes will have to follow. Whether we use a spatial linear or circular interpolation, is calculated at each moment the projection of a point running on the axes. This function is insured at the CN by PRODYS card level. The third function, executed here again on a PRODYS card, called of power, is the analogue digital transformation of the data by the variations which address a tension to each engine to rotate their axes, thus moving the tool and the brooch in space.

Next to these movement functions, cohabits a logical step (automate function) treating:

- the piloting of the tool-carrier
- the management of the speed of rotation of the brooches
- the command of the fixation of the brooch
- the security functions of the machine
- the lubrication command

The equipment is composed of a material part and a software part:

- the material is presented as a multiprocessor calculator whose elements are as follow:
    - a central treatment unit with microprocessor which is charged to interpret and realise the different operations (unit of treatment and zone of stock)
    - interface modules which elaborate the logical signals from the axes interfaces
    - an automate processor programmable (logical step)

All of this must communicate by buses. The program is placed on an electronic support or a dead memory PROM-ERROM, programmable and dependant of the central unit.

4.2-1.2 History

CAD's history, that is to say computer assister design, outside BERNARD's pre studies (CECN) in 1982 and DIMNEZ's (Ecole Centrale) at the same time, first goes through a bibliographic optimisation research. Rapidly, we admit that we must reorganise the modelling values at the CAD level (CAD/CAM). We had two possibilities as we wrote in 1982.

"We admit at this moment that the theoretical sizes of a crown are obtained and stocked. To go to the study to the manufacturing part, several methods are possible:

a) in MATRA's EUCLID system, an interface program exists "insuring the automatic transcription of an EUCLID geometry to a labelled geometry "PAT", "COMPACT", "PROMO", … which we still have to choose (DATAVISION). It is possible also, that in the same system, we use an interactive preparing the manufacturing and visualising to control the tools' movements; it is possible to automatically get orders of tool movements.

b) in the CATIA system, the principal is the same: "CAITA", with its third function, is the preparation tool of the manufacturing by digital command of the geometrical elements archived in the database. The preparer in front of the interactive graphic console, describes the movement of the drill or selects the geometrical movements on which the drill will be based. He defines the shape of the tool (spherical, toric, cylindrical) the type of manufacture (3 axes or 5 axes) and the necessary technological data."

After a few tries in MATRA's military manufacturing branch, we decide in November 1982 to call on outside help, that is to say a CNC of ICN system in Chambéry. The principal was to point a group of 400 points spread on 26 levels of cut, that is to say a precision in x, y of 250µ and in z of 500µ. The program was introduced manually from a theoretical tooth modelled in EUCLID on a cassette placed in the ICN "synthesis" console (figure 76). This command was presented at the GARANCIERE in 1983, before being abandoned for MOCN from KUHLMANN for reasons both financial and technical.

From 1984 (January) until November 1985, an extremely thorough study is done with the aim of associating KUHLMANN's micro drill, the FPK8 digital command and the CAM part of EUCLID. Moreover and in parallel, we pushed this German company to develop a specific model for dental surgery. This is how was presented on November 25th 1985 at the ADF, a tool machine capable of realising a crown. To get there, we first had to work on a digitalisation table and manually enter the theoretical teeth's dimensions then to establish an EUCLID/KUHLMANN connection and finally EUCLID's instructions from the digital step instructions and the logical step (figure 77).

From May 1986, we had to abandon totally the KUHLMANN solution for numerous reasons:

- price too high of the micro drill and its command
- no effort from KUHLMANN to go from 2 ½ axes to 3 axes
- scientific communication too difficult

For this reason, we established a complete specifications book and accepted the proposition of ETS LAMBERT. It obliged us to find a new digital command. Accidentally, M. CHIARAMELLA met HENNSON and enabled us to develop a digital command specific to our application (today the PRODYS company) part of the OCE group).

This digital command has three successive evolutions:

- application of the CN PRODYS on KUHLMANN
- creation of a prototype CN on LAMBERT's machine
- incorporation of a compact CN card

4.2-1.3 Generation of digital and logical functions

We have two working steps on the information issued from the external and internal modelling of the prosthesis. The first information is compact and structured by EUCLID when the second will be at CN by PRODYS level.

4.2-1.3.1 EUCLID work for digital command

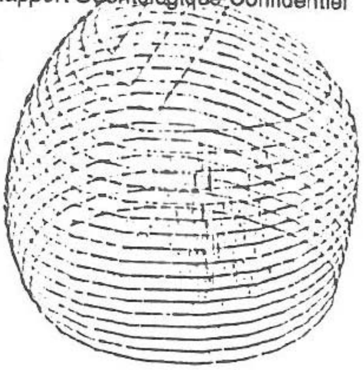
The prosthesis being known by the computer, all there is left to do, in theory, is manufacture it. However, the necessary treatment to get from modelling of the crown to the generation of the manufacturing commands, brings forward the parameters linked to "PRODYS" digital command's know-how, the fixation mode of the material to be manufactured, the characteristics of the tools used and the manufacturing mode…

The "DIGITAL COMMAND" application has for aim to take in charge the realisation of a dental crown, on a digital command unit, from a tri dimensional shape generated on a CAD system. Firstly, an EUCLID application enables the calculation, in the prosthesis space, of the whole of the tools movements corresponding to the chosen range.

a) Tool movement function (figure 78):

This function insures the generation of tools movements, initial step in the manufacturing process of a crown. When CAD launches this function, there is acquisition of the EUCLID CAM, the extrados, the intrados, the finishing line and the predefined range for each crown.

- the extrados is defined by the figure of the spline B channels describers constituting each crown
- the intrados given under a polyedric shape (surface) where each point being on the outside of the finishing line is brought back to an inferior altitude at the z minimum of this finishing line
- the finishing line which is presented in the shape of a broken line. This final manufacturing uses a sketch of 0.5mm by 1.5mm high, a semi finish of about 12 movements and the last movement on the tangent line
- the furrows: they are underlined as we have described in CAD at a constant depth for each pass. It was also possible to create sketches by progressive over manufacturing and generate furrows and facets at different depths.



SECTION NUMERO 4 SUREPAISSEUR 0.00

POINT NUMERO	1	X =	1.43208	Y =	0.09771	Z =	-0.32480
POINT NUMERO	2	X =	1.47239	Y =	-0.03849	Z =	-0.32482
POINT NUMERO	3	X =	1.54654	Y =	-0.14045	Z =	-0.32481
POINT NUMERO	4	X =	1.64448	Y =	-0.20727	Z =	-0.32480
POINT NUMERO	5	X =	1.75752	Y =	-0.23679	Z =	-0.32480
POINT NUMERO	6	X =	1.87423	Y =	-0.23033	Z =	-0.32480
POINT NUMERO	7	X =	1.98557	Y =	-0.19006	Z =	-0.32480
POINT NUMERO	8	X =	2.08213	Y =	-0.11948	Z =	-0.32480
POINT NUMERO	9	X =	2.15527	Y =	-0.02340	Z =	-0.32480
POINT NUMERO	10	X =	2.19637	Y =	0.09211	Z =	-0.32481
POINT NUMERO	11	X =	2.19708	Y =	0.21902	Z =	-0.32481
POINT NUMERO	12	X =	2.15205	Y =	0.35027	Z =	-0.32482
POINT NUMERO	13	X =	2.04019	Y =	0.50496	Z =	-0.32480
POINT NUMERO	14	X =	[illegible]	Y =	0.61491	Z =	-0.32480
POINT NUMERO	15	X =	[illegible]	Y =	0.68935	Z =	-0.32482
POINT NUMERO	16	X =	1.72403	Y =	0.72258	Z =	-0.32481
POINT NUMERO	17	X =	1.63927	Y =	0.72591	Z =	-0.32480
POINT NUMERO	18	X =	1.56339	Y =	0.70243	Z =	-0.32480
POINT NUMERO	19	X =	1.50010	Y =	0.65731	Z =	-0.32480
POINT NUMERO	20	X =	1.45160	Y =	0.57733	Z =	-0.32480
POINT NUMERO	21	X =	1.42147	Y =	0.45562	Z =	-0.32482
POINT NUMERO	22	X =	1.41305	Y =	0.29549	Z =	-0.32480

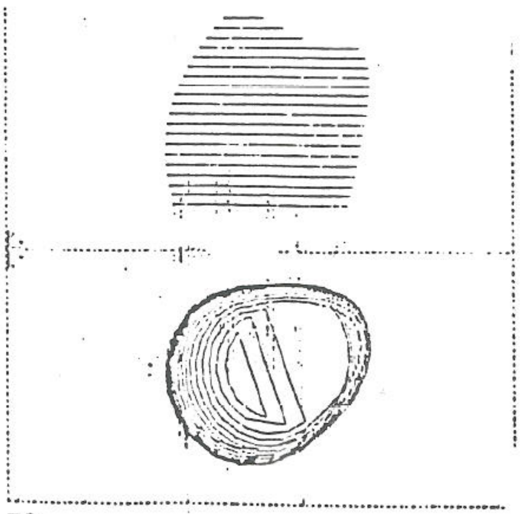
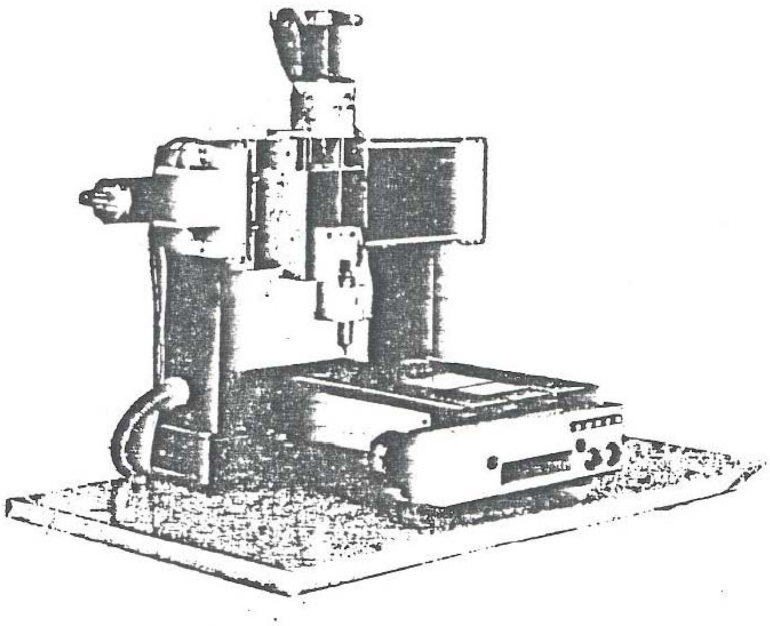


Figure 76

GARANCIERE 1983 (M.O.)



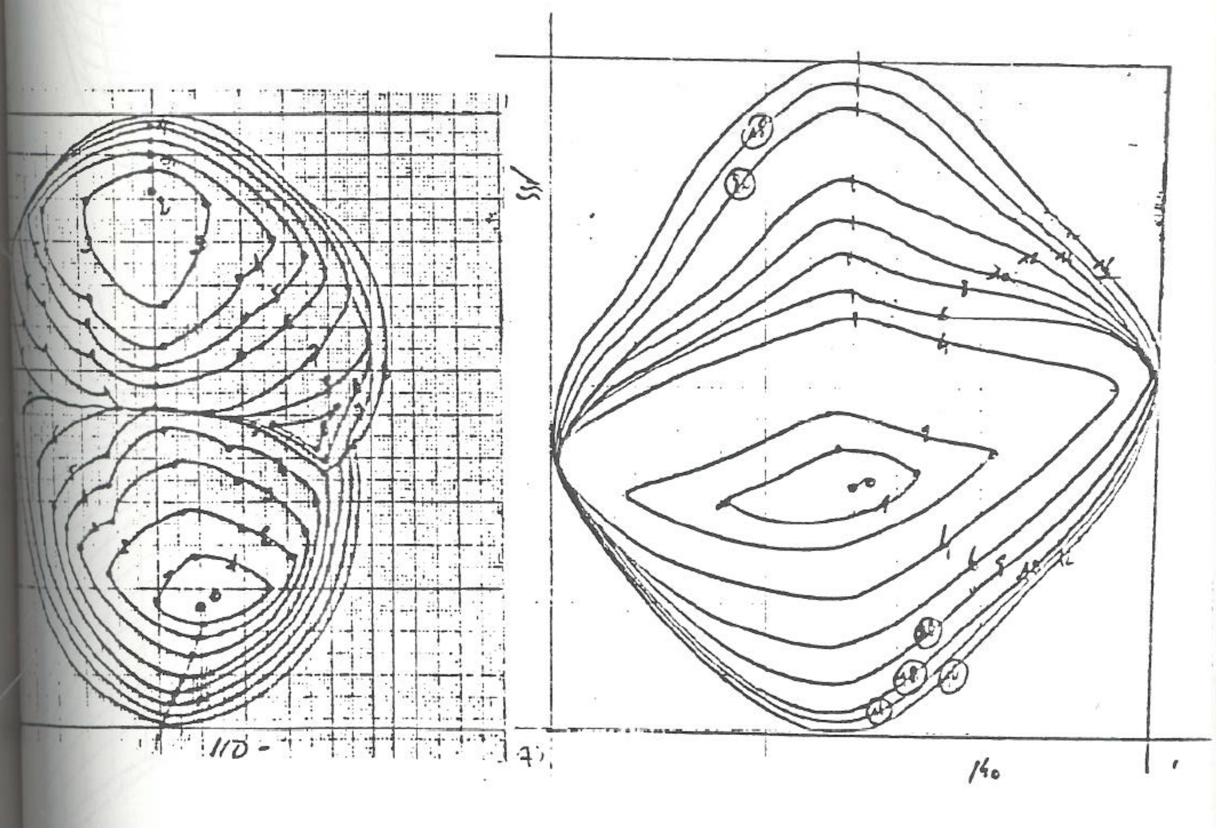


Figure 77

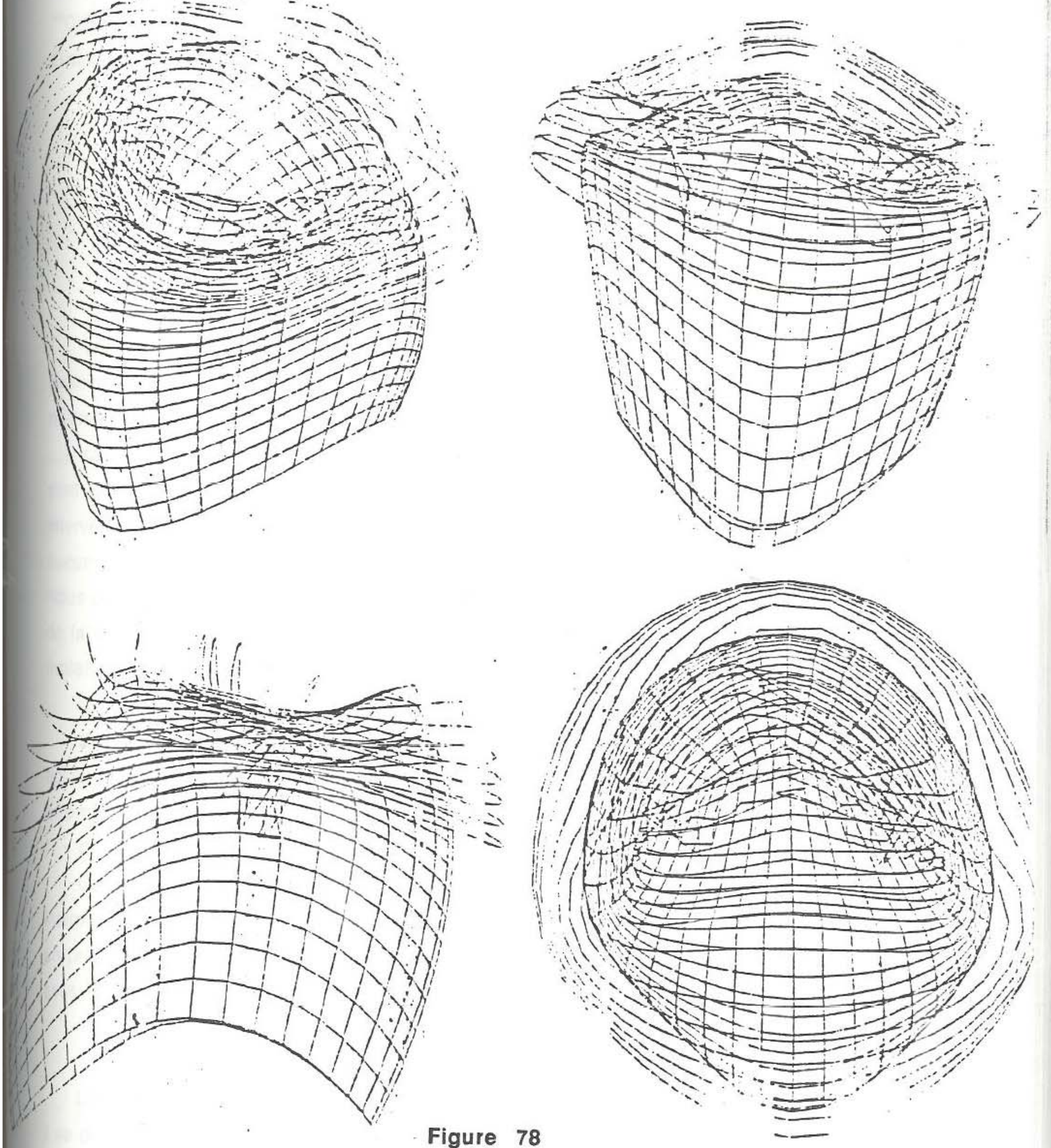


Figure 78

b) Gamm function

Even though they are totally transparent to the user, let's remind the principals of the determination of the Gamm (symbols). The name entered by the user when the manufacturing starts must correspond to a "DAT" fie which is found in the "DK$BIBLI" directory. This file contains all the code names of all the tools to use during the manufacturing of a crown. The first letter of the code indicates the nature of the considered tool:

- 'P' for pointing tool
- 'F' for drill
- 'C' for cylindrical drill (or conic)
- 'S' for spherical drill
- 'T' for toric drill
- 'I' for pointy conic drill (i.e. "flame")
- 'O' for hole rectification knife

The last three alpha-numeric characters of the code are different. We will take for example the diameter of the tool; thus a C400 code designates a cylindrical drill of 4mm diameter (figure 79). The nature of each tool (spherical, cylindrical, …), its own function (bowl manufacturing, intrados manufacturing, …) as well as the order in which the tools are used are unchangeable parameters on which the user can't and mustn't tried to apply change or suppression or addition of a new tool in the initially defined range. We give as annexed figures the example of the calculation of a manufacturing movement for a premolar. In the same way, we can see the manufacturing of a crown or the occlusal surface of a molar 'figure 80, 81, 82).

c) GEO function

After this double action, movement and gamm, is the GEO function which generates an extension sequential file where the movements of each tool are stocked. This file is automatically created and used as a data file for the post-processor.

d) Post-processor function

This program does a translation of the GEO file in DAT file directly interpretable by the digital command unit and addressed to an asynchronic line thanks to a pilot program. The file is still sequential but only understands data in the "character" form (ASC III).

4.2-1.3.2 PRODYS card work

The PRODYS step has for aim to transcribe into analogue the orders from thepost-processor. It is divided in one level called "RL 1" with an exit/RS 232 module and a CN programming in 6809 assembler.

EXEMPLE DE FICHIER DE GAMME


```
-----------------------------------------------------------------------
 OUTIL !          NATURE           ! DIAMETRE !       FONCTION        ! No !
-----------------------------------------------------------------------
F001    ! OUTIL A POINTER           !          !                        !  1 !
-----------------------------------------------------------------------
F650    ! FORET                     ! D= 650   ! AVANT-TROU             !  2 !
-----------------------------------------------------------------------
C400    ! FRAISE CYLINDRIQUE        ! D= 400   ! EBAUCHE                !  3 !
   33   ! Altitude du voile en % de ZMAX-ZMIN a partir de ZMIN         !    !
  100   ! Epaisseur du voile        !          !                        !    !
  500   ! Dx de degagement: distance de l'avant-trou a l'ebauche       !    !
-----------------------------------------------------------------------
S500    ! FRAISE SPHERIQUE          ! D= 500   ! EBAUCHE / FINITION     !  4 !
   10   ! Nombre de passes 3 axes sur le bol au dessus du voile        !    !
    5   ! Nombre de passes 2 axes sur le bol au dessus du voile        !    !
    5   ! Nombre de passes 3 axes sur la surface occlusale             !    !
    5   ! Nombre de passes 3 axes sur le bol en dessous du voile       !    !
    5   ! Nombre de passes 2 axes sur le bol en dessous du voile       !    !
-----------------------------------------------------------------------
S140    ! FRAISE SPHERIQUE          ! D= 140   ! FINITION OCCLUSALE     !  5 !
   10   ! Nombre de passes 3 axes sur la surface occlusale             !    !
-----------------------------------------------------------------------
I001    ! OUTIL POINTU              ! D=   0   ! FINITION DU SILLON     !  6 !
-----------------------------------------------------------------------
T400    ! FRAISE TORIQUE            ! D= 400   ! FINITION DU BOL        !  7 !
    5   ! Nombre de passes 2 axes sur le bol au dessus du voile        !    !
    5   ! Nombre de passes 2 axes sur le bol en dessous du voile       !    !
-----------------------------------------------------------------------
P002    ! OUTIL A POINTER           !          !                        !  8 !
-----------------------------------------------------------------------
F200    ! FORET                     ! D= 200   ! AVANT-TROU  INTRADOS   !  9 !
-----------------------------------------------------------------------
D200    ! COUTEAU                   ! D= 200   ! FOND INTRADOS          ! 10 !
-----------------------------------------------------------------------
C142    ! FRAISE CONIQUE            ! D= 142   ! USINAGE INTRADOS       ! 11 !
   50   ! Nombre de passes 2 axes d'usinage de l'intrados              !    !
-----------------------------------------------------------------------
S230    ! FRAISE SPHERIQUE          ! D= 230   ! DEGAGEMENT FINAL       ! 12 !
    5   ! Nombre de passes 2 axes de degagement de la couronne         !    !
  100   ! Largeur des deux ergots finaux !                              !    !
-----------------------------------------------------------------------

FORET DE DIAMETRE 200
-----------------------------------------------------------------------
  200   ! DIAMETRE
 1526   ! HAUTEUR DE MONTAGE DANS LA BROCHE.
   50   ! VITESSE D'AVANCE
   30   ! VITESSE DE COUPE


COUTEAU DE DIAMETRE 200
-----------------------------------------------------------------------
 2065   ! HAUTEUR DE MONTAGE DANS LA BROCHE
   50   ! VITESSE D'AVANCE
   30   ! VITESSE DE COUPE


FRAISE CONIQUE DE DIAMETRE 142
-----------------------------------------------------------------------
  142   ! DIAMETRE
 1766   ! HAUTEUR DE MONTAGE DANS LA BROCHE
   50   ! VITESSE D'AVANCE
   30   ! VITESSE DE COUPE


FRAISE SPHERIQUE DE DIAMETRE 230
-----------------------------------------------------------------------
  230   ! DIAMETRE
    0   ! HAUTEUR DE MONTAGE DANS LA BROCHE
   50   ! VITESSE D'AVANCE
   30   ! VITESSE DE COUPE
```

Figure 79

LA GAMME D'OUTILS

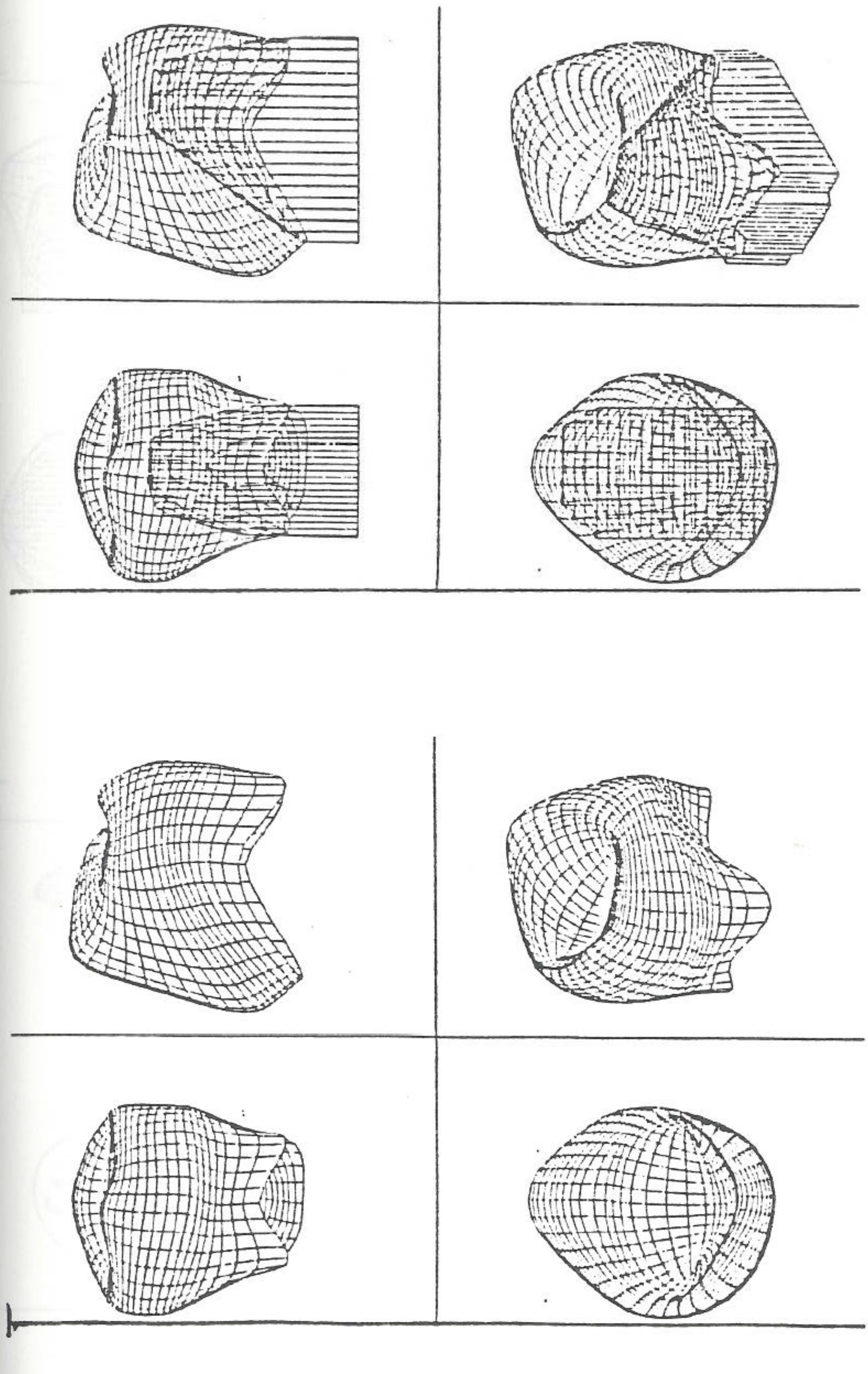


Figure 80

TRAJETS SUR PM (Intrados)

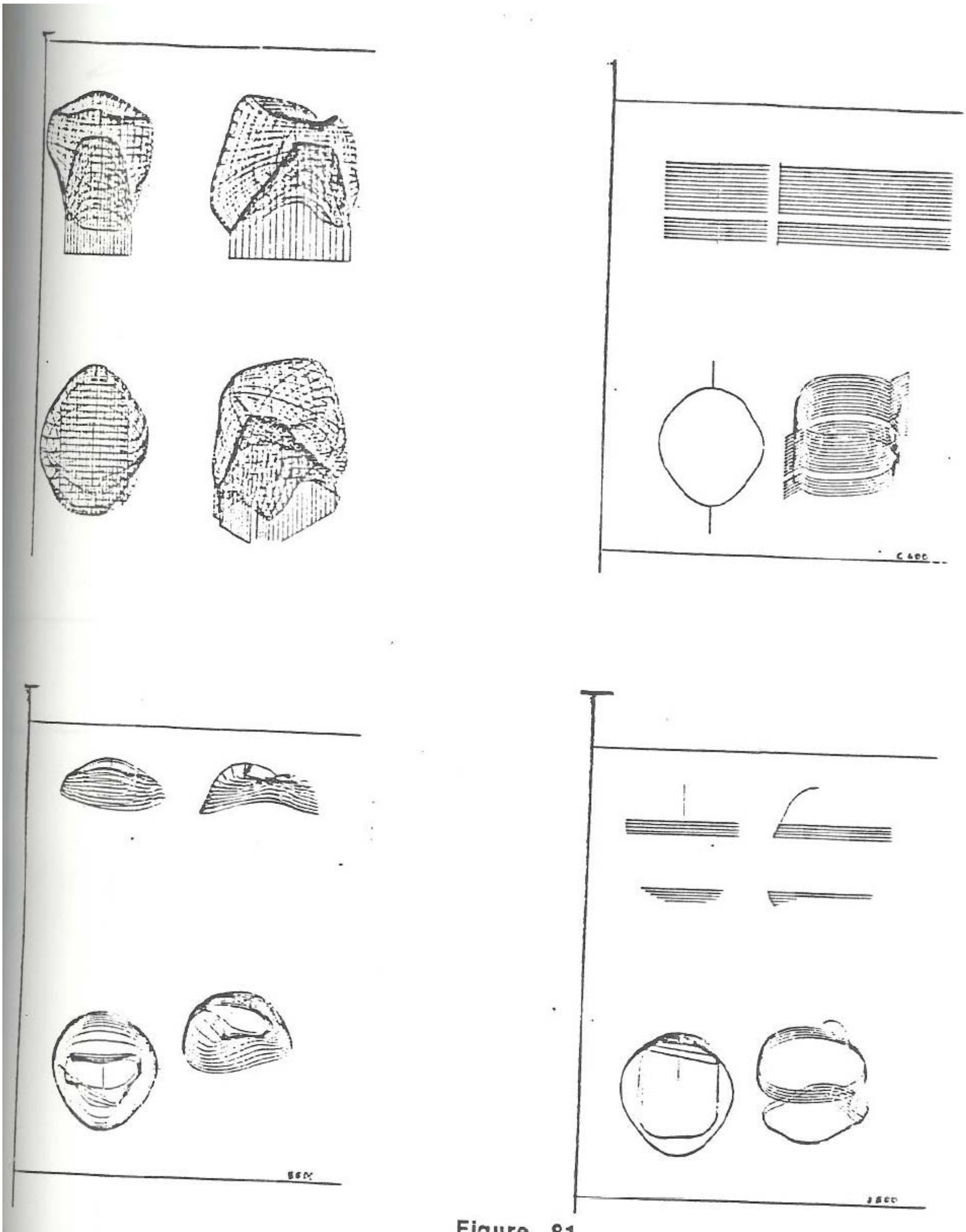


Figure 81

TRAJETS SUR PM (Extrados)

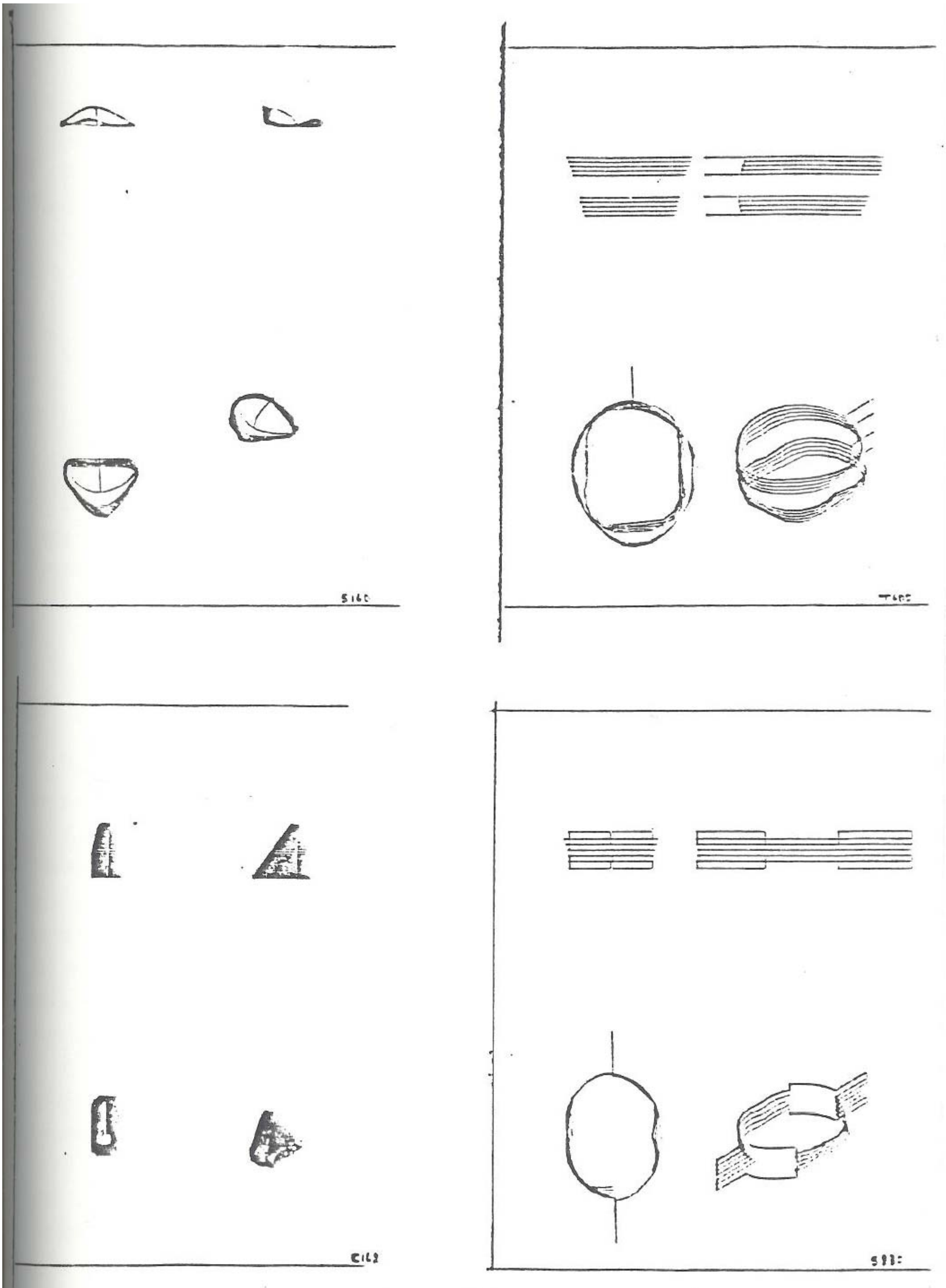


Figure B2

TRAJETS SUR PM (Extrados)

ANNEXE 1

Rapport Odontologique Confidentiel

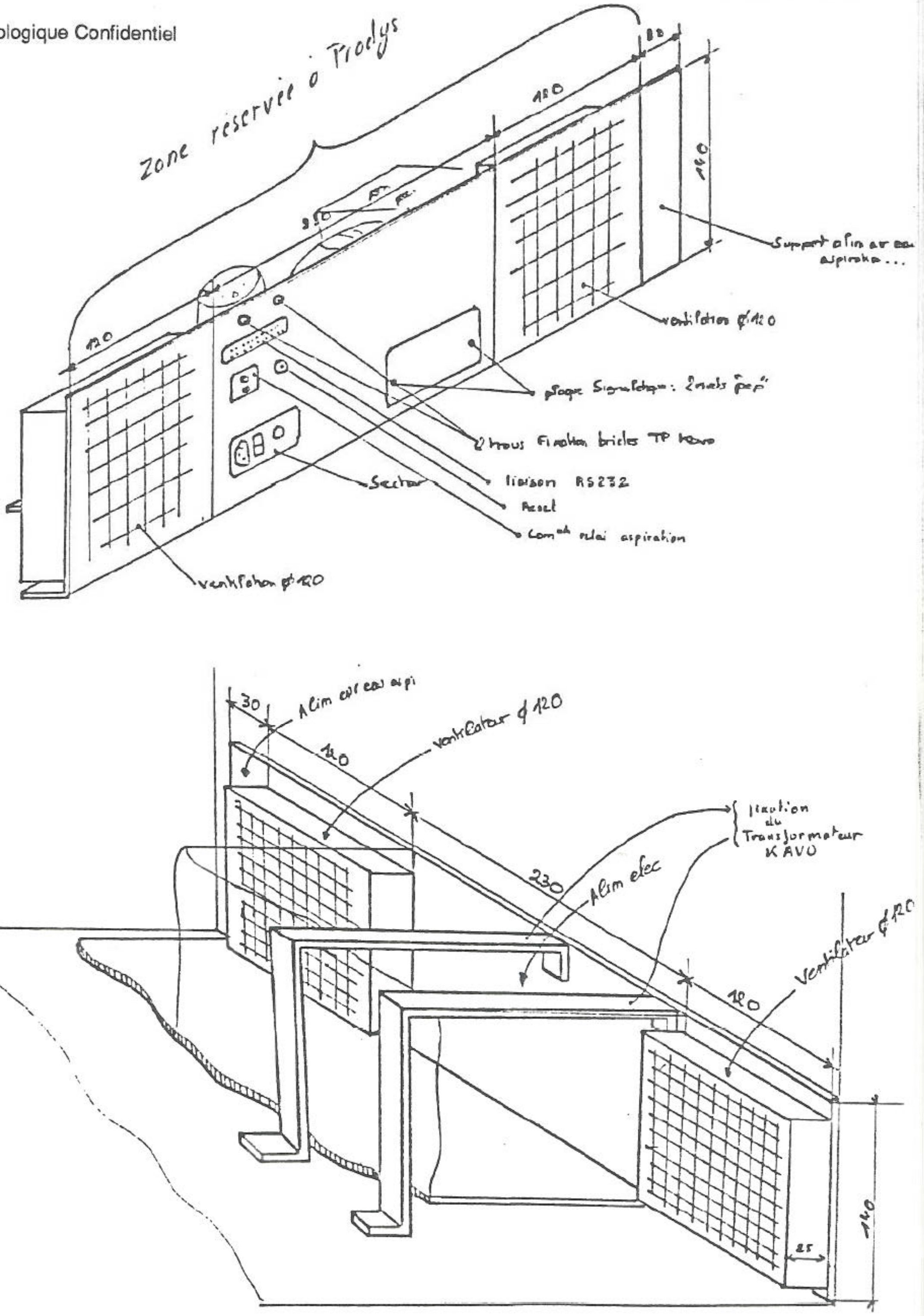


Figure 83

ZONES DE CARTES PRODYS ET KAVO

The RL 1 step is composed of 5 modules which can only work separately. We find the interpolation function, the tool change function, the flipping function, the setting function and the E/S function.

After exiting the interface system, there is an RS 232 link leading to an order interpreter.

The CN step is successively composed of:

- orders interpreter
- memorisation
- orders executer giving on an interpolation movement road and a "speed" road
- frequency generator (D/A conversion)
- amplifier on engine

and the Kavo card.

The brooch of the tool machine must be linked to the PRODYS card by the intermediary of the frequency changer to control, from the PRODYS car, the speed of the engine in synchronisation with the brooch (the KAVO card provides the 12V – 100mA energy).

Both cards are integrated to the tool machine (PRODYS and KAVO) (figure 83).

4.2-2 The tool machine

4.2-2.1 Definition

A digital command tool machine is a mechanical ensemble where each of the mobile parts is under the control of a digital calculator. It can only function if previously the manufacturing program has been correctly established. A tool machine, in dental prosthesis, is composed of three axes (x, y and z) and of a fourth to flip the piece to enable the manufacturing of the intrados. Moreover, other engines are use to move the tool magazine. Each axis can be butted and the tools are checked before being used on a micro sensor. The unit is composed of axes movers (engines), links and slides, position sensors, movement axes and a brooch.

a) there are 5 engines (three axes, one for flipping and one for the tools magazine). They are step by step engines. To avoid shakes we interpose between the power command and the engine a frequency variation. This engine works in all or nothing, for each inflexion (variable frequency) a rotor constituted of a magnet is orientated by a giant stator creating a field depending on the courant it is receiving. The engines can have up to 800 steps per round and their speed depends on the commutation of the spools frequency.

b) movers and slides: under the form of marbles screws (marbles along a never ending screw), they enable a transmission of the engine's movement to the unit's axes. This avoids shaking and prejudicial rubbing, a good functioning of the engine step by step which has a low torque.

c) the axes spread in space according to the Cartesian marking , there are four in the HENNSON unit. Three axes x, y and z are movements leading to the movement of the drill around the tooth and a fourth axis insures the rotation of the pre shape (called auxiliary rotation movement).

d) the annex functions for the lubrication and the evacuation insure a good realisation of the prosthetic piece.

4.2-2.2 History

Numerous drills have been tried, before was decided by HENNSON the construction of a specific machine. In 1983 the work started on the MUTAN 2000 by ETECMA. As we define it in our article in 1985, this machine has the following characteristics (figure 84):

- course 150 x 200 x 100 mm
- precision 2, Card 400: 25µ
- brooch speed: 1 to 10 for an engine power of 0.75Kw and a cylindrical drill of 4.5mm diameter

During the same period, after the GARANCIERE where we have presented ou study with the MUTAN 2000, we had met several manufacturers:

- CORTINI L 303 with its micro digital command and its 4 servomotor axes (abandoned for difficulties we had to communicate with Italy)
- The NEW HERMES CONCEPT 2000 unfortunately 2 axes, essentially an engraving machine
- The LIMOGE, precision too archaic in its conception
- The KUHLMANN

We chose the last one in January 1984 without knowing exactly its performances. To know better the qualities of this machine, we decided after a journey to Germany to buy the 20T with its digital command ITT 3030. This machine uses a KAVO brooch (which we still use) with a rotation of 15 000 to 60 000t/m, advancing speed of 80MM/sec, working field of 400 x 400 mm and a 20µ resolution. This machine has enabled us to work on the first manufacturing of a premolar during the 1985 summer (reception in April 1985). In September 1985, we received the definitive dental model or "20T", a lot more compact which enabled us to do the ADF demonstrations in Chambéry, Luxembourg and Marseille. Even though it was rather satisfying, we abandoned it because:

- it was too expensive

- it worked with 2 12 axes and the third was complex to add (digital command level)
- the contacts in Germany were often difficult

For these reasons, in January 1986, we decided to manufacture a specifically dental unit with ETS LAMBERT. From this date HENNSON only had one subcontractor. (5 av. Duchesne – 26102 VALENCE).

4.2-2.3 Dental tool machine

We can divide the unit into several parts:

- the mechanical part
- the hood
- the engines
- the brooch
- the aspiration system
- the lubrication system
- the utilisation mode

4.2-2.3.1 Mechanical part

a) digitalised axes:

Three axes are materialised as follows:

- horizontal x table, longitudinal 130mm
- vertical y table, longitudinal 80mm
- horizontal z table, transversal 70mm

The tables are guided by crossed rolls tracks, size 3, type SHNEEBERGER. They are commanded by marble screws with rectified fillets with nuts of 10mm diameter.

b) a material holder (figure 86, 87)

There are three pre shapes defined in their geometry (4 at the start). Two coaxial clips manually manoeuvred have the function of positioning and securing the pre shape.

c) Two fixed dolls

A left motor doll representing the fourth motorised axis by an indexer of step by step engine type identical to the axes' engines. A free doll on the right.

d) A tool holder (figure 88)

It is composed of a removable disc which has 12 manufacturing tools with characteristics defined later and an indexer step by step engine identical to the axes' engine.

This tool holder presents a hole for holding the tool in position, in front the brooch.

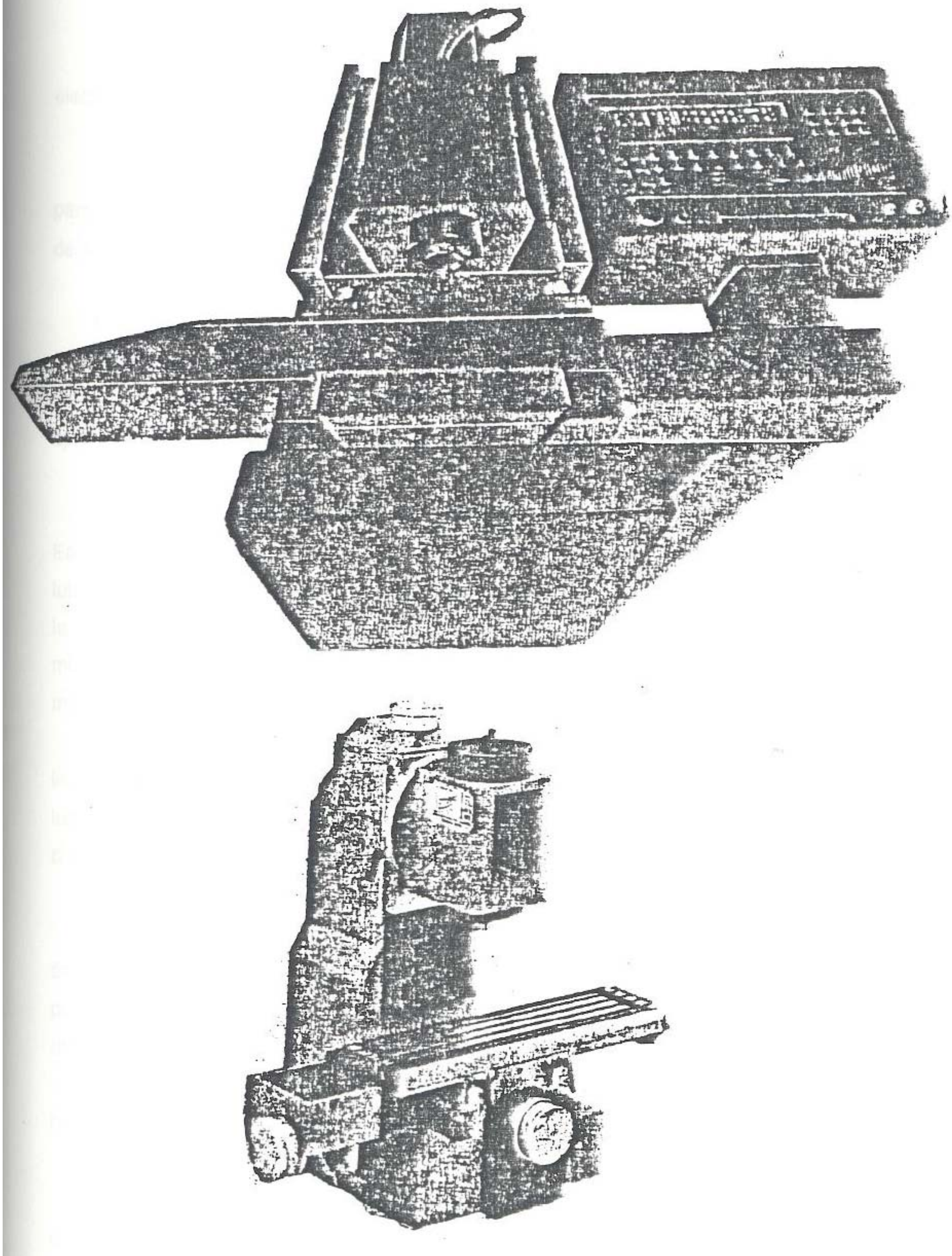


Figure 84

MACHINE-OUTIL ETECMA ET CORTINI

e) The unit's engine mounting (figure85)

Moulded piece and very rigid (heavy) which insures the reach of mechanical, electrical and digital command parts.

f) A median plan with bellow

It enables the partitioning of the unit between the active part (manufacturing, tool use) and the engine and digital command part. It enables the protection to material projections of the precision part.

g) Electrobrooch (figure 89)

We have kept KAVO's 4051 brooch with tool capture and automatic change (pneumatic) of 100W. It can function up to 5000 hours

h) Lubrication

A triple study has been led to determine the most optimal lubrication solution. Firstly, specifications defining the reason for this lubrication were done. This led to the following observations. The manufacturing of the new material destined to the dental CAD/CAM necessitates lubrication in order to get the best cut and minimum effort, a better longevity of the tool, cooling of the tool and of the material, a better state of the surface, evacuation of the chips and the calories.

To insure this lubrication, we have devised a system of pulverisation of liquid air, to optimise the cutting conditions and the consumption. This lubrication is composed of two parts: a liquid and air pulverisation and a system of automatic lubrication liquid alimentation.

i) Pulverisation

Two concentric hoses form the pulverisation base. This base is fixed on the brooch's nose in order to insure permanent lubrication of the tool/piece contact point. This pulverisation is insured by two concentric hoses and two electro valves. The used pressures are around 1 bar for air and 0,2 bars for liquids.

The hoses' diameters are 3mm external and 2.5mm internal diameter for air and for liquid 1.2mm external and 1mm internal diameter for liquid.

j) Automatic alimentation system

The lubrication liquid is composed of two elements: water and additive (cut oil developed specially for dental CAD/CAM by SPAD). We have tried to automate the functions necessary for the lubrication with a minimum of manual interventions. The functions to be automated:

- mixing both products (for 1 litre of water: concentration 4% additive)
- permanent arrival of the mixture towards the pulverisation system with a permanent pressure

- permanent arrival of water in mixing bowl

The only manual intervention for the practioner is changing the additive flask.

This enables the definition:

For the four prototypes

1) 8% concentration additive
2) 5 L/hour mixture
3) 5 to 6 crowns per day
4) 40 mn pulverisation for one manufacturing cycle of a crown, on average

With these elements, we have a global daily consumption of 25 litres of mixture (23 litres of water and 2 litres of additive). Isn't it more interesting, currently, to forecast a simple tank (25 to 30 litres) under pressure (0.2 to 0.8 bars) to insure the necessary daily lubrication? Every morning, we do the only manual intervention which is filling the tank.

For the series, we have defined the following points:

We can redo other bids invitations for our lubrication system, after a longer trial period, a better knowledge of the lubricant and after a complete determination of all the parameters in a more rigorous way depending on the manufacturing tests (material, lubricant, flow, time, pressure, etc…). SPAD Company has implemented a lubricant corresponding to their material. This obliges this company to know exactly the manufacturing conditions, the cutting speeds and movement speeds and the state of the obtained cuts. After the pre series realised between January and March 1987 (we were obliged to wait for the arrival of the definite material), we have done the correlative trial tests between the state of the surface and the lubricant's composition. The experiments have enabled us to define a product optimising the surface state and limiting the tool's wear. This product has the advantage of being conditioned in 2 litres containers changed at the end of every two weeks for 40 elements.

k) Waste receptacle and aspiration

A chip recuperation device, with opening at the front and closed at the back with a supple rubber enabling the brooch's movements, is installed around both dolls. At its base is an aspiration orifice to drain maximum waste.

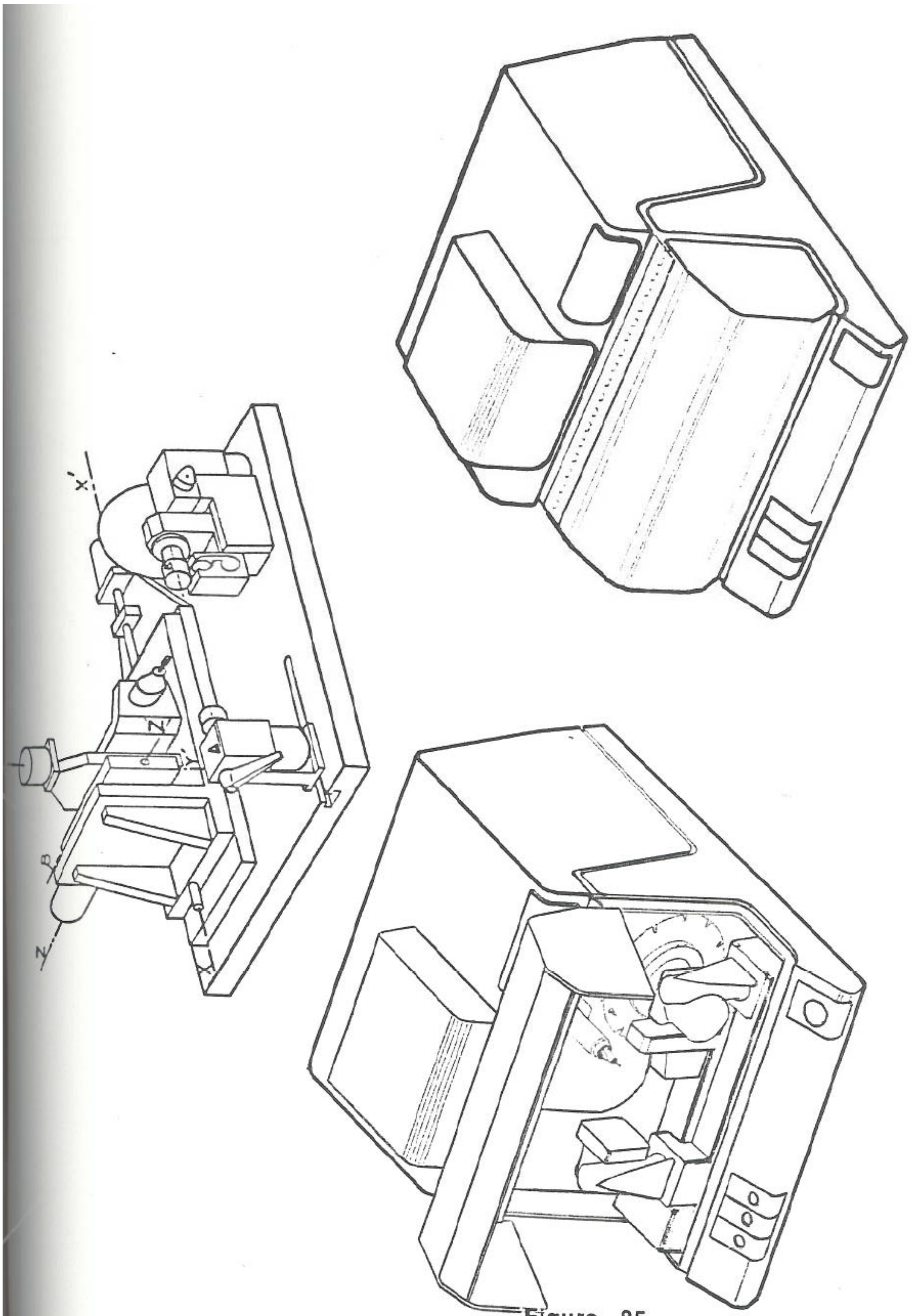


Figure 85

LA PARTIE MECANIQUE

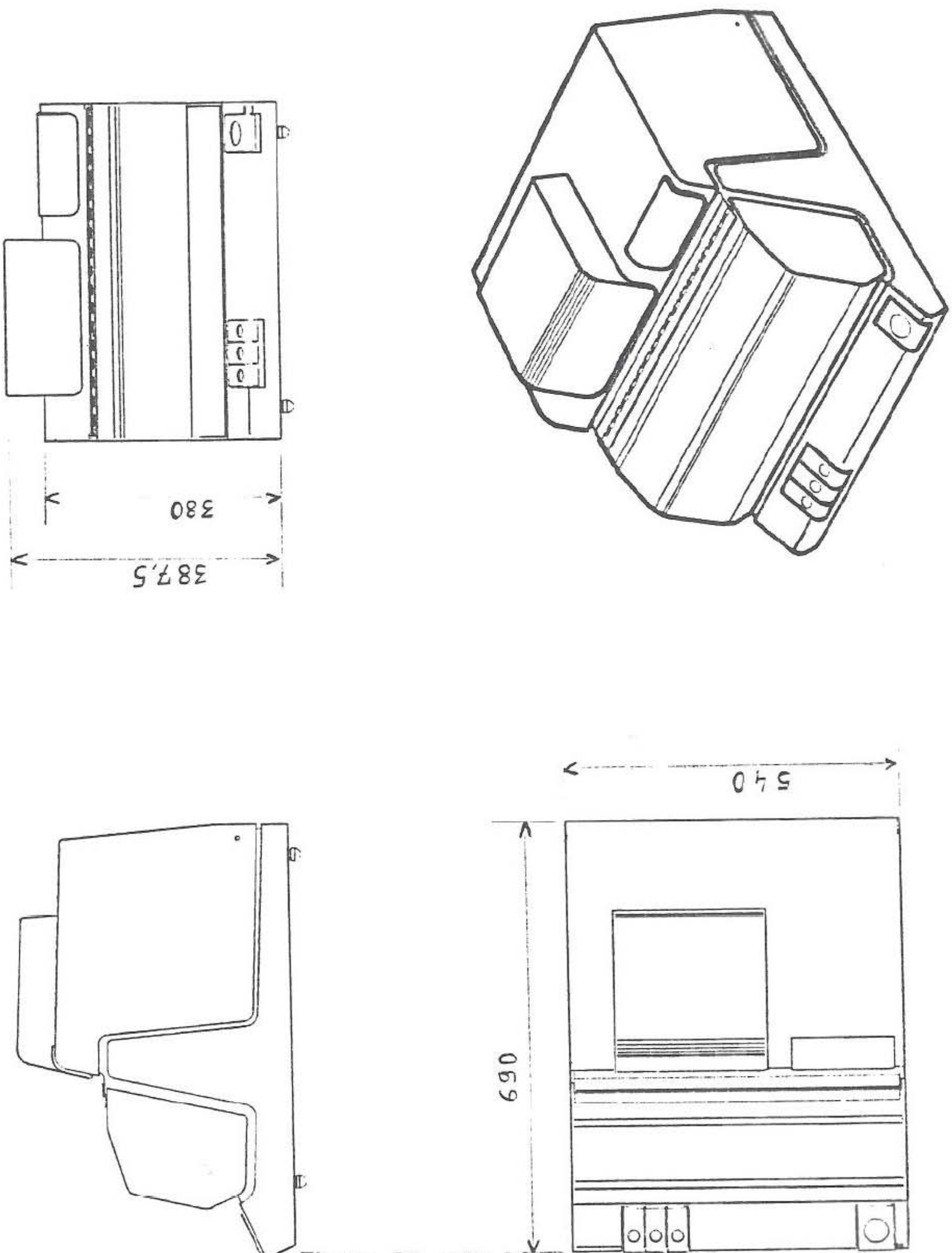


Figure 85 suite

LA PARTIE MECANIQUE

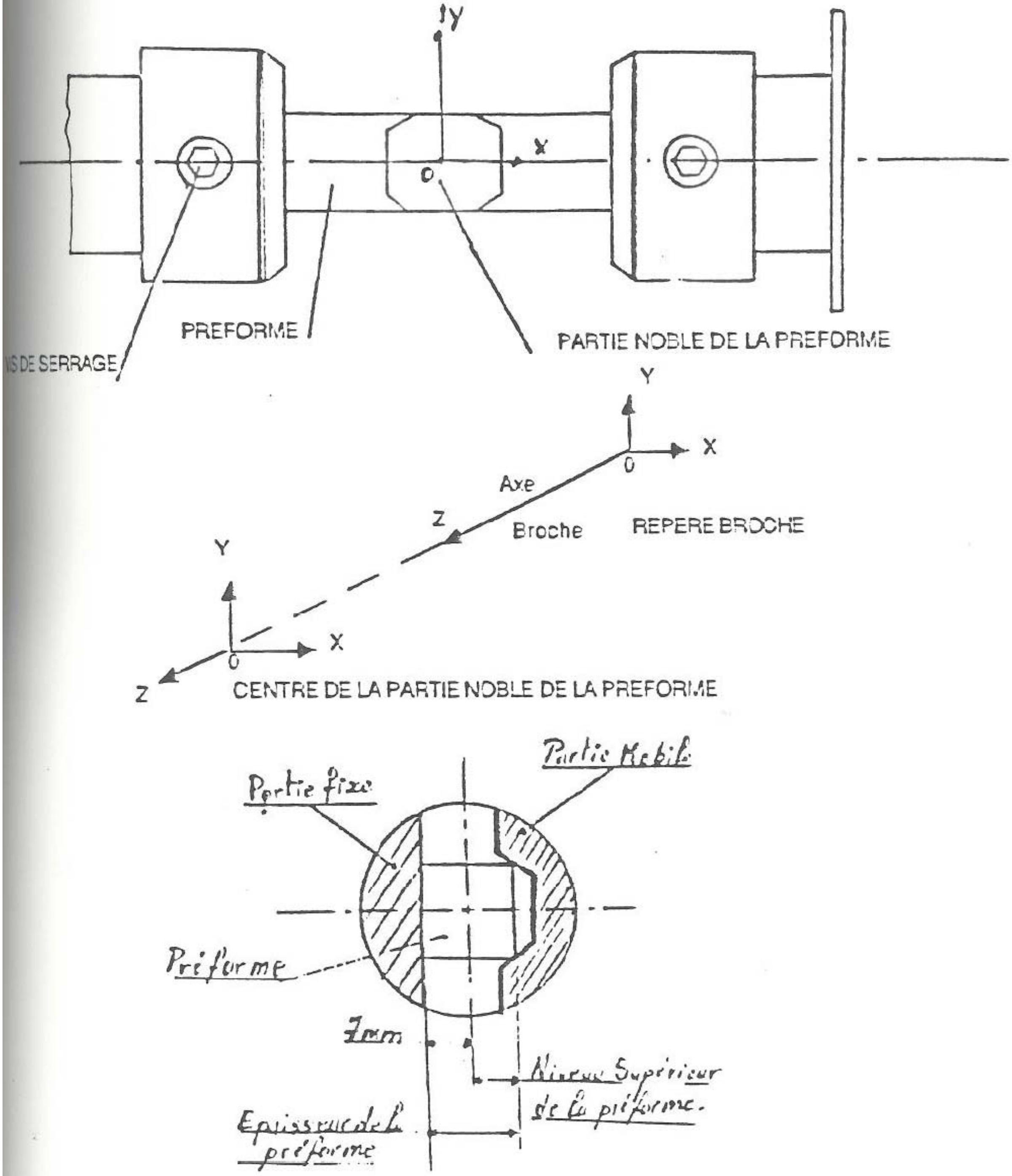


Figure 86

LA PARTIE MATIERE

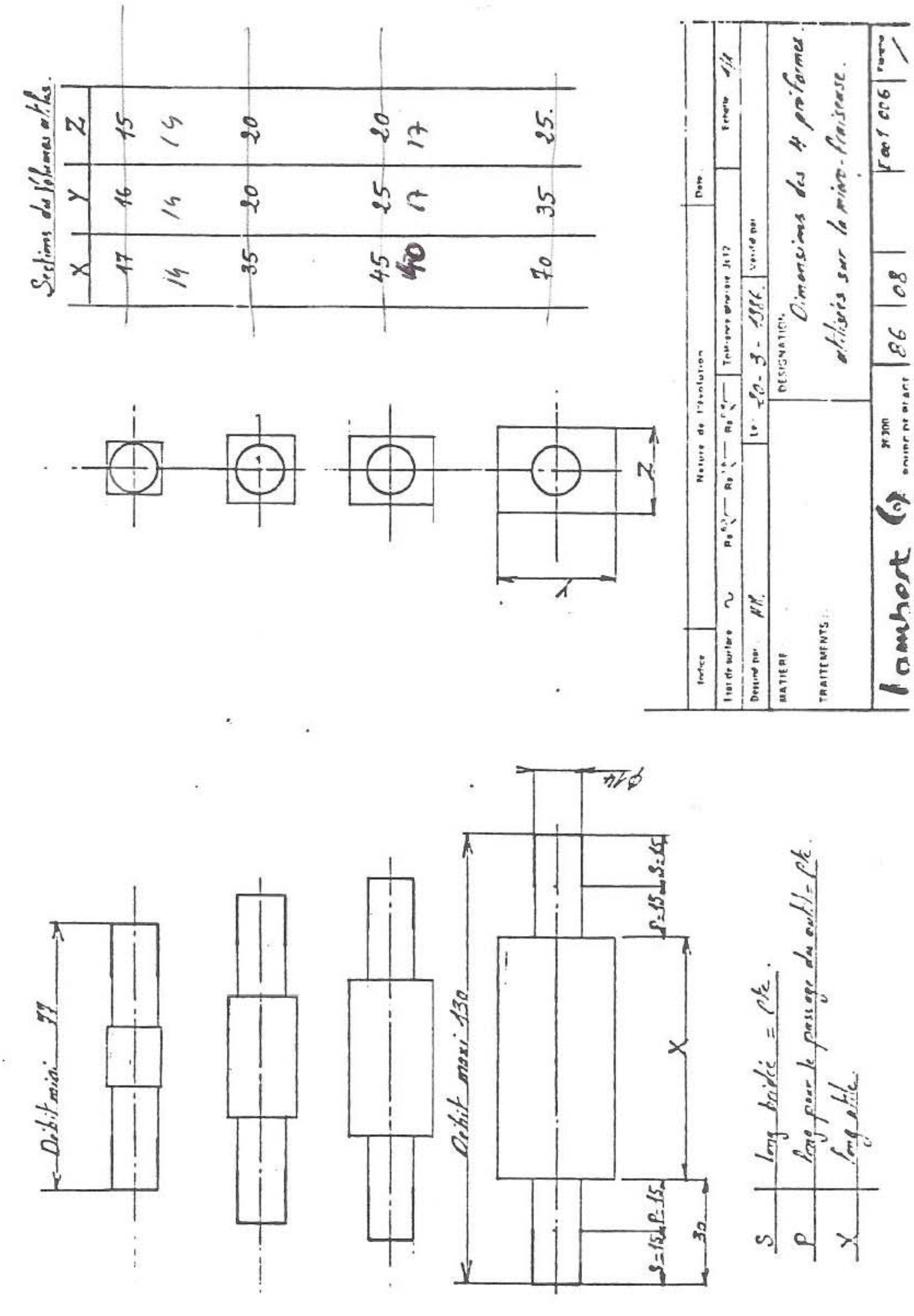


Figure 87

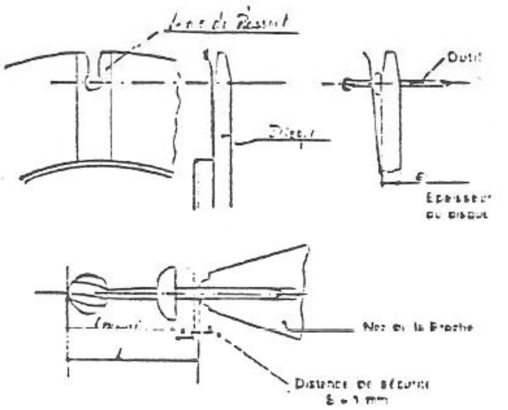
LES PREFORMES
(seules les 3 premières sont retenues)

Station	Code	Diam.	Prof. de passe	LONGUEUR L d'outil	Vitesse d'avance	Vitesse de coupe		Forme
1	C40A	400	25	2200	100	1		Cyl
(1')	C41A	400	25	2200	70	60		Cyl
2	S31A	310	/	1700	80	60		Sph
(2')	S32A	310	/	1700	60	80		Sph
3	S12A	120		1700	80	60		Sph
4	S06A	60	/	1700	80	60		Sph
5	ID1A	/	/	1700	60	80		Pointu
6	T40A	400 120	/	1700	150	1		Torique
7	F15A	150	/	1500	20	100		Forêt
8	C12A	120	/	1700	60	5		Conique

LES UNITEES DE LA MACHINE :

- Base de mesure : 1/100 mm ; 1 mm = 100
- Base de temps : 1/10 s : 0,1 s

EXPLICATIONS DE LA TOUCHE "7"



POSITION DES OUTILS SUR LE DISQUE

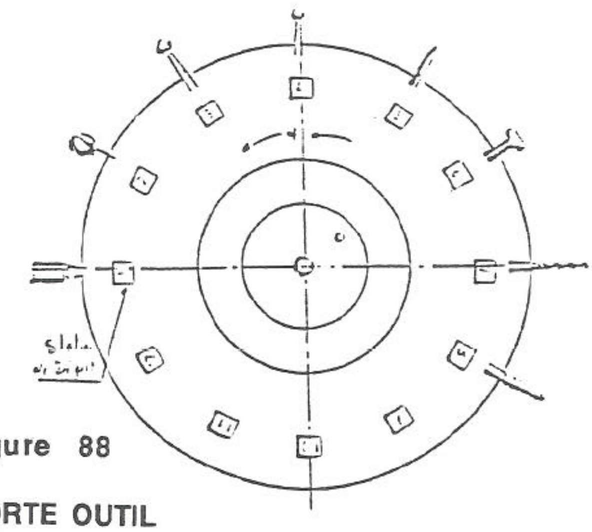


Figure 88

LE PORTE OUTIL

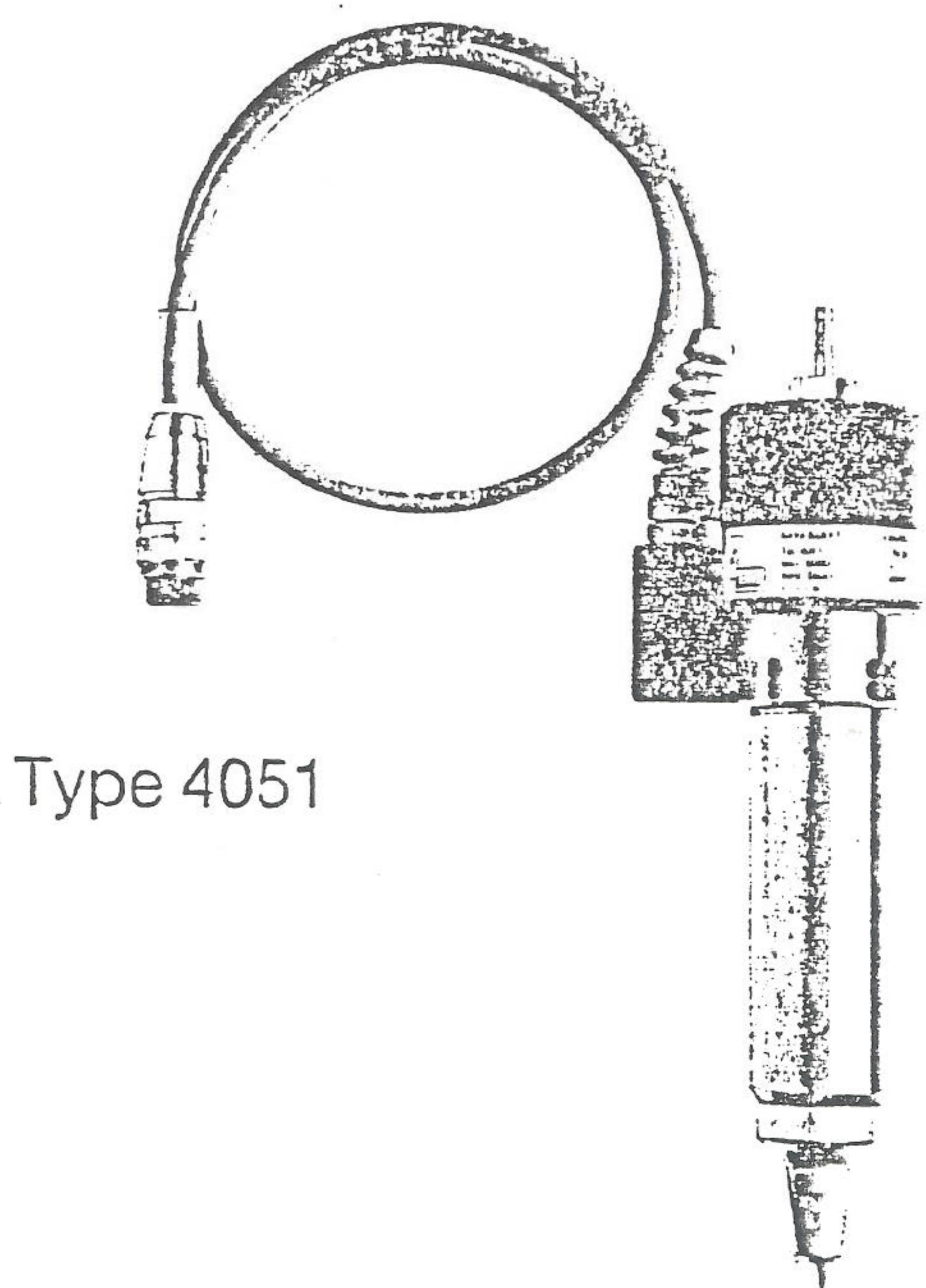


Figure 89

LA BROCHE

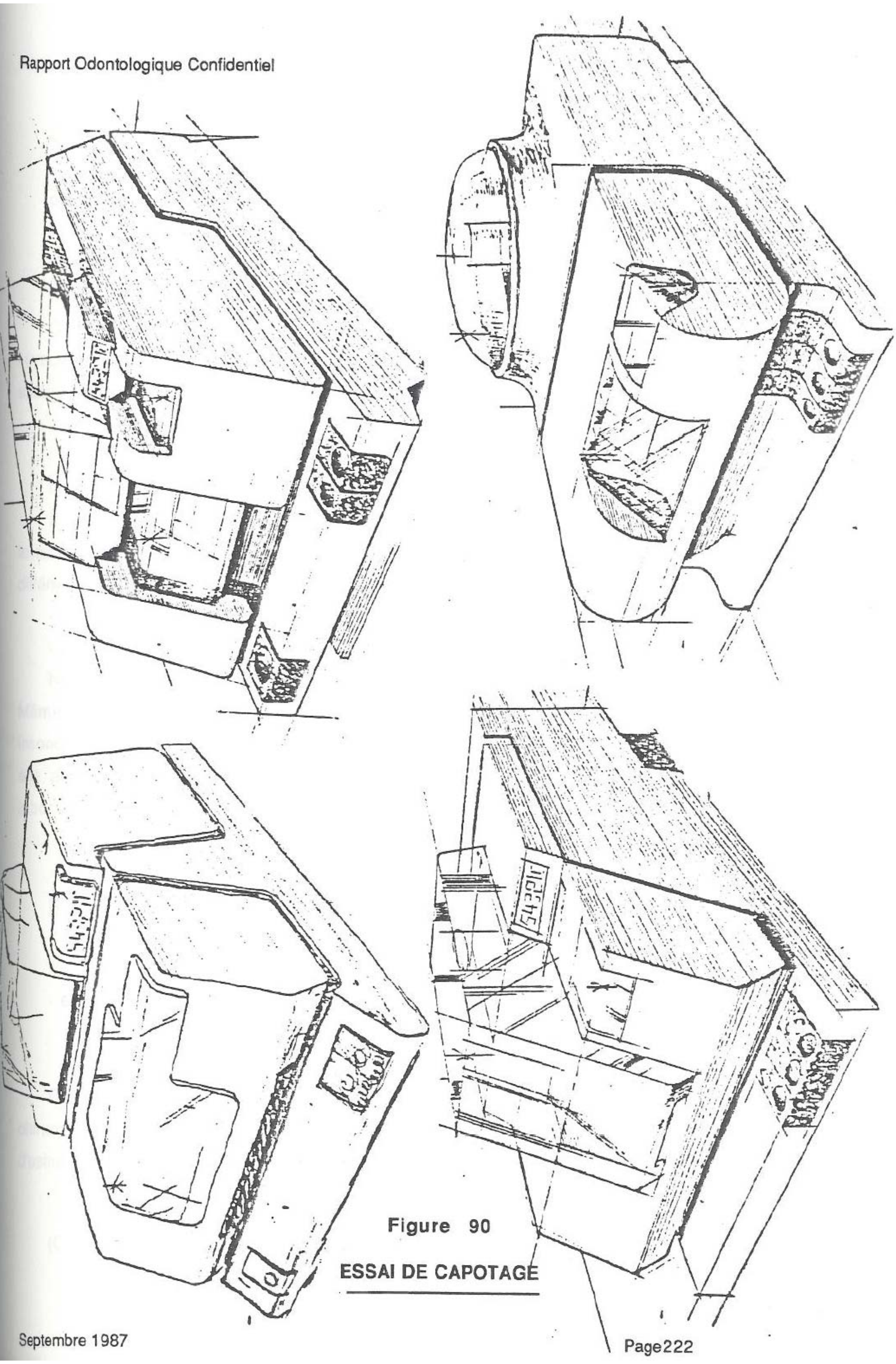


Figure 90

ESSAI DE CAPOTAGE

Evacuation by gravity isn't enough because:

- the evacuation orifice of the receptacle has a diameter of 12mm; moreover, there is a cross to keep the pieces in
- the horizontal hose under the machine facilitates chips depot inside the hose
- lubrication is under pressure and the evacuation flow by gravity through the receptacle orifice is very low

That is why an aspiration of the manufacturing waste is necessary to improve the evacuation and eliminate the depot risk. This aspiration is commanded by the CN to insure a simple and unique function. We use:

- either a classic system installed if it exists in the practice or laboratory
- or in the other case, we install a classic aspiration engine

l) Body

It is the object of an extremely in depth study, in order to integrate the tool machine in a dental practice context (figure 90). Two designers not from the company have offered different solutions for the body.

- ITECA (IZEAUX)
- J M J LEMAIRE

We have chosen the SYNTH solution, replacing the front body by a complete window. Even if the installation of the back fan increases the general functioning noise, a general soundproofing enables the integration of the set in a practice. This soundproofing has also been the subject of a study enabling the integration in a practice or laboratory.

4.2-2.3.2 Electrical part

We successively find:

- digital command + current
- 5 step by step engines
- KAVO electronics

4.2-2.4 Handling

Outside the fixation of the pre shape and the control and replacement of the tools, the dental surgeon has no work to do. The automatic functioning is the manufacturing of a manufacturing file existing in the Microvax under the name:

Nom du fichier ● GEO ; xx

(these files are in the "GEO" directory)

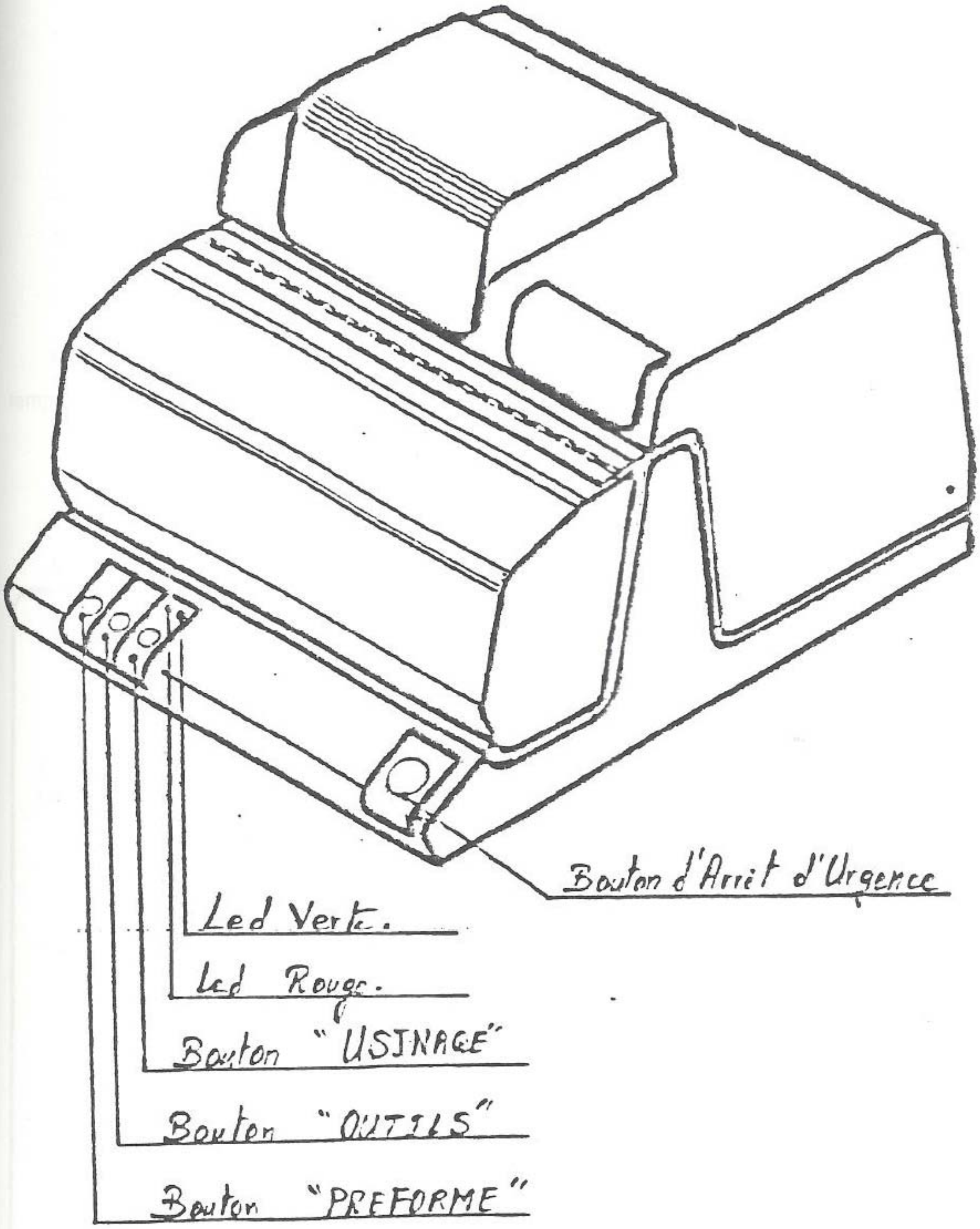


Figure 91

LA BOUTONS D'ACTION DE LA M.O.

We must follow the following protocol (figure 92):

- Check on the tool machine that:

- the brooch is empty and its clip is open
- the receptacle membrane is properly placed and the central ring opposite the brooch
- the disc is correctly placed
- the tools are correctly mounted and in their place on the disc (see next chapter)
- the pre shape is installed correctly and energetically fixed (the noble part opposite the brooch)
- the tightening keys not on the mandrins
- the bodies closed

Note: in the "tools" table, the measuring base is 1/100mm : 1mm = 100 and the time base is 1/10s : 0.1s

The buttons have for function:

- the big red one is emergency stop
- the three little ones are manufacturing, tools and pre shape

The following table summarises the role of each button:

	ON THE TOOL MACHINE
Momentary stops the manufacturing happening, the wait is done at the end of a tool cycle	Press on the MANUFACTURING button (at the end of the tool cycle, if the button was already pressed, the green LED turns off and the red one lights up)
If this momentary stop is asked (red LED lit up, green LED off) It is possible to:	
- move the tool disc one station per action (counter clockwise)	Activate the TOOLS button
- move the pre shape to see the manufacturing already done 30° per action (rotation towards the outside)	Activate the PRE SHAPE button
Start again and carry on with the current manufacturing	Press the MANUFACTURING button (the disc comes back in place, the pre shape too, the red LED turns off and the green LED lights up and the manufacturing starts again

4.3 Precision of micro drill

4 parameters influence the machine's precision.

- geometrical precision of axes (the relative position of the views with regards to the others (statistical elements))
- precision of the movements (quality of screws, minimum increment, dynamic elements)
- deformations linked to the manufacturing
- temperature

4.3-1 Geometric precision

Linked to the conception, the rigidity of the elements, to the geometrical precision, the machine with its architecture can never pretend to better then ± 5µ in its axes' geometrical positioning, because:

- the conception tolerance of the ± 5µ chariots partly recoverable by a very precise mounting of the machine
- control and alignment means within a 5µ span (to get better, we need huge precautions by comparison to the product, air conditioned white room, …)
- the quality of the materials used which can deform in time, 5µ but recoverable in part by initialisations of the machine

Consequences:

We can't do better than ± 5µ tolerance but this error corresponds to a translation in space of the shape to be reproduced and can in some cases be considered as inexistent.

The final error should be, on the tooth: divided by 2

$$\Delta_{géo} = \pm\ 2{,}5\ \mu m \text{ pour } \underline{\underline{\text{une dent}}}$$

It's a systematic error.

4.3-2 Movement precision

- **quality of screw**

Two cases are seen to situate this problem:

Positioning error of a screw rectified with regards to a rolled screw.

This error can go from an e_c value (unknown) ± 6µ to an e'_c value ± 52µ for the rolled screw.

The e_c or e'_c values are to be determined by the user as they differ from one screw to another even is the screws are in the same precision class.

Rigorously, the minimum error possible on a screw will be

$\Delta_{vis} \pm 2{,}5\ \mu m$ knowing that vPU = 5µ

The actual error is $\pm\ 17{,}5\ \mu m + e_c$ (inconnu)

- **Deformation of origins**

The origins definition probe is reproducible at ± 1µ, knowing that it acts on a 33% slope, the reproducibility changes to ± 3µ:

$$\Rightarrow \Delta_{origine} = \pm 3\ \mu m$$

- **Minimum increment**

Today, it is 6.25µ: size of the 2.5µ screw with one round = 400 steps (200 x 2).

For the series machine, it will be 25µ as the screw's step will be 2mm and one round corresponds to 800 steps (200 x 4).

$$\Rightarrow \Delta_{incrément} = \pm 2{,}5\ \mu m$$

Consequences, the error on precision of the movements will be:

$$\Rightarrow \Delta_{mouvement} = \pm 2{,}5\ \mu m$$

It won't be lower than ± 2.5µ in the current state of things.

4.3-3 Deformation linked to manufacturing

Errors linked to the manufacturing have three origins:

- tool flexion
- machine flexion
- brooch fake rotation round

- **Tool flexion**

For a 500g charge, the tool flexion is:

If L = 18mm

For: Ø 2.35mm F = 10µ

For: Ø 3 mm F = 27µ

- **Machine flexion**

Machine flexions are at a level of 1 to 2µ for a comparable effort.

- **Brooch's fake rotation round**

The brooch's fake rotation round is 0.0.5µ for the KAVO brooch. It can be 0.005µ with a brooch such as Brammer.

Being finished, these different errors should contradict each other or completely cancel each other out. The accumulation of these errors shouldn't be over Δ_{usi}.

$$\Rightarrow \boxed{\Delta_{usi} = \pm 2{,}5\ \mu m}$$

4.3-4 Temperature

It is the parameter that can generate the greatest error on materials such as ZA12 its impact is of 23µ/°C/m so 0.023µ/°C/mm.

Knowing the course of the axes is around 100mm, the generated error is 1.2µ/°C on the course of an axis, that is to say this error, for 1°C, is the same size as the others.

TABLEAU RECAPITULATIF DE L'IMPACTE DES DIFFERENTS PARAMETRES SUR LA PRECISION DE LA MICRO-FRAISEUSE

		Fraiseuses de séries	Fraiseuses prototypes
Précision Géomérique	Conception des Chariots	5 µ	5 µ
	Moyens de contrôle	5 µ	10 µ
	Qualité des matériaux	5 µ	10 µ
	Valeur Globale pour une dent	± 2,5 µ	± 5 µ
Précision des Mouvements	Qualité des vis	± 2,5 µ	± 17,5 µ
	Définition des origines	± 3 µ	± 3 µ
	Incrément minimum	± 2,5 µ	± 6,25 µ
	Valeur Globale	± 8 µ	± 27 µ
Déformation liées à l'usinage	Flexion de l'outil (500 gr)	10 µ	27 µ
	Flexion de la machine (500 gr)	1 à 2 µ	1 à 2 µ
	Faux rond broche	7 µ	20 µ
	Valeur Globale	± 2,5 µ	± 5 µ
Dilatation Thermique	Coefficient de dilatation	0,023µ/°C/mm	0,012µ/°C/mm
	erreur sur la pièce pour une valeur de"x°C"	x = 5 : 10 µ x = 25 : 50 µ	x = 5 x = 25 : 120 µ
A température constante et pour le volume d'une dent, la précision de la Micro-fraiseuse est :		± 13 µ	± 37 µ

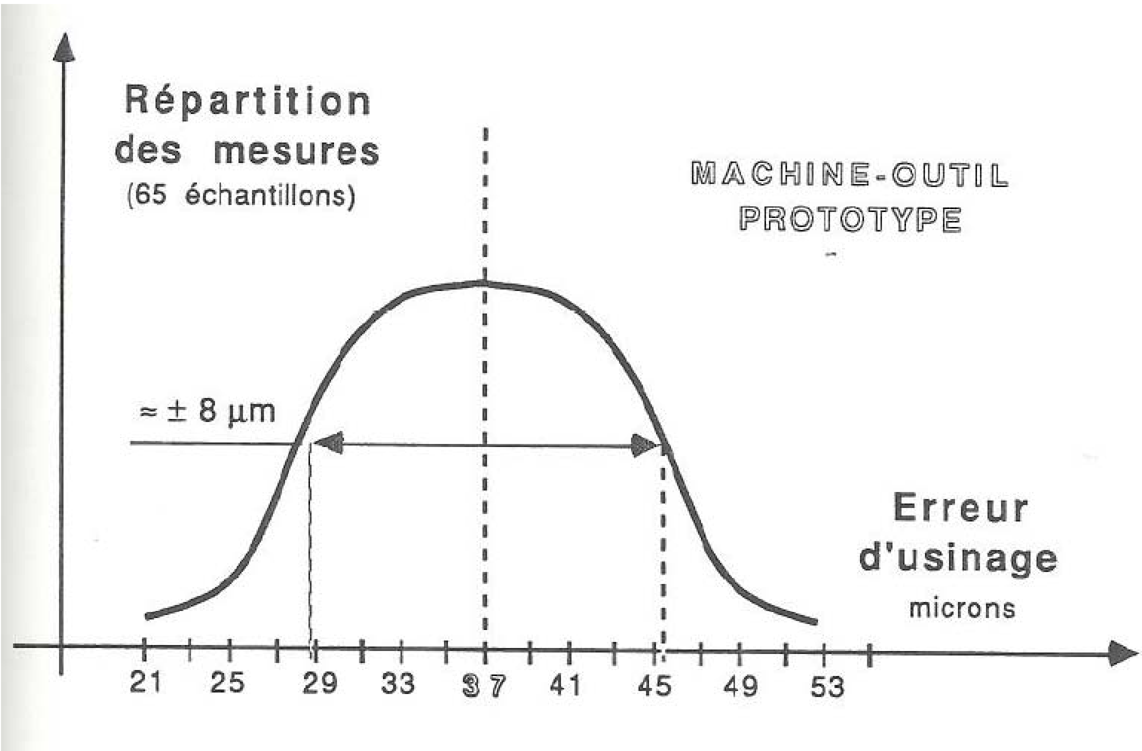
4.4 Conclusion

Outside the instructions about :

- the fixation of the pre shape
- the control and replacement of the tools
- the safety advice
- the interactive functions (4)

The dental surgeon or the prosthodontist have no interventions to make. The handling is extremely simple.

MANUFACTURING ERROR ON THE TOOL MACHINE



5-TOOLS

5.1 History

During four years, from 1983 to 1987, numerous tools have been tried. Let's signal particularly the following companies:

- TRIEFUS
- FFDM – PNEUMAT
- GF – HANSOTTE
- KOMET
- DIAMECA

It was necessary, in the first place, to define the shape of the drill. To do that, several ranges were tried. During the 1985 ADF, we have defined the following tools:

- KOMETT	72	104 050
	H41	104 014
	H46	204 012
	H33R	104 016
	H138E	104 023
	74	104 050

It was necessary to fix a leaning ring on the type of tool (2.37 diameter) in order to have a perfect idea of the position of each tool with regards to the piece to manufacture (figure 92). During 1986, we have devised a manufacturing range for pre molars by changing such or such tool shape. Particularly, in order to get a good surface state, the shape of the tool of the intrados was blocked after numerous tests. The tool were valuable for the teeth.

5.2 Function of each tool (figures 93 to 103)

5.2-1 Cylindrical tools (PLN/0005/MF)

This tool is used for the rough pre shape (preparation and draft). That is why this tool must be robust and must have a very good life span of cutting power, in order to minimise the frequency of tool change, time and manufacturing efforts.

Use conditions:

- rotation speed: 42 000 t/m
- brooch movement speed: 15mm/s
- pass depth: 0.5mm to 1mm

For a crown, this drill runs on average 900mm manufacturing distance. So there is a necessity of rather long life span depending on the tool's wear percentage. This tool doesn't need great precision, just the average h10, h11.

5.2-2 Spherical tools (PLN/0006,7,8/MF)

The whole realisation of a crown and the manufacturing precision will depend on the quality and the precision of these three tools. Each tool has a semi finish phase and a finishing phase. The spherical tool must work as well on the superior part of the sphere. That is why, the shape between the superior cutting part and the tail of the tool must be conical, with a narrowing and on the superior quarter of the sphere to avoid collision between the manufactured piece and the tool's body (figure 95). The manufacturing of these tools must be careful and the precision of the realisation is on two points:

- the spherical shape of the cutting part of the tool
- the manufacturing precision must be around h7 (equivalent to reamers)

Spherical tools run, on a crown, the following distances:

PLN/0006/MF	diam. 3	1480mm
PLN/0007/MF	diam.1,2	400mm
PLN/0008/MF	diam. 0,6	185mm

Use conditions:

- rotation speed: 33 600 t/m
- brooch movement speed: 8mm/s
- pass depth: not controlled (1mm maximum), 3D tool movement

Given the distances ran, the precision and the manufacturing quality asked, it is necessary to do tools of high quality for an important life span.

5.2-3 Sharp tool

The function of this tool resides in its pointy shape. Currently, we keep the elliptic shape, knowing it may be modified (to pointy shape). The distance ran is around 110mm for a crown. The precision and the hardness of this tool must be enough to keep the general shape (h10).

Use conditions:

- rotation speed: 33 600 t/m
- brooch movement speed: 8mm/s
- pass depth: not controlled (0.5mm maximum), 3D tool movement

5.2-4 Toric tools (PLN/0010/MF)

The function of this tool is manufacturing and finish of the counter remains (figure 95). The link between the sharp part and the tail of the tool is the same as the spherical tools. The precision of manufacturing of the tool is the same as the spherical tools (h7).

The distance ran is around 400mm.
Use conditions:

- rotation speed: 42 000 t/m
- brooch movement speed: 15mm/s
- pass depth: very low, not controlled around 0.2mm

5.2-5 The drill

This tool must drill the necessary holes for the manufacturing of the intrados. The only constraint is the tool's life span.
Use conditions:

- rotation speed: 33 600 t/m
- brooch movement speed: 3mm/s

5.2-6 Cylindrical tool with spherical tip (PLN/0011/MF)

The manufacturing of the whole inferior part of the crown is done with this tool (manufacturing of the intrados). It must be precise and robust as it is used both as draft tool and a finishing tool. The precision of this tool must be the same as the other finishing tools (h7), equivalent to the reamers. The distance ran is around 700mm. Given the use rate of this tool and of its precision, it is necessary to have an important quality and life span.
Use conditions:

- rotation speed: 38 300 t/m
- brooch movement speed: 8mm/s
- pass depth: around 0,2mm

Note:

PRECISION TABLE

DIAMETRES	Précision en µ		
	h.7	h.10	h.11
1 à 3	0 - 10	0 - 40	0 - 60
3 à 6	0 - 12	0 - 48	0 - 75

5.3 Composition of tools

5.3-1 Shape

It is defined in "LAMBERT's" drawing (figure 92)

5.3-2 Materials

a) TOOLS MATERIALS

We have studied at least three propositions showing the advantages, inconvenients and conditions in each case, which are:

- tools in mono bloc steel (tungsten carbora)
- tools in rapid steel with titan or nitrure de bore or other coating
- tools in rapid steel with the sharp part in diamond

Note: any other solution to optimise the manufacturing conditions can be envisaged.

b) NUMBER OF TEETH

The mechanical characteristics of the material have not yet been chosen. The number of teeth will be determined by the manufacturer with your collaboration to optimise the conditions and manufacturing time (cutting angle, pass depth, surface state…). They are currently being studied in Bordeaux.

5.3-3 Ring

The mounting height of the tool inside the brooch is determined by a ring fixed on the tool, see "LAMBERT" drawing. The characteristics of the ring:

- superficially hardened material
- the spherical surface is polished
- the quality of the diameter surface depends on the fixation mode of the tool (ex; glueing)

5.4 Manufacturing

The tools are manufactured by the DIAMECA company fro Geneva (the prototypes are being studied)

5.5 Conclusion

After trials by LOUIS, we are able to define the definitive material and the number of teeth for each tool. In the mean time, we know the shape of each tool as well as their dimensions. The practioner will only have to place each tool in its place depending on its number from 1 to 8 (which are known, see drawing). All there is left to do is define the polishing mode currently being studied.

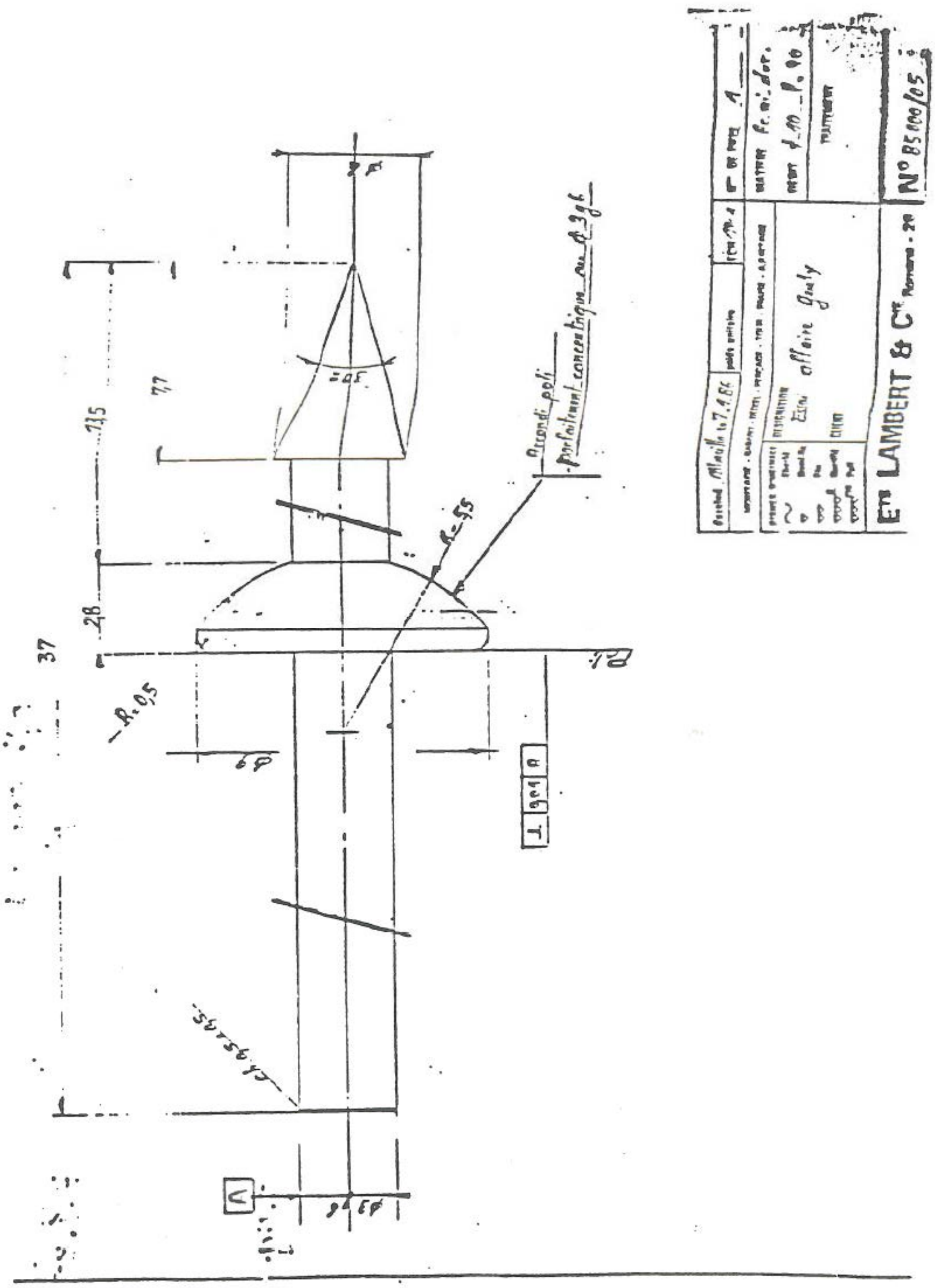


Figure 92

Outils et conditions souhaités.

Tableau 2

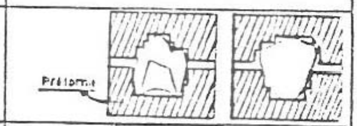
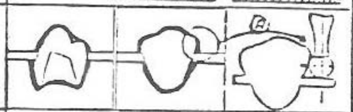
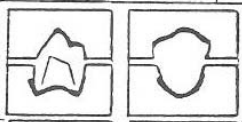
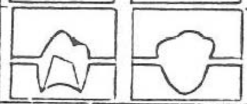
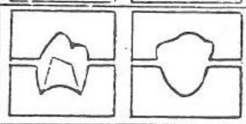
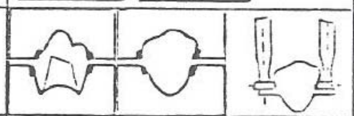
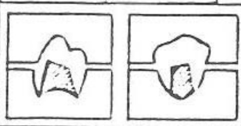
[illegible]	N° PLAN	Diam. partie coupante en mm	Nbre de lèvres	Angle d'hélice	Précision en micron	Vitesse rotation t/mn	Vitesse Avance mm/s	Profondeur de passe en mm.	Dist. d'usinage moyenne en mm.	Fonction	Descriptif
[illegible]	PLN/D003/FF	4	4	30°	h11	40.000	15	0,5 à 1	900	Ebauche	
[illegible]	PLN/D005/FF	3	6	15°	h7	60.000	40	1 maxi	1400	1/2 finition et finition	
[illegible]	PLN/D007/FF	1,2	6	15°	h7	40.000	40	0,5 maxi	400	1/2 finition et finition	
[illegible]	PLN/D008/FF	0,6	6	15°	h7	40.000	40	0,3 maxi	185	1/2 finition et finition	
[illegible]	PLN/D009/FF	elliptique	6	-	h10 ou 11	40.000	40	0,5 maxi	110	finition	
[illegible]	PLN/D010/FF	4 rayon 0,5	diamant ou 8	-	h7	40.000	40	0,3 maxi	400	finition	
[illegible]	PLN/D011/FF	1,5	4	30	h7	40.000	40	0,2	700	finition	

Figure 93

Outils utilisés actuellement — Conditions actuelles

Tableau 1

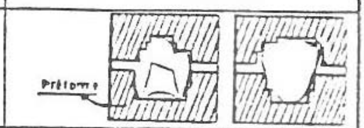
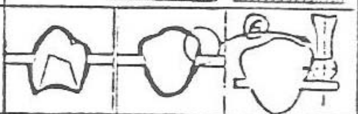
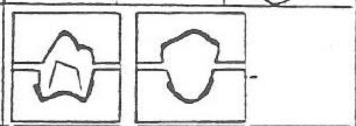
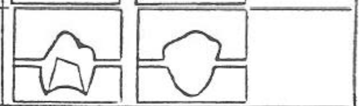
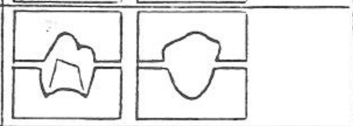
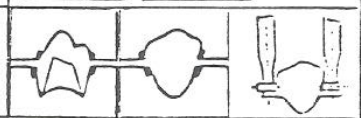
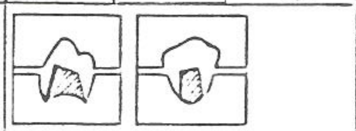
N° PLAN	Diam. partie coupante en mm	Nbre de lèvres	Angle d'hélice	Précision en micron	Vitesse rotation t/mn	Vitesse Avance mm/s	Profondeur passe en mm	Dist. d'usinage moyenne en mm	Fonction	Descriptif
PLN/0005/MF	4	4	30°	h11	47 000	15	0,5 à 1	900	Ebauche	
PLN/0006/MF	3	8	15°		33 600	8	1 maxi	1450	1/2 finition et finition	
PLN/0007/MF	1,2	6	15°		33600	8	0,5 maxi	400	1/2 finition et finition	
PLN/0008/MF	0,8	6	15°		33600	8	0,3 maxi	185	1/2 finition et finition	
PLN/0009/MF	elliptique	lime	droit		33600	8	0,5 maxi	110	finition	
PLN/0010/MF	4 rayon 0,6	Diamant	-		42000	15	0,3 maxi	400	finition	
PLN/0011/MF		lime	30		38[illegible]	8	0,2	700	finition	

Figure 94

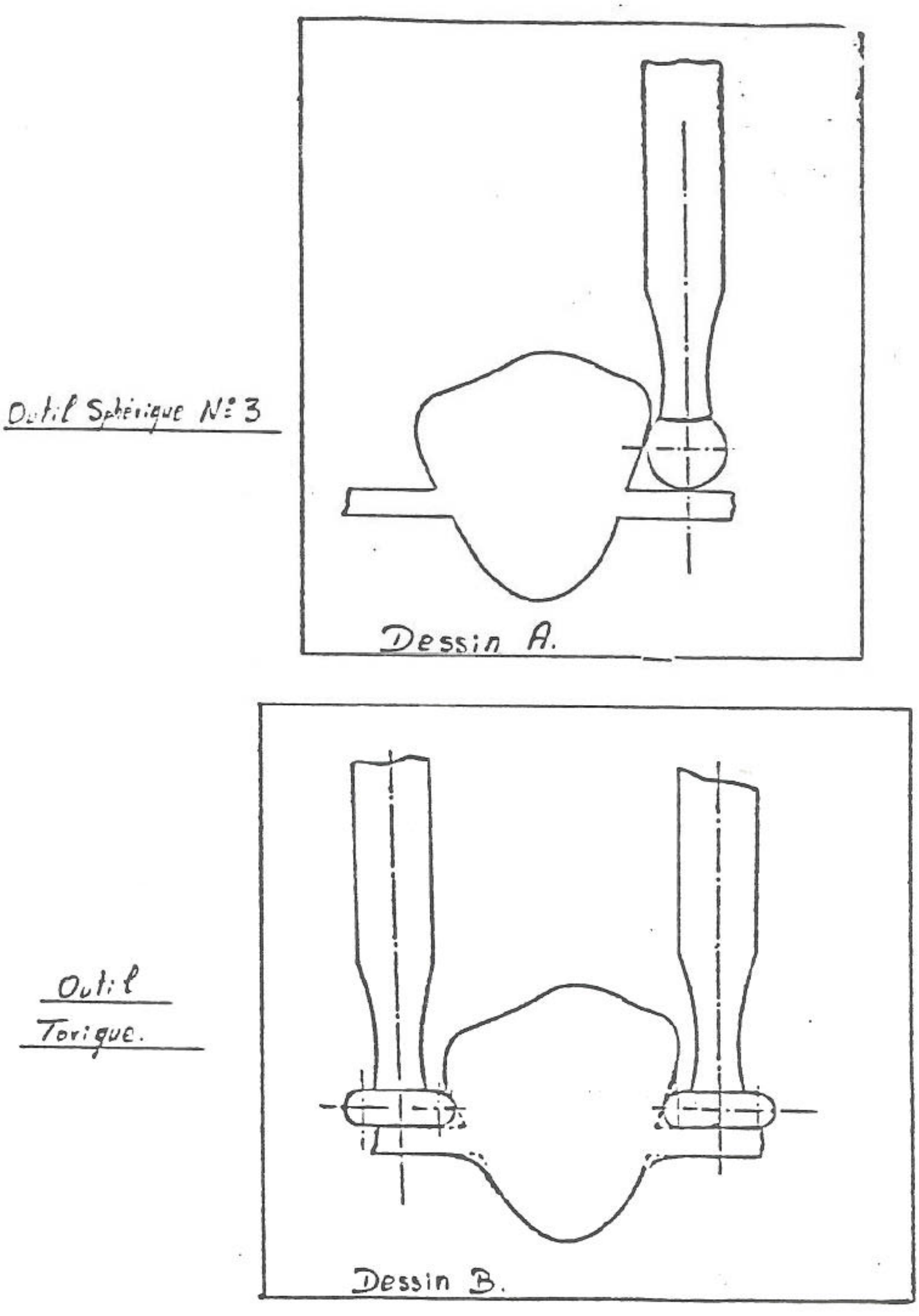
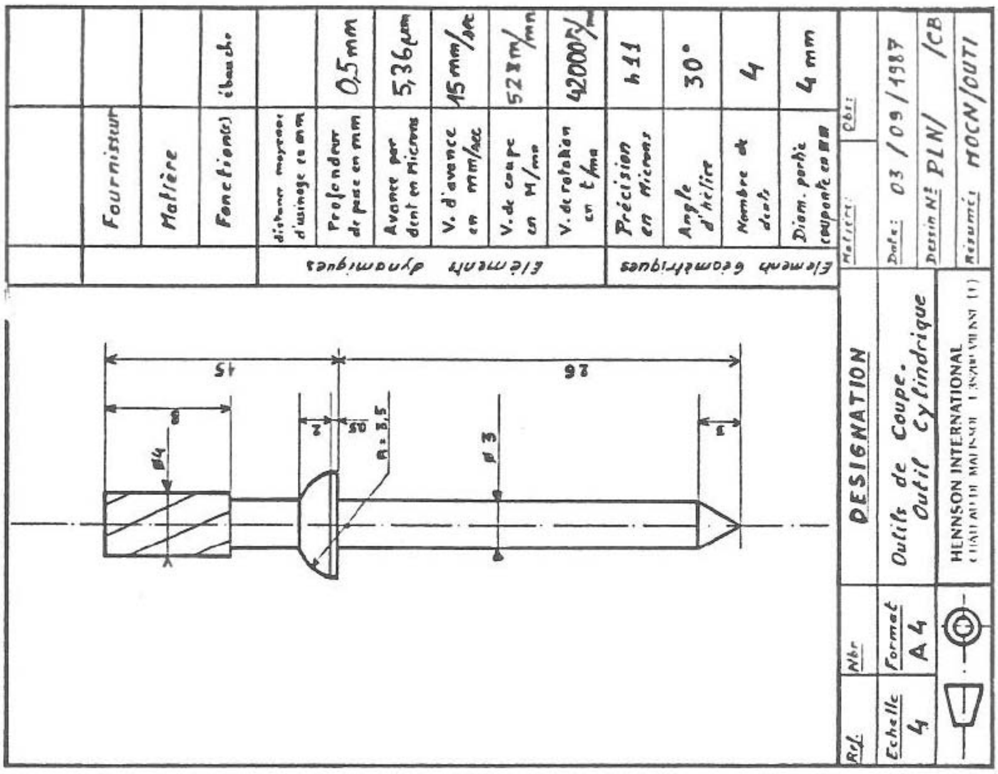


Figure 95


Fournisseur
Matière
Fonction(s) ébauche
distance moyenne d'usinage en mm
Profondeur de passe en mm 0,5 mm
Avance par dent en Microns 5,36 µm
V. d'avance en mm/sec 15 mm/sec
V. de coupe en M/mn 528 m/mn
V. de rotation en t/mn 42000 t/mn
Précision en Microns h11
Angle d'hélice 30°
Nombre de dents 4
Diam. partie coupante en mm 4 mm
Eléments dynamiques
Eléments Géométriques
DESIGNATION
Outils de Coupe. Outil Cylindrique
HENNSON INTERNATIONAL
Date: 03/09/1987
Dessin N° PLN/ /CB
Résumé: MOCN/OUTI
Echelle 4
Format A4

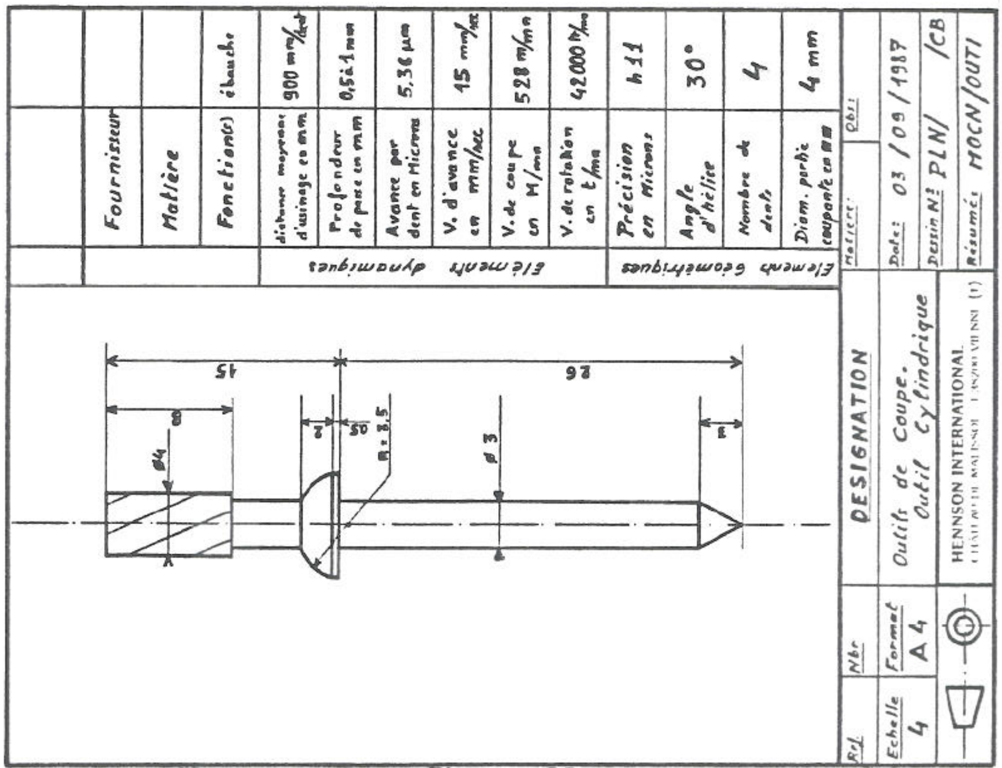
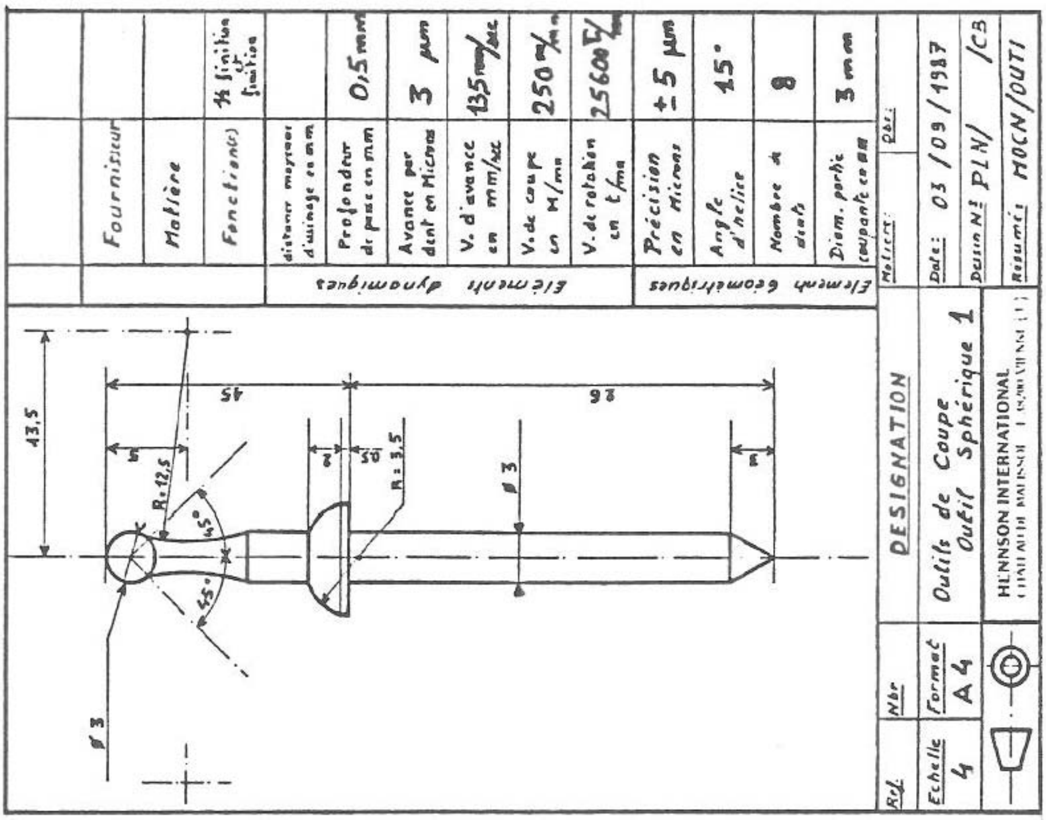

Fournisseur
Matière
Fonction(s) ébauche
distance moyenne d'usinage en mm 900 mm/sec
Profondeur de passe en mm 0,5 à 1 mm
Avance par dent en Microns 5,36 µm
V. d'avance en mm/sec 15 mm/sec
V. de coupe en M/mn 528 m/mn
V. de rotation en t/mn 42000 t/mn
Précision en Microns h11
Angle d'hélice 30°
Nombre de dents 4
Diam. partie coupante en mm 4 mm
Eléments dynamiques
Eléments Géométriques
DESIGNATION
Outils de Coupe. Outil Cylindrique
HENNSON INTERNATIONAL
Date: 03/09/1987
Dessin N° PLN/ /CB
Résumé: MOCN/OUTI
Echelle 4
Format A4

Figure 96


Fournisseur
Matière
Fonction(s)
½ finition et finition
Eléments dynamiques
distance moyenne d'usinage en mm
Profondeur de passe en mm
0,5 mm
Avance par dent en Microns
3 µm
V. d'avance en mm/sec
135 mm/sec
V. de coupe en M/mn
250 m/mn
V. de rotation en t/mn
25600 t/mn
Eléments Géométriques
Précision en Microns
± 5 µm
Angle d'hélice
15°
Nombre de dents
8
Diam. partie coupante en mm
3 mm
DESIGNATION
Outils de Coupe
Outil Sphérique 1
HENNSON INTERNATIONAL
Date: 03/09/1987
Dessin N° PLN/ /CB
Résumé: MOCN/OUTI
Echelle 4
Format A4
43,5
45
26
R=12,5
45°
R=3,5
ø 3

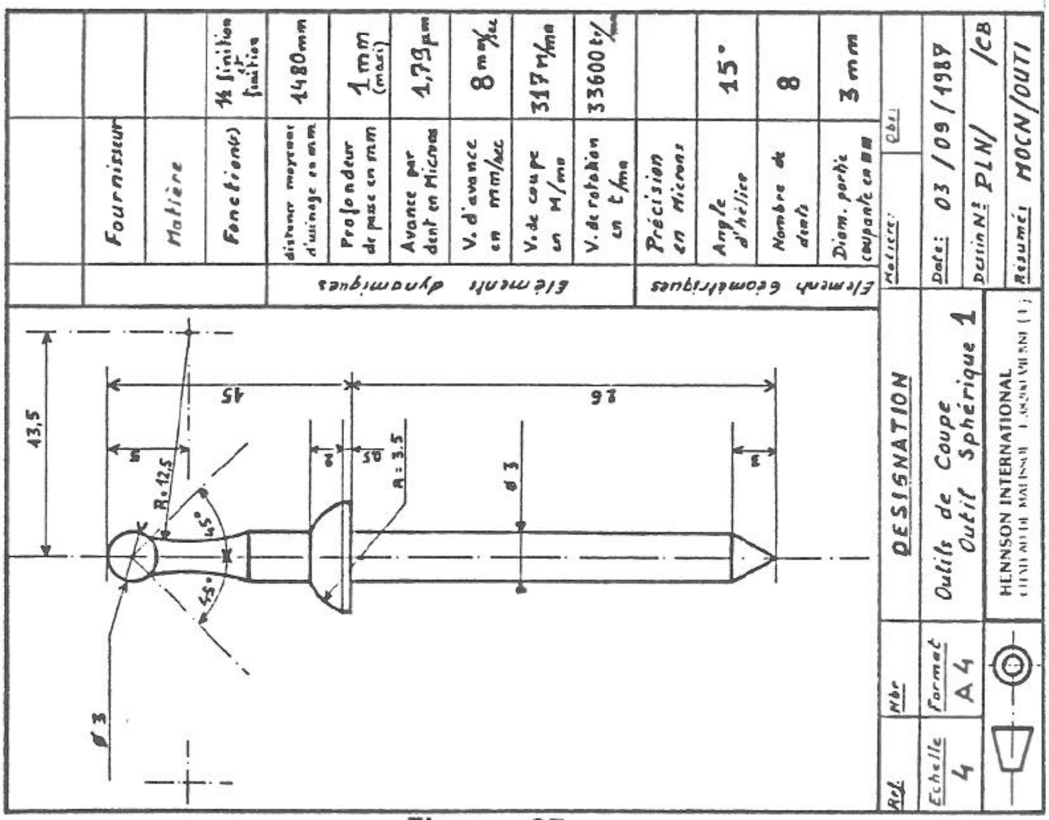
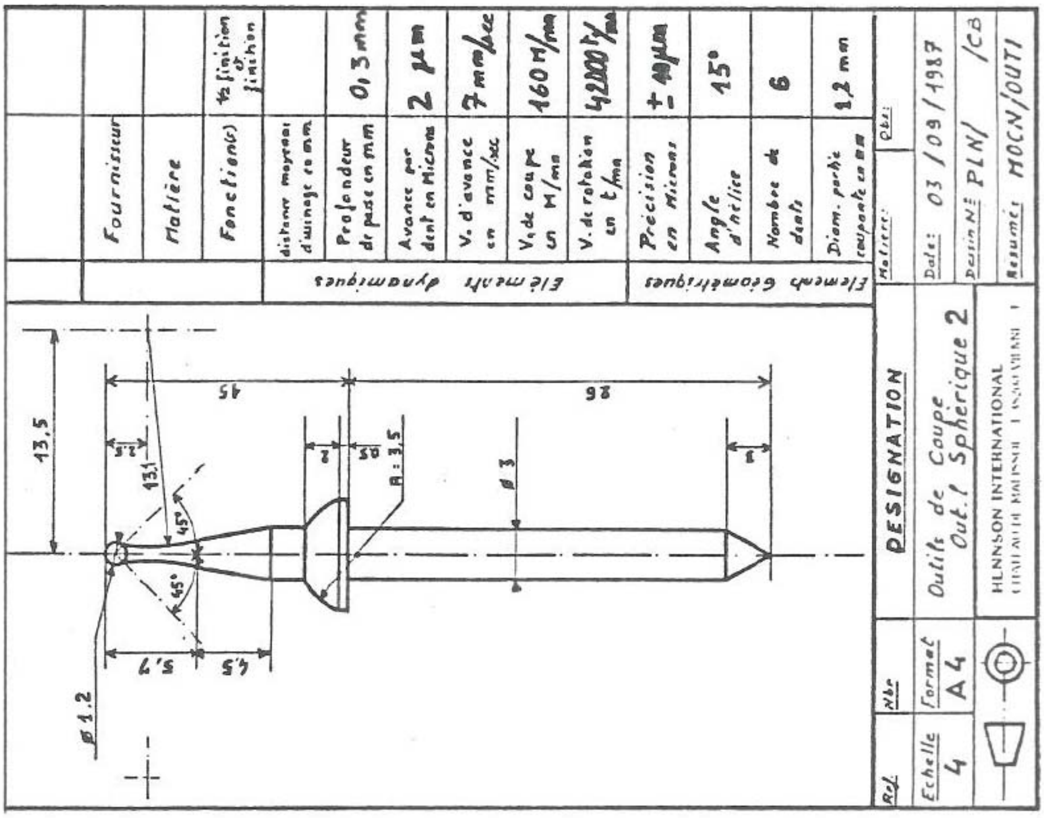

Fournisseur
Matière
Fonction(s)
½ finition et finition
Eléments dynamiques
distance moyenne d'usinage en mm
1480 mm
Profondeur de passe en mm
1 mm (maxi)
Avance par dent en Microns
1,79 µm
V. d'avance en mm/sec
8 mm/sec
V. de coupe en M/mn
317 m/mn
V. de rotation en t/mn
33600 t/mn
Eléments Géométriques
Précision en Microns
Angle d'hélice
15°
Nombre de dents
8
Diam. partie coupante en mm
3 mm
DESIGNATION
Outils de Coupe
Outil Sphérique 1
HENNSON INTERNATIONAL
Date: 03/09/1987
Dessin N° PLN/ /CB
Résumé: MOCN/OUTI
Echelle 4
Format A4
43,5
45
26
R=12,5
45°
R=3,5
ø 3

Figure 97



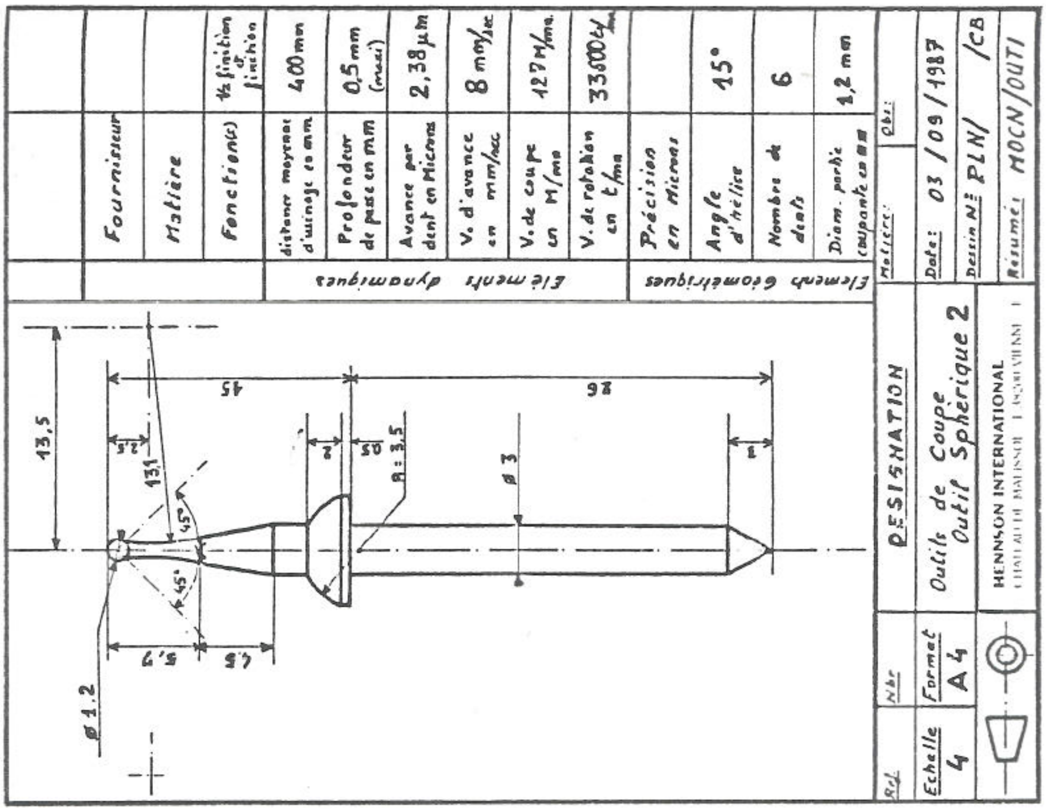
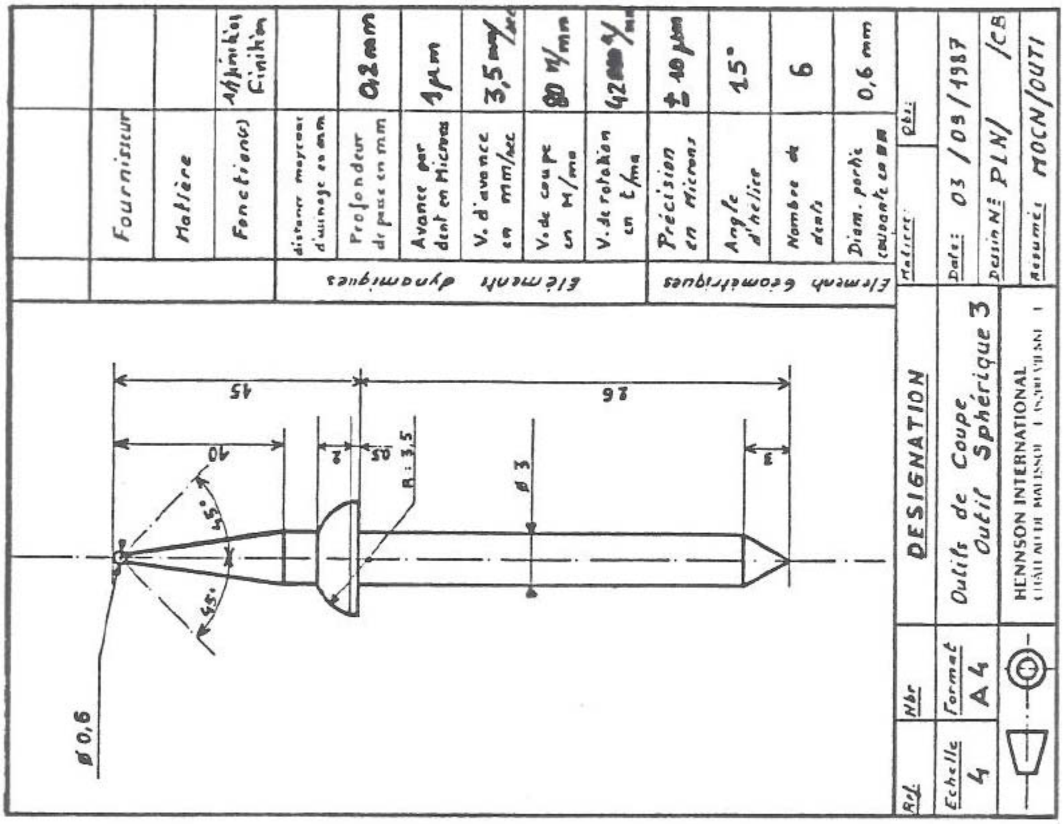


Figure 98


Fournisseur
Matière
Fonction(s)
distance moyenne d'usinage en mm
Profondeur de passe en mm
0,2 mm
Avance par dent en Microns
1 µm
V. d'avance en mm/sec
V. de coupe en M/mn
V. de rotation en t/mn
Précision en Microns
Angle d'hélice
15°
Nombre de dents
6
Diam. partie coupante en mm
0,6 mm
Eléments dynamiques
Eléments Géométriques
DESIGNATION
Outils de Coupe
Outil Sphérique 3
Date: 03/09/1987
Dessin N° PLN/ /CB
Résumé: MOCN/OUTI
Echelle 4
Format A4
HENNSON INTERNATIONAL
ø 0,6
45°
ø 3
R: 3,5

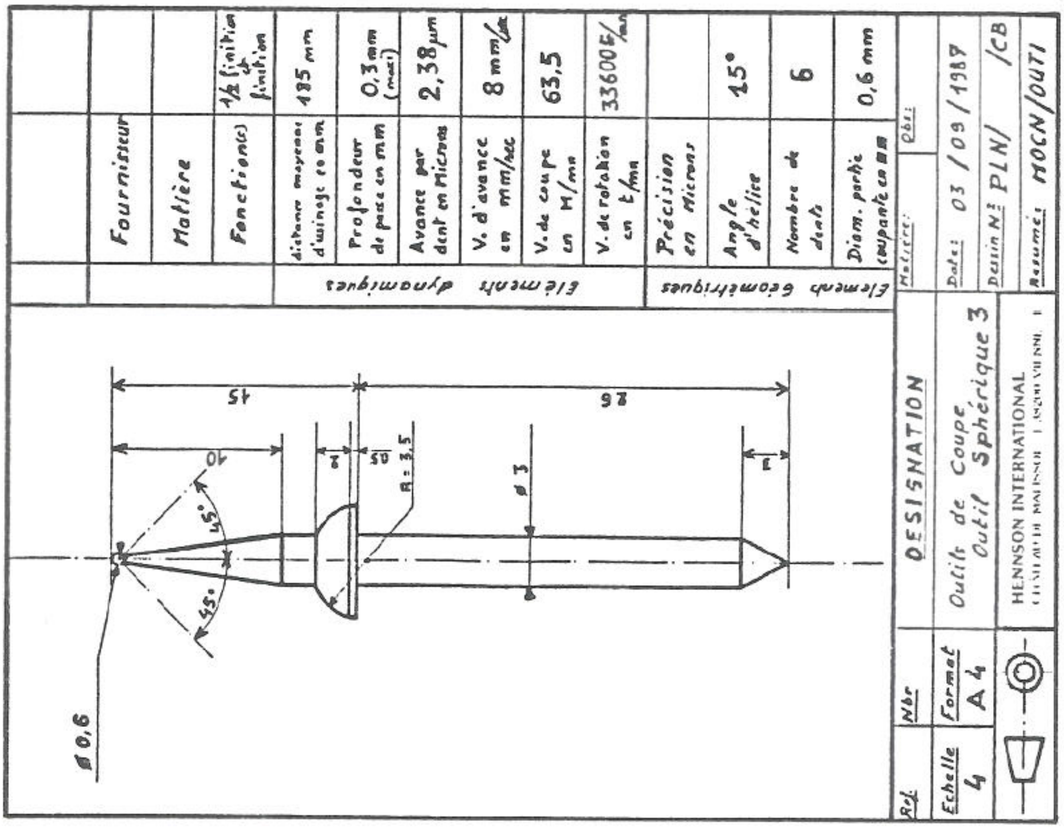
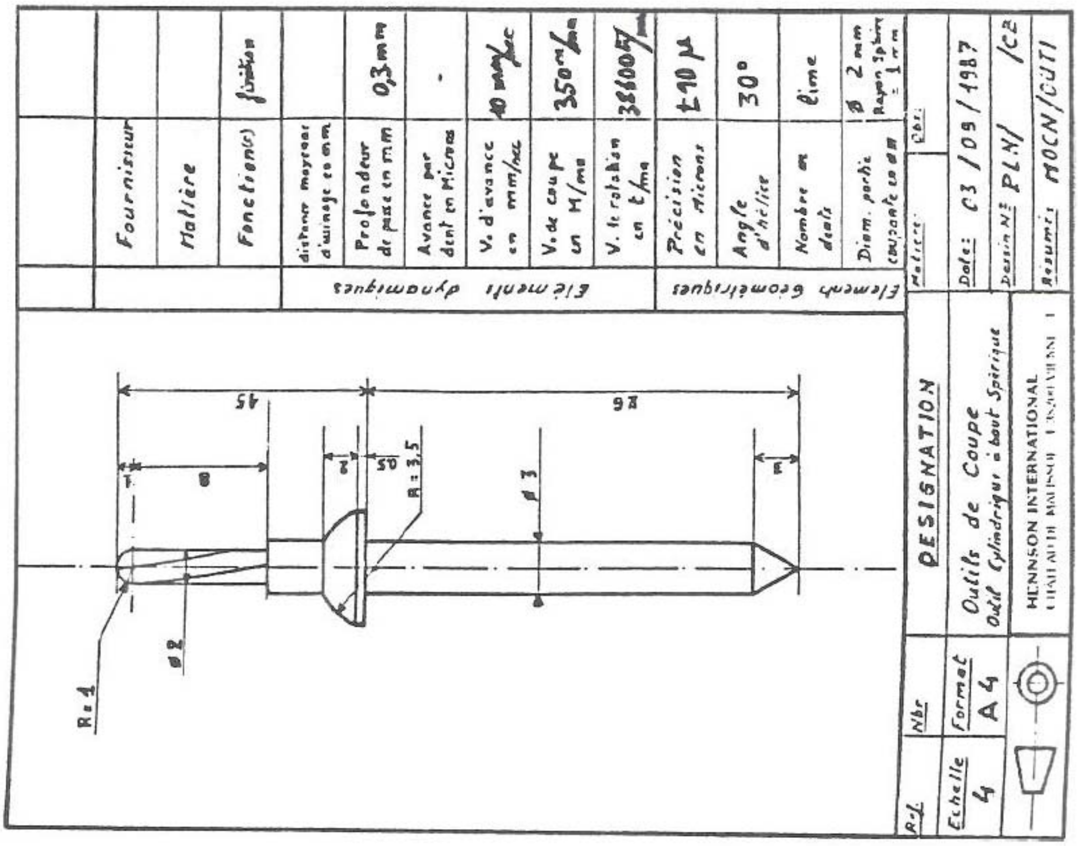

Fournisseur
Matière
Fonction(s)
distance moyenne d'usinage en mm
125 mm
Profondeur de passe en mm
0,3 mm (maxi)
Avance par dent en Microns
2,38 µm
V. d'avance en mm/sec
V. de coupe en M/mn
63,5
V. de rotation en t/mn
Précision en Microns
Angle d'hélice
15°
Nombre de dents
6
Diam. partie coupante en mm
0,6 mm
Eléments dynamiques
Eléments Géométriques
DESIGNATION
Outils de Coupe
Outil Sphérique 3
Date: 03/09/1987
Dessin N° PLN/ /CB
Résumé: MOCN/OUTI
Echelle 4
Format A4
HENNSON INTERNATIONAL
ø 0,6
45°
ø 3
R: 3,5

Figure 99


Fournisseur
Matière
Fonction(s) finition
Profondeur de passe en mm 0,3 mm
Precision en Microns ±10 μ
Angle d'hélice 30°
Nombre de dents lime
DESIGNATION
Outils de Coupe
Outil Cylindrique à bout Sphérique
Echelle 4
Format A4
Date: 03/09/1987
HENNSON INTERNATIONAL

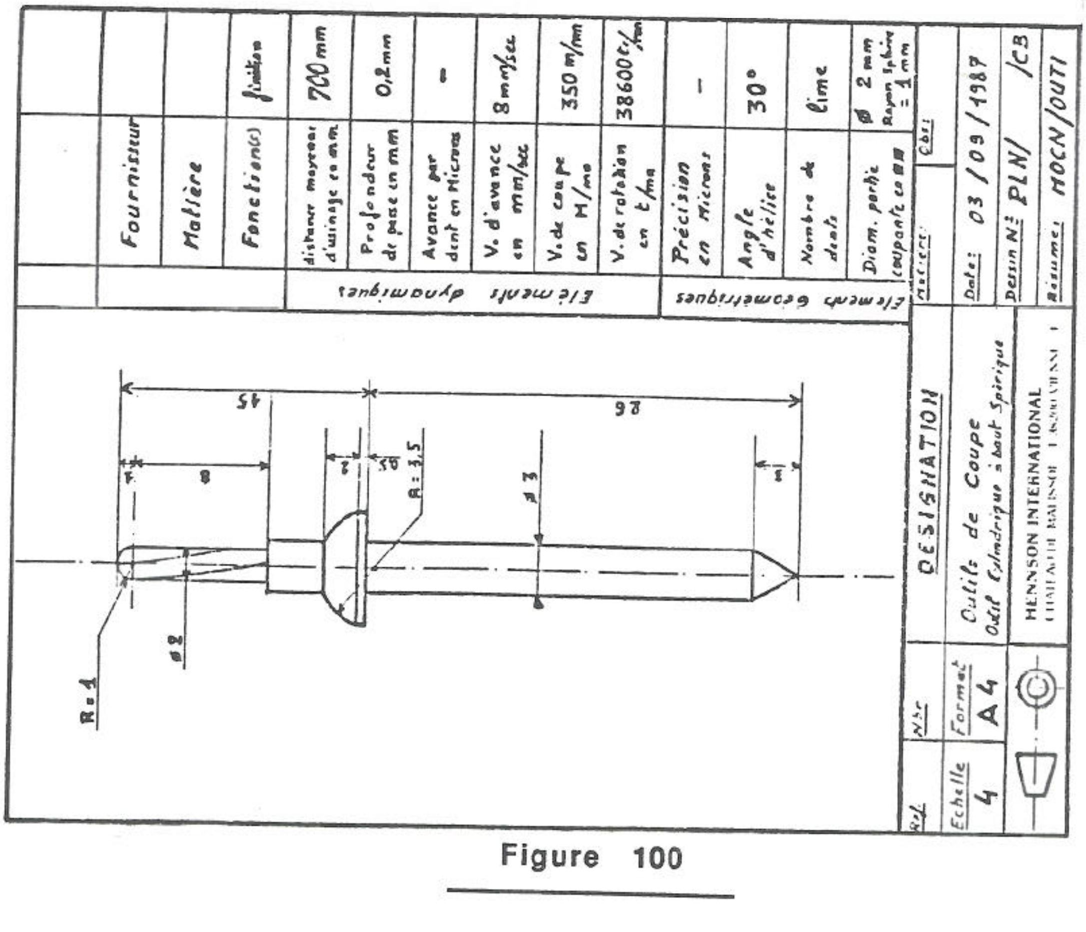
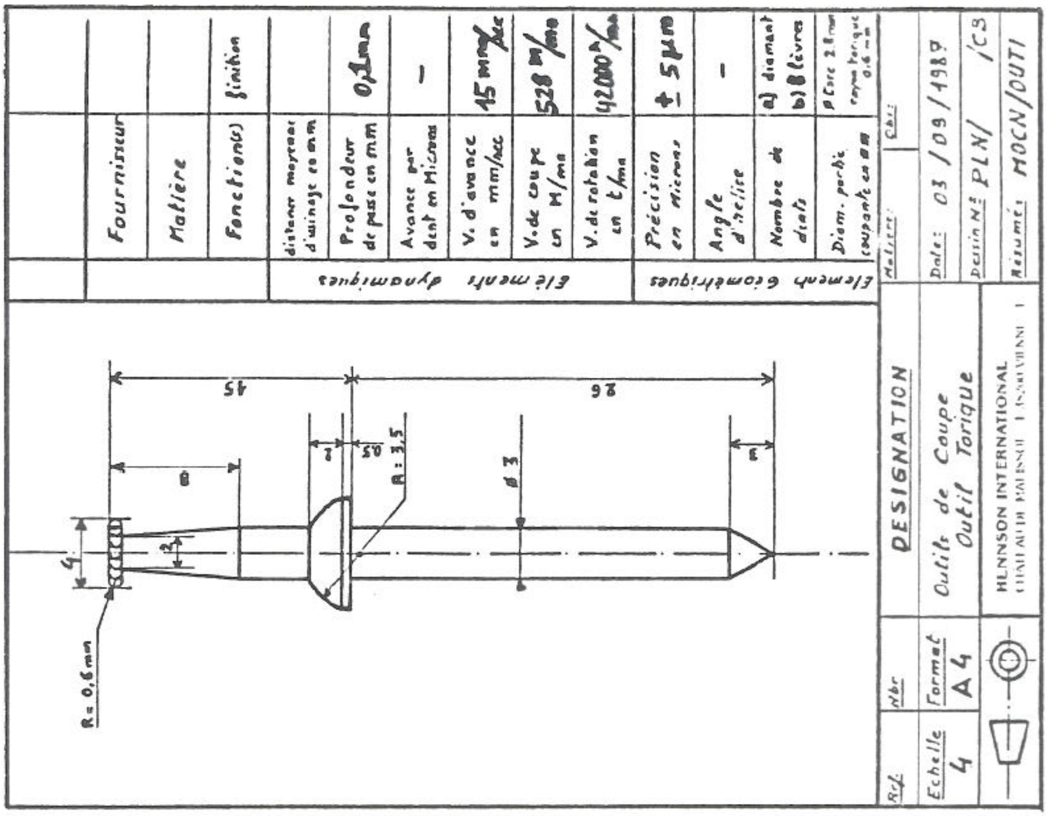

Fournisseur
Matière
Fonction(s) finition
700 mm
Profondeur de passe en mm 0,2 mm
8 mm/sec
350 m/mn
38600 t/mn
Angle d'hélice 30°
Nombre de dents lime
DESIGNATION
Outils de Coupe
Outil Cylindrique à bout Sphérique
Echelle 4
Format A4
Date: 03/09/1987
HENNSON INTERNATIONAL

Figure 100


R = 0,6 mm
4
3
8
45
86
R: 3,5
Ø 3
Fournisseur
Matière
Fonction(s)
finition
distance moyenne d'usinage en mm
Profondeur de passe en mm
0,1 mm
Avance par dent en Microns
-
V. d'avance en mm/sec
15 mm/sec
V. de coupe en M/mn
528 m/mn
V. de rotation en t/mn
42000 t/mn
Précision en Microns
± 5 µm
Angle d'hélice
-
Nombre de dents
a) diamant
b) 8 lèvres
Diam. partie coupante en mm
Ø Core 2.8 mm rayon torique 0.6 mm
Eléments dynamiques
Eléments Géométriques
Ref
Echelle 4
Nbr
Format A4
DESIGNATION
Outils de Coupe
Outil Torique
HENNSON INTERNATIONAL
Matière:
Obs:
Date: 03/09/1987
Dessin N°: PLN/ /CB
Résumé: MOCN/OUTI

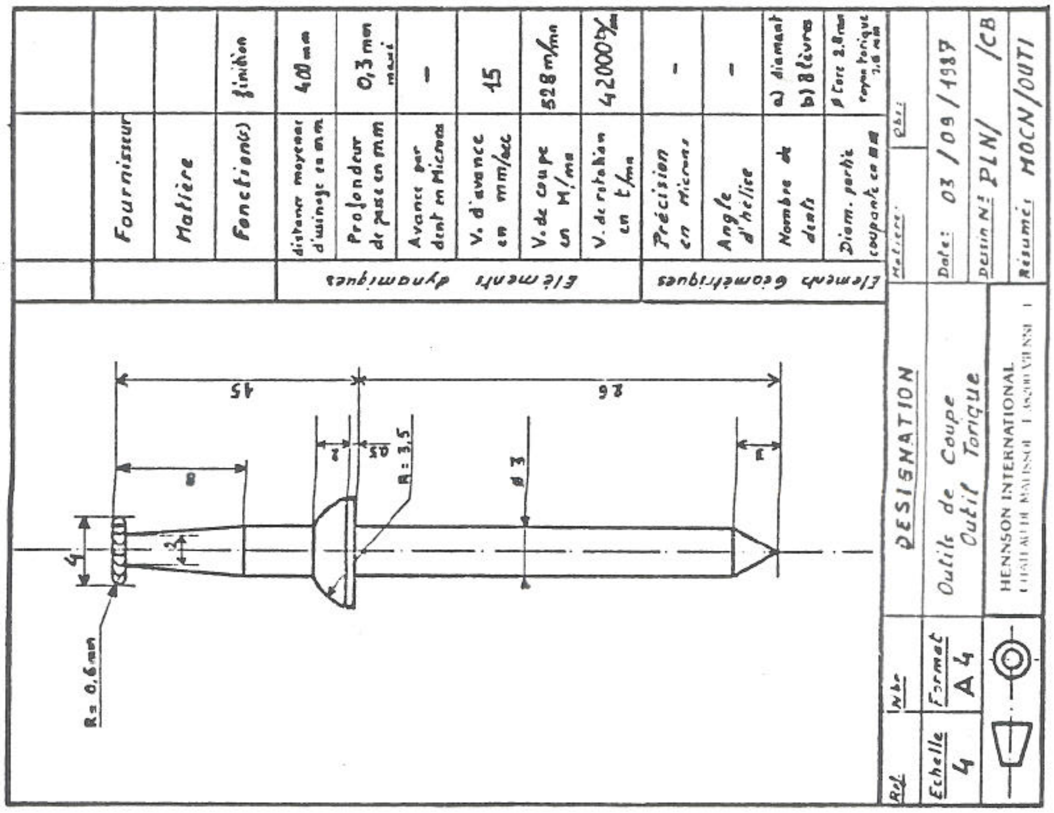
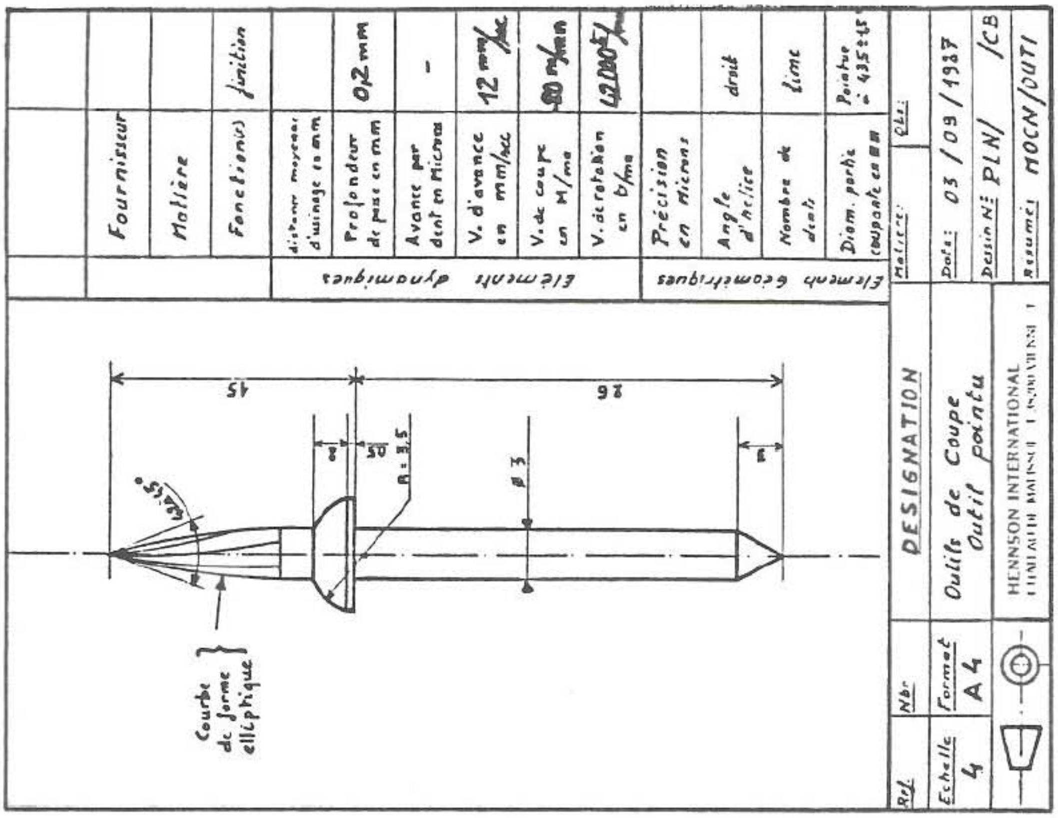

R = 0,6 mm
4
3
8
45
86
R: 3,5
Ø 3
Fournisseur
Matière
Fonction(s)
finition
distance moyenne d'usinage en mm
4,00 mm
Profondeur de passe en mm
0,3 mm maxi
Avance par dent en Microns
-
V. d'avance en mm/sec
15
V. de coupe en M/mn
528 m/mn
V. de rotation en t/mn
42000 t/mn
Précision en Microns
-
Angle d'hélice
-
Nombre de dents
a) diamant
b) 8 lèvres
Diam. partie coupante en mm
Ø Core 2.8 mm rayon torique 0.6 mm
Eléments dynamiques
Eléments Géométriques
Ref
Echelle 4
Nbr
Format A4
DESIGNATION
Outils de Coupe
Outil Torique
HENNSON INTERNATIONAL
Matière:
Obs:
Date: 03/09/1987
Dessin N°: PLN/ /CB
Résumé: MOCN/OUTI

Figure 101


Fournisseur
Matière
Fonction(s)
finition
distance moyenne d'usinage en mm
Profondeur de passe en mm
0,2 mm
Avance par dent en microns
V. d'avance en mm/sec
12 mm/sec
V. de coupe en M/mn
V. de rotation en t/mn
42000 t/mn
Précision en microns
Angle d'hélice
droit
Nombre de dents
lime
Diam. partie coupante en mm
Pointue à 43.5±45°
Eléments dynamiques
Eléments Géométriques
Courbe de forme elliptique
15
26
R = 3.5
Ø 3
DESIGNATION
Outils de Coupe
Outil pointu
HENNSON INTERNATIONAL
Ref.
Echelle
4
Nbr
Format
A4
Matière
Obs.
Date: 03 / 09 / 1987
Dessin N°: PLN/ /CB
Résumé: MOCN/OUTI

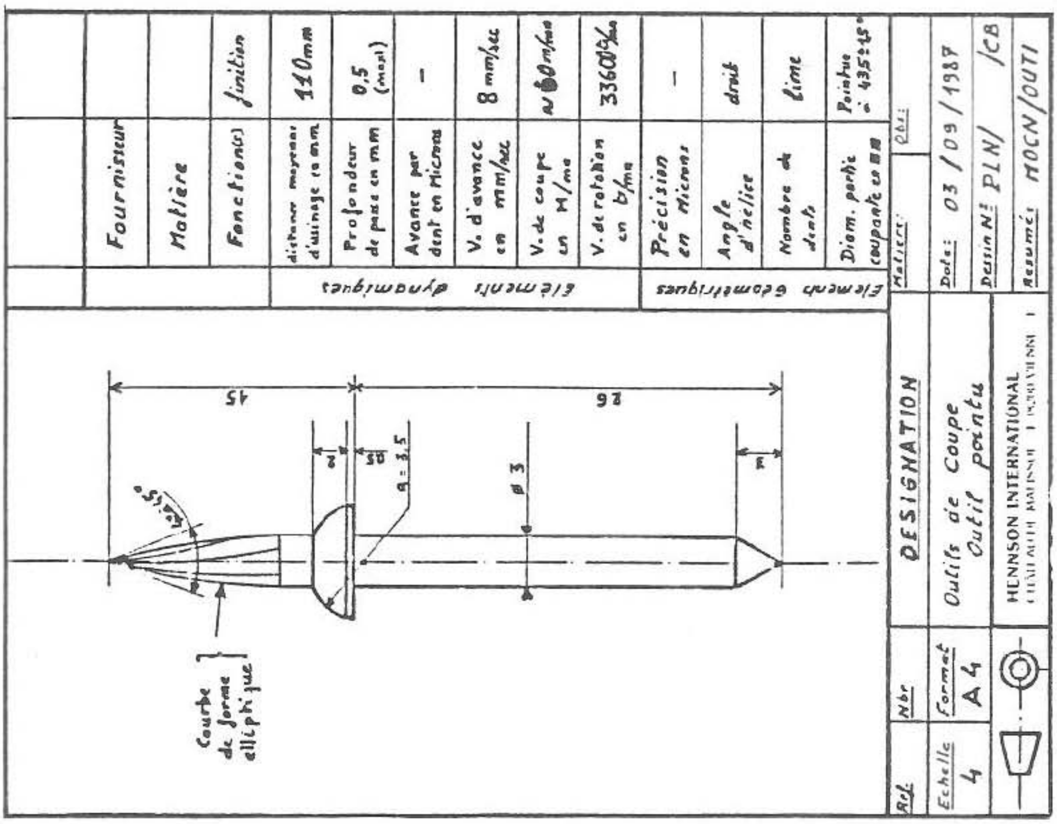
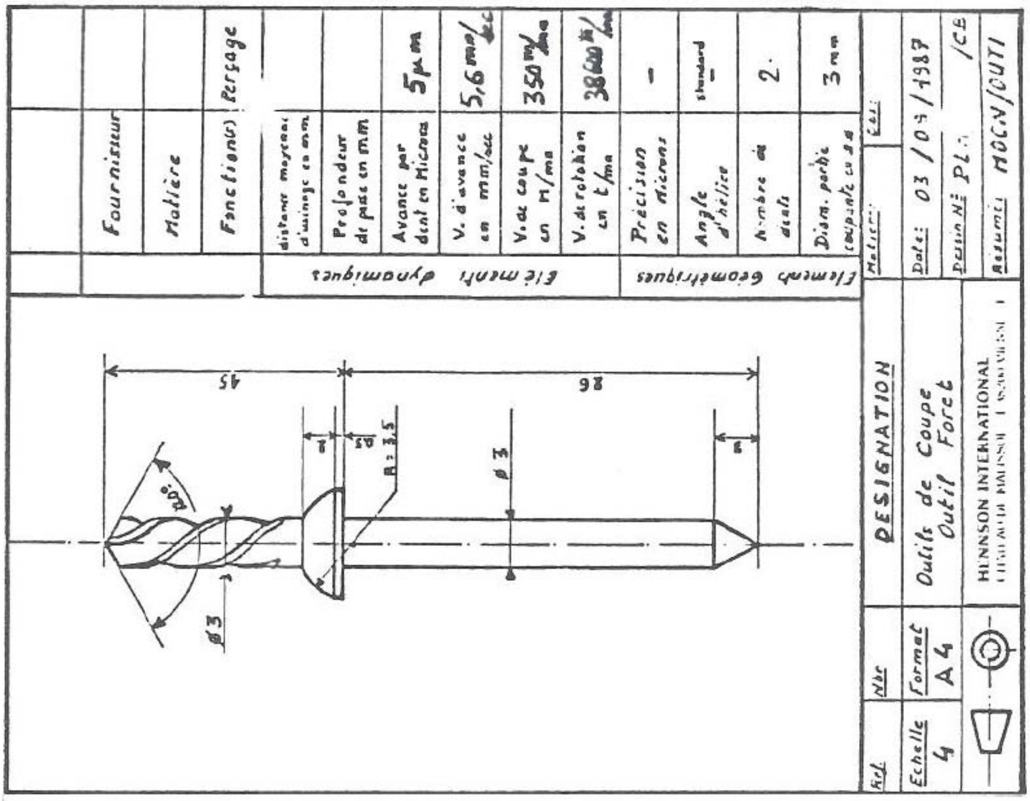

Fournisseur
Matière
Fonction(s)
finition
distance moyenne d'usinage en mm
110 mm
Profondeur de passe en mm
0,5 (maxi)
Avance par dent en microns
V. d'avance en mm/sec
8 mm/sec
V. de coupe en M/mn
V. de rotation en t/mn
33600 t/mn
Précision en microns
Angle d'hélice
droit
Nombre de dents
lime
Diam. partie coupante en mm
Pointue à 43.5±45°
Eléments dynamiques
Eléments Géométriques
Courbe de forme elliptique
15
26
R = 3.5
Ø 3
DESIGNATION
Outils de Coupe
Outil pointu
HENNSON INTERNATIONAL
Ref.
Echelle
4
Nbr
Format
A4
Matière
Obs.
Date: 03 / 09 / 1987
Dessin N°: PLN/ /CB
Résumé: MOCN/OUTI

Figure 102


Fournisseur
Matière
Fonction(s) Perçage
Profondeur de passe en mm
Avance par dent en Microns
5µm
V. d'avance en mm/sec
5,6 mm/sec
V. de coupe en M/mn
350 m/mn
V. de rotation en t/mn
38600 t/mn
Précision en Microns
Angle d'hélice
standard
Nombre de dents
2
Diam. partie coupante en mm
3 mm
Eléments dynamiques
Eléments Géométriques
45
86
DESIGNATION
Outils de Coupe
Outil Foret
Date: 03/09/1987
Echelle
4
Format
A4
HENNSON INTERNATIONAL

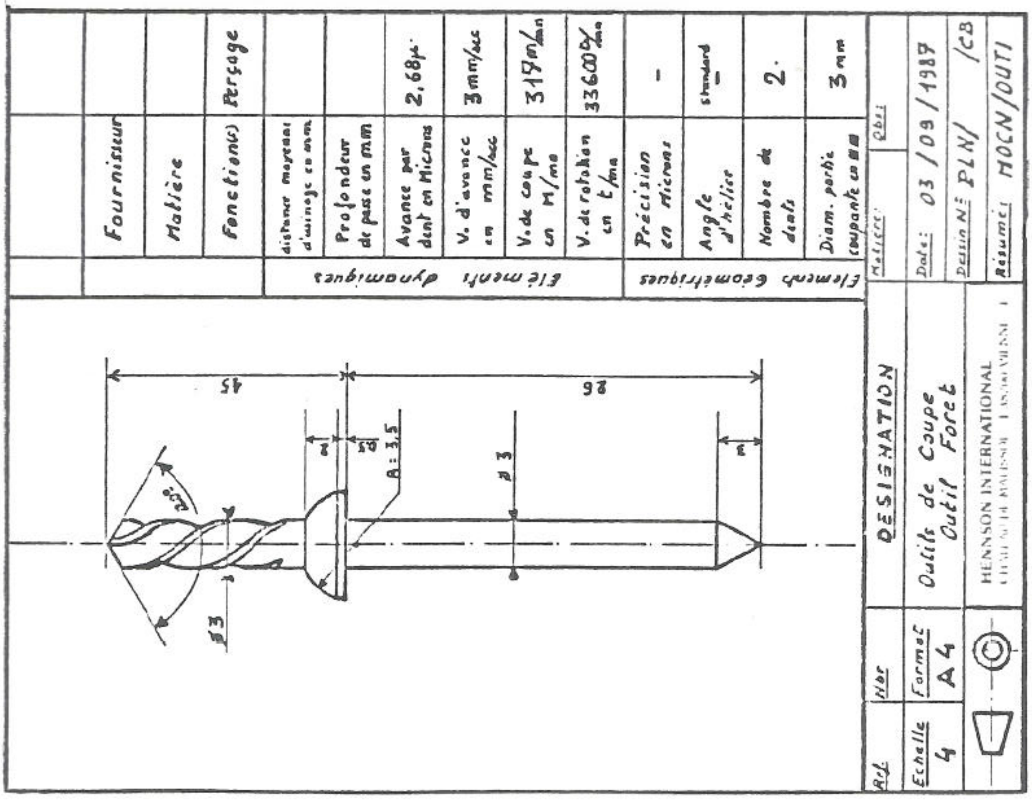

Fournisseur
Matière
Fonction(s) Perçage
Profondeur de passe en mm
Avance par dent en Microns
2,68µ
V. d'avance en mm/sec
3 mm/sec
V. de coupe en M/mn
317 m/mn
V. de rotation en t/mn
33600 t/mn
Précision en Microns
Angle d'hélice
standard
Nombre de dents
2
Diam. partie coupante en mm
3 mm
Eléments dynamiques
Eléments Géométriques
45
86
DESIGNATION
Outils de Coupe
Outil Foret
Date: 03/09/1987
Résumé: MOCN/OUTI
Echelle
4
Format
A4
HENNSON INTERNATIONAL

Figure 103

6-MATERIALS

Computer aided conception of dental prosthesis defines with great precision and a constant reproducibility the ideal prosthetic volume wanted by clinical imperatives. Then this prosthetic volume will be converted in a definitive prosthesis by digital command manufacturing in a bio material bloc devised for a precise clinical objective.

Presented un this super simplified aspect, this new technology plunges in a deep reflexion the creators of bio materials who see their specifications fundamentally disturbed since it is not the reproduction of shapes imperatives which are important anymore but the specialities of substance loss. It appears that current bio materials have no interest as they are malleable and their biological properties are often second to this imperative which is nevertheless essential for current dental prostheses. Thus, we see the arrival inside the mouth of unsuspected substances such as:

- metals (gold, steel, alloys) for their aptitude to reproduce shapes by using lost wax methods and their mechanical properties
- aesthetical substances, charged or non resins and ceramics, pretty but without the sufficient mechanical properties

Both ensembles are often associated to form a coherent set.

6.1 Research aim

CAD/CAM gives us the prosthetic shape and volume. We must now devote our research entirely to one or more materials whose mechanical, biological and aesthetic specificities, associated to the fixation on the receiving site process will enable us to satisfy better the clinical requirements.

The biggest priority will be given to the statistical and dynamic study of the tissue to be replaced, then to the implementation of a substance capable of replacing it. It appears to be logical to start by clearly defining our needs according to the tissue we want replaced, and its function. This is in our view, a new way of doing things as it's not the implementation technique of a material or its original particularities who are going to define our clinical concepts but rather the opposite.

6.2 Research methods – specifications

In fact, all we need to do is devise without any other practical considerations the material whose characteristics are closest to those of the tissue to be replaced. Then, we must condition this material so that it can be fixed then manufactured on the digital command device. This implies the writing of specifications of the bio material. This type of study will always start by a precise analysis of the needs, that is to say the close examination of the substance loss. Only after will the reflexion, research and choice of bio material phases arrive.

For a better comprehension of things, we distinguish two aspects in the specifications:

- statistical characteristics
- dynamic characteristics

We study for each characteristic those specific to the loss of substance and we will deduce those desirable for the material.

6.2-1 Static characteristics

6.2-1.1 Substance loss

We keep for practical reasons this average values list given by authors to the dental structure as a reflexion base.

a) Physical properties

	EMAIL	DENTINE	
DENSITE :	2,2 à 3	2.	
INDICE DE REFRACTION :	1,655	1,55	
TRANSPARENCE	80 %	10 %	
Pés OPTIQUES	ANISOTROPE	ISOTROPE	
SOLUBILITE	INSOLUBLE DS LA SALIVE		
CHALEUR MASSIQUE	1600	1000	J/(Kg.°C)
CONDUCTIVITE THERMIQUE	0,9	0,5	W/(m.°C)
DIFFUSIVITE THERMIQUE	0,4	0,1	mm2/sec
DILATATION LINEIQUE	11	8	°(C^{-1}X10^6)

b) Mechanical properties

	EMAIL			DENTINE	
DURETE	340	KHN	....	70	KHN
COEFFICIENT DE FROTTEMENT.....	0,2		....	0,5	
MODULE D'ELASTICITE	80	GPa	....	18	GPa
COMPRESSION	350	MPa	....	280	MPa
TRACTION	45	MPa	....	15	MPa
FLEXION	90	MPa	....	140	MPa

6.2-1.2 Material

It will have to take into account the values of the substance loss without forgetting any. Here again, let's us remind that is the dental tissue that needs it!... Among these dental structure values, some, such as the scissoring values, flexion and traction, will be increased for safety reasons. Moreover, for some properties we will take into account the enamel values more than the dentine ones or vice versa depending on the clinical objectives. For example, in elasticity mode, we will take the radicular dentine value as it is for a radicular post and the enamel and coronary dentine values for a crown. Finally, we have approached our values, still for safety reasons, to those of the material leader for mechanical properties for prostheses: yellow gold. Thus rethought we have edited the specifications for the statistical specifications of the bio material for crowns, onlays and inlays for example:

a) Physical properties

DENSITE :	2,2 à 3	
INDICE DE REFRACTION :............................	1,5	
TRANSPARENCE	80	%
ANISOTROPE		
SOLUBILITE	INSOLUBLE DS LA SALIVE	
CHALEUR MASSIQUE	1000	J/(Kg.°C)
CONDUCTIVITE THERMIQUE	0,5	W/(m.°C)
DIFFUSIVITE THERMIQUE	0,1	mm2/sec
DILATATION LINEIQUE	8	$(°C^{-1} X 10^6)$

b) Mechanical properties

DURETE	....	340	KHN ou 90 SHORE D
COEFFICIENT DE FROTTEMENT 0,2	.....	0,5	
MODULE D'ELASTICITE	....	18	GPa
COMPRESSION	....	300	MPa
TRACTION	....	300	MPa
FLEXION	....	300	MPa

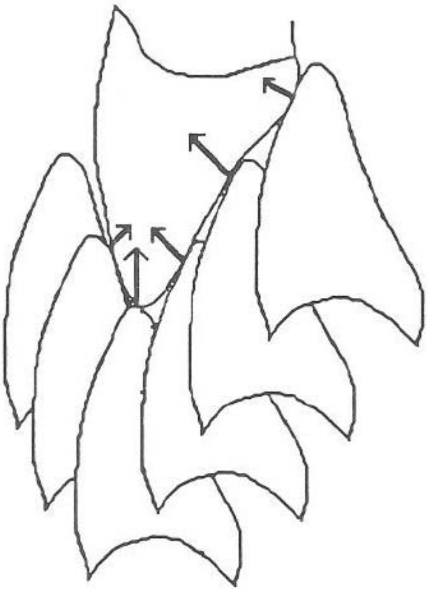
Evidently, such a material doesn't exist among the known bio materials used for dental prostheses (figure 106, 107, 108).

6.2-2 Dynamic characteristics

6.2-2.1 Substance loss

After having fixed those values, we are going to study all the dynamic constraints which will apply to the material during the different functional sequences of the mastication. In the case of a tooth it means we must envisage all possible cases on contact between teeth during the mandibular movements in all types of occlusion. In order to simplify this presentation, we will study these constraints for each tooth in the vertical way, vestibular lingual and palatal, mesio-distal and vice versa, then we will evaluate the behaviour in intermediary situations (figures 104, 105).

Dans le sens vestibulo-lingual nous distinguerons : Articulé inverse
Bout à bout
Intercuspidation maxima
Position balancée



Dans le sens mesio-distal : Bout à bout en rétrusion
Intercuspidation maxima
Bout à bout en protrusion

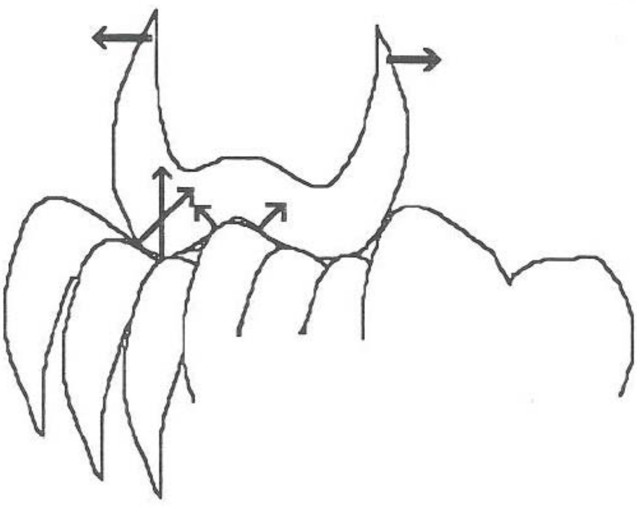
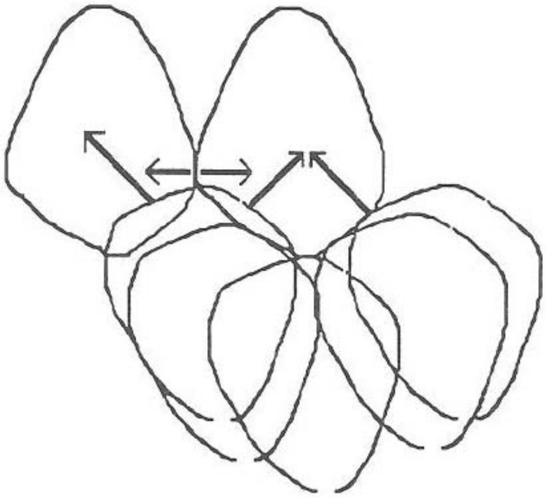
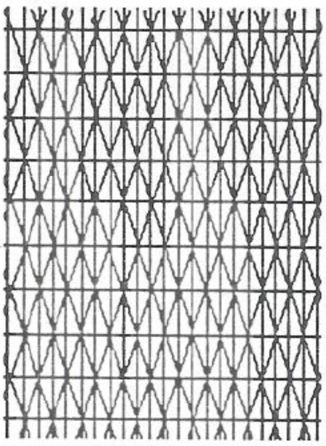
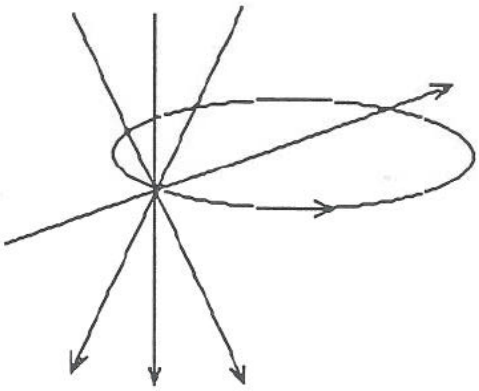


Figure 104





COUPE LONGITUDINALE
DE L'ARCHITECTURE
SELON UN DIAMETRE



REPRESENTATION SPATIALE AU NOEUD
D'INTERSECTION DES DIFFERENTES
ORIENTATIONS DU FILAMENT

Figure 105

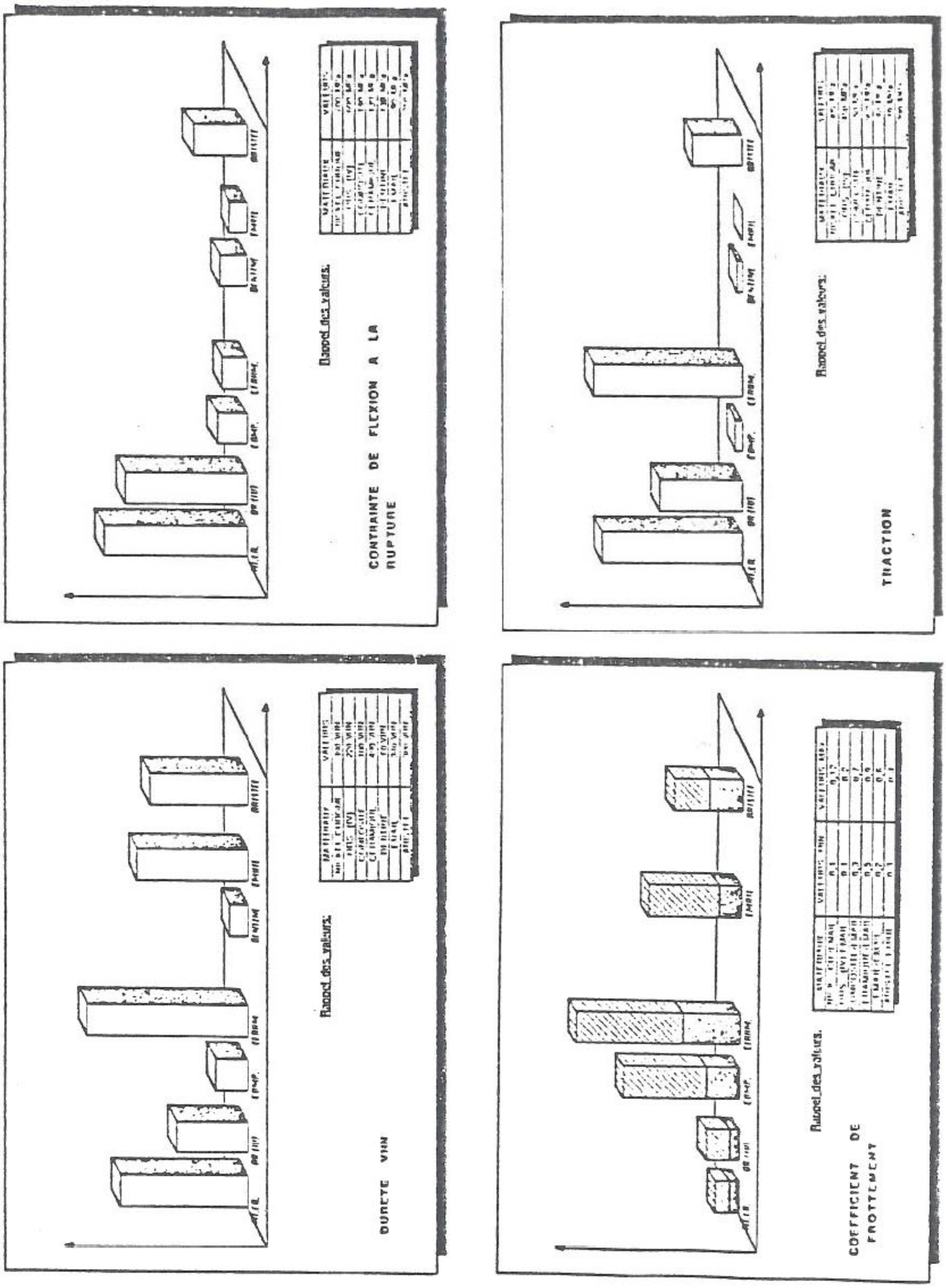


Figure 106

PROPRIETES PHYSIQUES DU MATERIAU

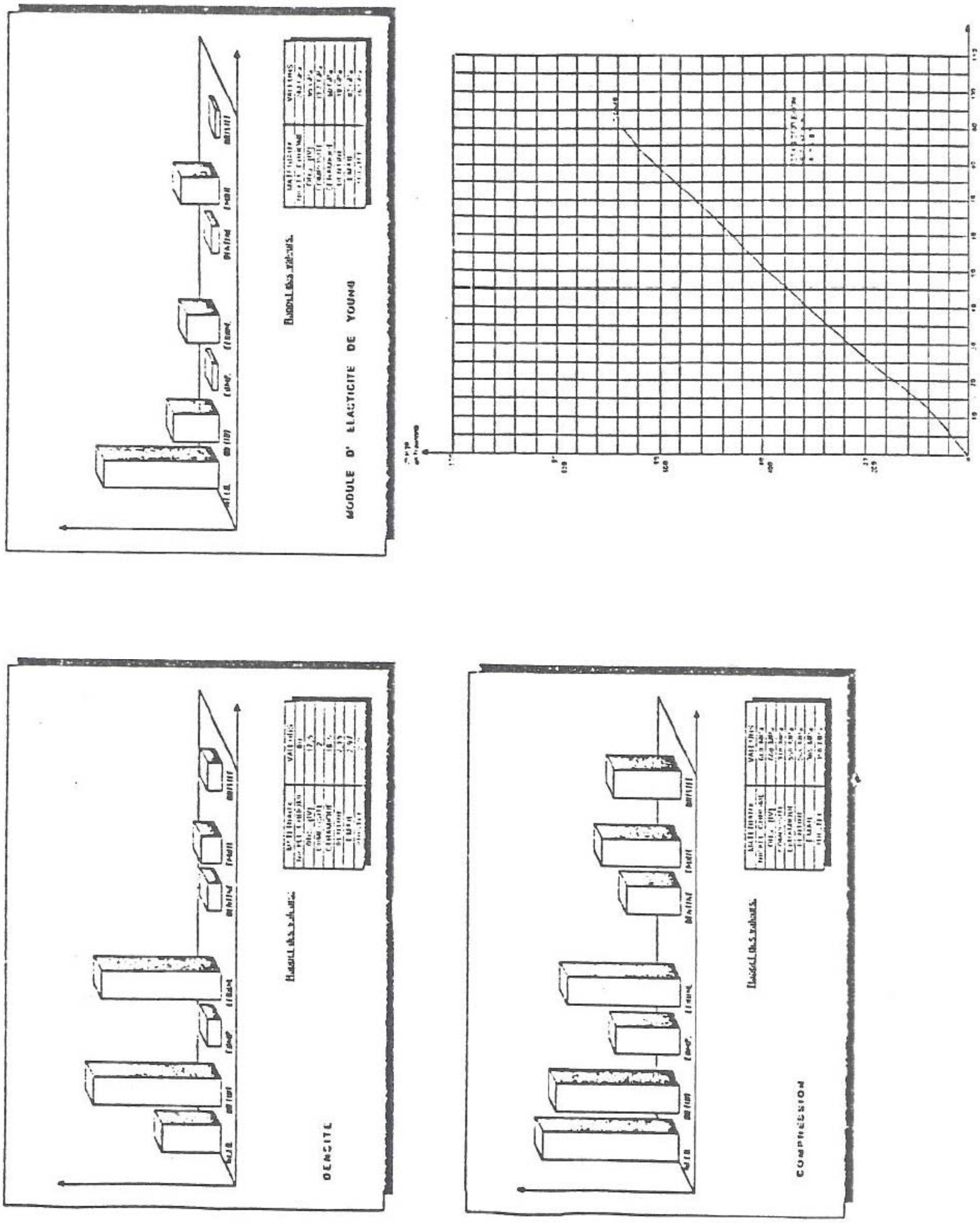


Figure 107

PROPRIETES PHYSIQUES DU MATERIAU

	EMAIL	DENTINE	ARISTEE
- DENSITE	2,9	2,15	2,2
- REFRACTION	-	-	1,6
- P. OPTIQUE	ANNISOTROP	ANNISOTROP	ANNISOTROP
- DILATATION	-	-	11 à 13
- DURETE	93 SHORE D	20 SHORE D	89 SHORE D
- FROTTEMENT	0,2 - 0,6	-	0,3
- ELASTICITE	82 GPa	18 GPa	18 GPa
- COMPRESSION	365 MPa	265 MPa	350 MPa
- FLEXION	-	-	250 MPa
- TRACTION	10 MPa	40 MPa	300 MPa

EMAIL : 92 à 96 % de matiére minérale
8 à 4 % de matière organique

DENTINE : 66 % de matiére minérale
93 % de matière organique

ARISTEE (MATERIAU CFAO)

82 à 84 % de matiére minérale
- Fibres
- Cristaux de quartz
- Silice

16 à 18 % de matière organique

certains adhésifs

Figure 108

PROPRIETES PHYSIQUES DU MATERIAU

After having defined the direction and intensity of these forces, we have defined the strength and orientation of the constraints inside the tooth, the prosthesis.

6.2-2.1 Material

We have thus established there should be inside the material privileged orientations of resistance to these constraints. These directions will increase the base values of these specificities of the material. At this stage in our reflexion, we are hit by the following finding:

- how our current techniques oblige us to only use some substances and keep us away from the fundamental subject: make a whole or part of a new tooth!
- how much it appears complex maybe even impossible to copy structures as admirable and mysterious in their finality as dental tissues.

6.3 Material choice

From these different studies, three fundamental remarks are to be taken into account for choosing the material:

- enamel represents a heterogeneous structure, with a mineral phase and an organic phase
- its optical properties are very specific
- its very particular physical and mechanical characteristics must be carefully returned by our bio material, statically and dynamically

A rapid examination of the current materials proves that they only one, two or maximum three of their specificities close to those of our specifications. From this reflexion phase, we conclude that a material as complex wouldn't exist in a simple form and that it must be the fruits of a very performing association between different carefully chosen materials. The diversity of characteristics our material must show, their association sometimes contradictory (good attitude in flexion and high hardness), the heterogeneity of the substance loss shows that only one material of an "adaptable" type or more often called "composite" will be capable of uniting in one body such diverse properties. The first dental CAD/CAM material with unitary vocation, that is to say for crown, onlay or inlay will be a composite material with a specific internal multidirectional architecture conceived and realised to answer in all circumstances the different constraints that will apply to the prosthesis.

6.4 Structure and composition

As for any composite material, it will be made up of several distinct materials mixed in several directions, intimately linked with each other, one transmitting to the other the constraints which will apply. About this, it is important to specify in order to avoid regrettable confusion that the charges resins used today in dental prosthesis under the improper name composite material aren't a part of this category of materials, for the simple and good reason that they only have two non oriented components and you must know as well that if the presence of charges increases the resistance to compression, it considerably diminishes the flexion value and the scissoring of the material. It is the opposite of a composite material!!

We distinguish:

- the internal architecture or reinforcement
- the matrix
- the interface
- the charges and additives

6.4-1 Internal architecture

It is of "continuous wire" type, glass fibre E of 9µ of diameter, itself composed of three elementary filaments. It represents 18 to 20% of the material in weight.

The realisation of this architecture needs – as well as a knowhow which is the subject of a patent – an extremely sophisticated and original manufacturing tool. The disposition and orientation of the filament comes as we have described of long dental researches which were essentially about the determination of the directions of the internal constraints of the tooth during the different engagements. This material is already presented like a material specifically dental because of its orientated structure.

This architecture enables the disposition of an aesthetic material with enough adapted mechanical properties. Other elements will reinforce this action, such as charges but we must understand that this architecture and its linking modes with the matrix constitute the originality of this composite material without precedent in dentistry.

To be orientated, crossed, linking with each other, these fibres suffer a first treatment: textile size which makes them supple and able for this type of shaping (figure 105).

6.4-2 Matrix

The architecture itself, without filling material is only a theoretical value. For it to exercise all of its action, it must be included in a support tissue with which it must have extremely strong physico-chemical links.

This matrix must present different “accessibility” criteria.

- compatible with glass architecture and charges
- capable off mechanically flow between the architecture’s links during the injection
- affordable
- close to the general properties of our material
- present properties of known bio compatibility

For these reasons, we have chosen a poly-urethane matrix acrylic modified. This low organic fraction of the material (16 to 18%) will correspond to the organic phase of the human enamel and the dentine, while the glass fibre architecture and the charges will correspond to the mineral phase (82 to 84%).

6.4-3 Interface

Of its quality will depend the cohesion between the components, and thus the mechanical value of the material. The performances of our fibrous architecture will only happen if the links with the matrix are solid as through them are transmitted the mechanical constraints of the matrix to the reinforcement. Moreover, during the establishment of the constraints on a composite system, the constituents mustn’t be moved otherwise this lack of homogeneity will unavoidably translate by a disaggregation of the material and a fracture.

After shaping the architecture, different operations of sizing and re sizing are done in order to treat the surface of the fibre chemically and mechanically to create an indestructible link during the constraints between the different components.

Only an implementation with highly performing industrial means can help realise this type of links and we understand here the interest of the DENTAL CAD which, by helping us manufacture our own prostheses enables us to finally access this type of material totally unworkable because of the complexity of its implementation, by the current dental techniques applied.

6.4-4 Charges and additives

After having suffered a constant quality control, an antistatic treatment and being silanized, they are mixed to the matrix in a vacuum.

These are essentially:

- glass beads …………………10 to 15µ
- quartz crystals ………………10 to 15µ
- colloidal silica………………100Å

These charges will modulate the mechanical characteristics of the matrix without perturbing the other fundamental values which are insured by the fibrous architecture linked to the matrix.

6.4-5 Additives

Other substances, several additives are also mixed to the matrix before its injection. Their role is very specific.

They are essentially:

- antistatic agents
- inifugeant substances
- links, etc…

whose function is to intervene usefully during the polymerisation.

6.5 **Implementation means**

To realise this type of material, it is necessary to have a production chain in which are reunited both the knowhow and the most performing processes of modern industry in composite materials. It isn't possible to enter here a complete study of this production unit.

6.6 **Coloration and aesthetics**

Different processes of shading of the tooth are currently being used in traditional techniques. None, except the DYCOR, uses the optical properties of a material, for the good and simple reason that all our aesthetical materials don't have the necessary mechanical properties and must be substantiated with metallic infrastructures and to get rid of this metal, we darken their natural transparency. To realise the colour of a tooth, our approach is very clear and we give priority in that order:

- optical properties of the material
- own colour of the material
- subjacent layers colour
- surface coloration

6.6-1 Optical properties of material

Our base research in this domain was on the realisation of a material with the anisotropic optical attitude as close as possible to that of the enamel. We estimated that the fundamental particularity of the shading by the tooth comes from a reflexion, a transmission and a diffusion of the colours of the deep layers (dentine), of the immediate environment (gums), through the dental structures (enamel), themselves coloured.

We have chosen to work our components: matrix, fibrous architecture, charges to get a material with an optical attitude close to that of enamel. The fibrous architecture was totally occulted by the heart penetration of the matrix in the fibres through micropores. Moreover, with its fibres, it plays a very important role by diffusing light inside the material's mass, through a process similar to that of the optical fibres that could be roughly compared to the prisms of human enamel.

The naturally strong translucency of the matrix has been modified by the adjunction of opacifying charges.

6.6-2 Material's own colour

Then we have treated the proper of the material's own colour, thus imitating the different own shades of enamel, colouring our material inside the mass. The material perfectly colours with a pigment so long as the material has been carefully checked before their addition. The material's colour is controlled at all stages of the manufacturing: mixing of the pigments, architecture, charges, pre polymerisation, polymerisation and stabilisation. Four base colours have been chosen, from which the different tones will be realised.

6.6-3 Subjacent layers colour

These different tones are obtained by using lacquer glue whose vivid shades enable us to get the chosen tone on a palette of referenced tones, either empirically or with the help of a colorimeter for those who choose this formula. Here again we only use the optical properties of the material by copying the natural mode that transmits the colours of the dentine through the enamel.

6.6-4 Exceptional alterations

What's left is what we will call exceptional alterations, which, as in nature, escape any logic criteria. We need to intervene manually, artistically this time, by giving the practioner a set of complete dyes which he can put on the surface by photo polymerisation or thermo polymerisation in an oven, or by depositing a varnish highly resistant.

6.6-5 Specificities

Currently, we aren't able to provide the definitive values of the different characteristics of our material. The means used for the implementation aren't the means of a laboratory, in order to make vary the different parameters which happen during the implementation of a product. However, we have done numerous mechanical tests, during the evolution of the material and we are going to communicate the values of the most representative sample of the series.

Two remarks must be done:

- the technological lacks of the laboratory's machine decrease by 25 to 30% the values that we could expect from an industrial implementation
- the tests we made (NF norm of composite material) have been, as is custom, in space's three dimensions, which considerably penalises our material whose preferential strength lines have been chosen for a specifically dental use and with an orientation defined at the start

In the first table, we will bring closer our values to those of the substance loss according to the principal previously stated. Then in order to situate the material with regards to those that exist, we will provide per characteristic, the values of existing materials and ours.

6.7 **CAD pre shape**

To be ready of the digital command manufacturing, it is necessary that the sample be presented in a shape such as it can be manufactured in the best speed and precision conditions. The material sample is "driven" in a resin block, the whole thing constitutes the CAD pre shape.

This pre shape has two parts:
- the noble part
- the prehension resin (figure 109)

6.7-1 Noble part

The noble part is the prosthetic material that we have just described. We will only say that its shape and volume have been calculated so that it is always possible to include all shapes of crowns.

6.7-2 Prehension resin

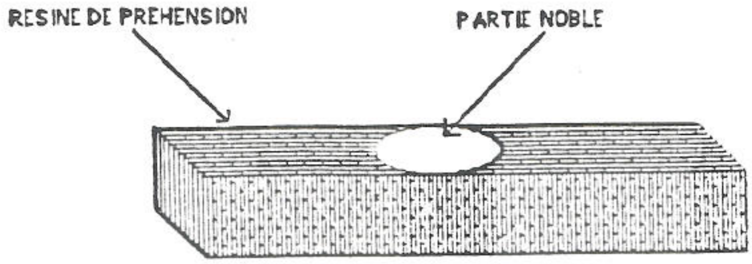
The prehension resin deserves several remarks and has as well specifications for its function in the CAD chain.

To summarise:
- easy to manufacture
- very resistant to flexion
- compatible with the material's matrix
- affordable
- easy to handle

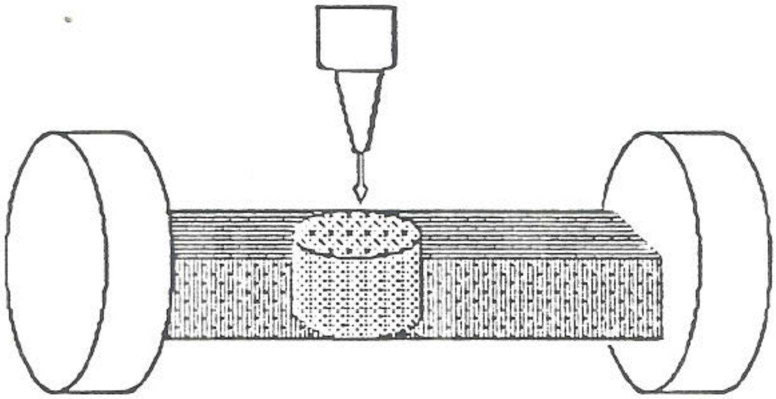
6.8 **Conclusion**

CAD/CAM applied to dental prosthesis presents in many regards a considerable evolution in a rationalisation of interventions sense and a great rigor in the execution of actions. It isn't daring to say that as the choice and material quality levels, the input is so considerable that it constitutes a sufficient reason of going in the direction of this new prosthetic action conception. The results to this day are only the first step. It isn't doubtful that, freed from current technological constraints we will be able to implement new bio materials, more and more stable, compatible and adapted to our legitimate clinical pretentions. What we had to do was radically change the realisation processes of our prostheses in order to give the realisation of bio materials to highly specialised units offering all the necessary guaranties to get a material conforming in all circumstances with the concerned specifications.

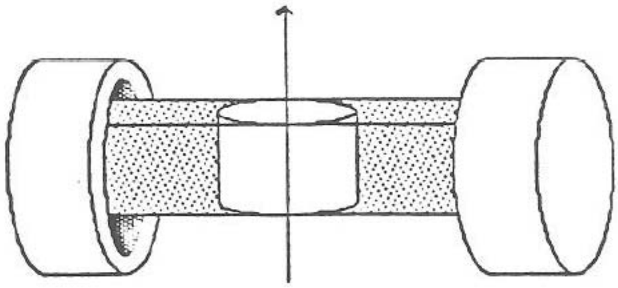
I will add that this opportunity places bio materials at the same rank as state of the art technologies and so it insures the immediate benefit of ulterior more performing discoveries contrary to the current situation where we see bio materials realised with industrial lesser products because of the low interest they represent for big industrial groups. This aspect of the problem has unquestionably played a role in our choice of "adaptable" materials which seem more apt today to insure a true evolution of our product.



LA PREFORME CAO



PREFORME MONTEE SUR LA MACHINE
A COMMANDE NUMERIQUE



LA RESINE DE PREHENSION
SITUE ET ORIENTE LA PARTIE NOBLE
PAR RAPPORT AU POINT O D'USINAGE

Figure 109

6.9 Biocompatibility

This study has for aim to insure the safety and local good tolerance of both materials for dental prosthesis of the composite destined to the realisation of conjoined prostheses with CAD/CAM technique.

Essentially formed of fibres and glass micro beads, as well as a high degree polymerisation resin, the CAD/CAM composite is presented in the shape of a hard mass, insoluble, which, at first hand, has no toxic potential. However, given the large diffusion planned for the CAD/CAM composite, in France as well as abroad, we check the absence of toxic risks through trials on animals, cellular cultures, bacteria as well as clinical trials on humans in real use conditions. Under the name "preliminary trials", we have regrouped three simple and cheap tests. They enable a rapid check of the good local tolerance and the absence of general toxicity of the CAD/CAM composite. In the improbable case of unfavourable results, they would avoid unnecessary and costly trials.

6.8-1 These preliminary trials or phase 1 are:

a) cytotoxicity tests: gelos overimposition method.
This test will be done by Professor ADOLPHE
ECOLE PRATIQUE DES HAUTES ETUDES
15 rue de l'Ecole de Médecine
75006 PARIS

c) implant test on two rabbits according to the USP technique
d) safety trial per bone on 20 male mice and 20 female mice

Given that a systematic toxicity can only be due to substances from the composite and turned into a solution, this trial will be done not with the CAD/CAM composite itself but with liquid extracts of it. For this trial, extraction solvents proposed by the USP have been used. Direct ingestion of the CAD/CAM composite isn't possible even in a pulverised manner as we risk lesions of the digestive tractus, given the hardness of the ingested particles (see phase 3). These trials will be realised by the Company

BIOGIR S.A.
Z.I. DE TOCTOUCAU
33610 CESTAS

Under the responsibility of M. SABOUREAU.

6.8-2 Phase 2

It's about the verification of the absence of allergic risks and muting risks.

- the study of the the sensitisation risks is done on the guinea pig, according to the MAGNUSON technique, by using extraction liquids. This study will be done by the BIOGIR company
- the Ames test will evaluate the muting risk. The technique will be adapted to the insoluble nature of the material. It will be given to Professor MARZIN

INSTITUT PASTEUR DE LILLE

15 rue Camille Guérin
B.P. 245
59019 LILLE CEDEX

If phase 2 gives favourable results, we can start phases 3 and 4.

6.8-3 Phase 3 (toxicity trials on animals)

It includes a local tolerance trail and a general toxicity trial per bone.

- under skin implant on the guinea pig
- local tolerance study on the buccal mucus of the guinea pig
- toxicity study of 14 days on the rat

Even though the composite is destined to stay in the mouth for several years, its absorption is in fact only limited and accidental, it doesn't seem necessary to do long term toxicity trials. These 3 trials are done by BIOGIR.

6.8-4 Phase 4 (clinical trial)

The protocol for this trial will be inspired by the ISO/TR 1984 norm, biological evaluation of dental products, paragraph 6.14, trials on pulp and dentin of restoration products. It would be interesting to complete the study by an electronic microscopy examination of some tooth/crown slices, to show the regularity of the junction between the stump and the crown. But such a study seems unlikely as because of the hardness of the CAD/CAM composite. It has been done and shown in several congresses. This trial being done on humans, there won't be negative witness teeth and even less positive witness teeth.

Even though the ISO/TR 7405 – 1984 norm offers the possibility of realising this tolerance trial on pulp and dentin on a monkey, we prefer human trials, which seem closer to real use conditions, the intolerance risk being very low because of the nature of the material tested. Moreover, a study on a monkey would necessitate including all monkey data in the CAD/CAM computer for the realisation of a prosthesis!

We are thinking of doing a study on 50 patients in two centres. No clinical expert has been chosen yet.

It doesn't seem necessary to check the attitude of the CAD/CAM composite after it has been submitted to X rays. The ionising radio doses it can receive during x rays on a patient are ridiculously low with regards to those during its manufacturing.

LEXIQUE INFORMATIQUE

A

TERMES SPÉCIFIQUES	DÉFINITION
ACCES	Les données, qui se trouvent dans les fichiers* peuvent être exploitées par l'ordinateur* si celui-ci y accède. Il existe 3 grandes méthodes d'accès : accès séquentiel, accès direct et accès indexé.
ACCES SEQUENTIEL	On dit qu'on accède séquentiellement à un enregistrement* si, pour le trouver, il faut être «passé» sur tous ceux qui le précédaient. Ex. : sur un magnétophone, le troisième enregistrement ne peut être lu qu'après qu'on ait lu les deux premiers (voir SEQUENTIEL, FICHIER SEQUENTIEL).
ACCES DIRECT	L'accès à un enregistrement* se fait directement quand on connaît l'endroit exact où il se trouve. Lorsque vous posez le bras du tourne-disque directement sur le morceau qui vous intéresse, vous faites de l'accès direct (voir FICHIER DIRECT).
ACCES INDEXE	Pour accéder à un enregistrement, on utilise un «index» qui indique «l'adresse»* de l'enregistrement*. Ex. : le chapitre sur le système solaire se trouve à la page 22 du tome 4 de l'encyclopédie. Cette méthode combine l'avantage de l'accès direct (plus rapide) et de l'accès séquentiel (peu de perte de place). (voir FICHIER INDEXE. INDEX).
ADI	Service du Ministère de l'Industrie chargé de tous les problèmes de l'informatique.
ADIRA	Association pour le Développement Informatique Rhône-Alpes (formation, clubs, conférences, ...).
ADRESSE	Localisation d'une donnée en «mémoire centrale»* ou en «mémoire auxiliaire»*.
ALEATOIRE	– «Au hasard» – Se dit d'un fichier dans lequel les enregistrements* sont stokés sans ordre préétabli.
ALGOL	Langage* de programmation*
ALGORITHME	«Processus de calcul permettant d'arriver à un résultat final déterminé». Par extension, c'est la description précise de la méthode à employer pour arriver à un certain résultat. Ex. : pour ajouter deux nombres, il faut connaître l'algorithme de l'addition qui précise tous les détails de l'opération (tables, règles de retenue, etc...).
ANALYSE	Etude détaillée d'un ensemble consistant à décomposer celui-ci en ses plus petits principes constituants.

* *L'astérisque qui suit certains termes portés dans la colonne «Définition» signifie que ces termes sont explicités, par ordre alphabétique, dans le présent Lexique.*

ANALYSE FONCTIONNELLE	Relève de la technique de l'organisation des données* et de leur traitement*.
ANALYSE ORGANIQUE	Technique de l'analyste-programmeur qui traduit l'analyse fonctionnelle dans le langage choisi et en fonction du matériel et de son «logiciel de base»*. Précède la programmation même (voir PROGRAMMATION).
ANALOGIQUE	Quand une information est représentée par une valeur susceptible de varier de façon CONTINUE, comme par exemple la tension aux bornes d'un microphone, on dit que c'est une information analogique. Pour qu'un ordinateur puisse utiliser une telle information, il faut la numériser : cette opération s'appelle la conversion analogique-numérique. (voir DIGIT). La conversion transforme le signal analogique en digit* binaire*.
ANSI	Organisme américain de normalisation.
APPLICATION	Fonction, dans l'entreprise, regroupant de manière cohérente des travaux effectués en vue d'obtenir un résultat simple, à laquelle on applique la méthode d'organisation informatique des données. Ex. : application «gestion de stock». L'ensemble des application forme le «système général de traitement des informations»* de l'entreprise.
ARCHITECTURE	Façon d'organiser les éléments d'un système* entre eux (Voir Fiche I.3).
ARTICLE	Groupe de données constituant une unité par rapport à un traitement déterminé. Par exemple, dans un logiciel de gestion, chaque client constitue un article.
ASCII	Table de traduction. Le Code ASCII permet de définir des caractères (lettres, chiffres, ponctuation) en les codant sur 7 bits. On l'utilise dans les échanges entre ordinateur* et périphériques*. En lui ajoutant un huitième bit*, chaque caractère est traité comme un octet*.
ASSEMBLEUR	Langage de programmation symbolique* très proche du langage machine.
AUDIT	Contrôle du bon fonctionnement d'un système*.
AUTOMATISME	Liaison d'un automate avec un ordinateur destinée à lui faire exécuter, dans des situations diverses, les opérations prévues dans un programme. (voir ROBOT, ROBOTIQUE).
AUTOMATE	Voir ROBOT

B

BANDE MAGNETIQUE	Support magnétique de données sur bande, de grande capacité, à «accès séquentiel»* uniquement, constitué d'un ruban de matière plastique souple recouvert, sur une face, d'une touche magnétisable.
BANQUE DE DONNEES	Ensemble de collections de données, c'est-à-dire de fichiers voisins ou apparentés, mis à la disposition du public.
BASE DE DONNEES	Système d'organisation des données sur disque indépendant de l'organisation des traitements. Le lien entre base et traitements se fait par le SGBD*.
BASIC	Langage de programmation* le plus répandu pour les «ordinateurs individuels»*. Il est à la fois évolué et facile à apprendre. Les instructions de base sont rédigées en Anglais.
BATCH	Traitement des données* par l'ordinateur* sous forme de «lots», effectué avec un décalage plus ou moins important dans le temps par rapport à la saisie* des informations, et sans intervention de l'utilisateur. (Contraire : traitement interactif). Ex. : augmentation et édition d'un tarif. (Voir Fiche I.3.

BAUD	– Unité de vitesse de modulation. – Assimilable dans certains cas à une vitesse de transmission. (1 baud = 1 bit/seconde)
BINAIRE	Le code* binaire utilise le système de calcul en base 2, qui ne comporte que deux états : Ø et 1.
BIT	Elément d'information qui peut prendre deux valeurs arbitrairement notées Ø et 1. Abréviation de «binary digit»* : chiffre binaire.
BUFFER	Mémoire-tampon assurant l'échange entre «l'unité centrale»* et un périphérique*.
BUG	Tout programme* que l'on vient d'écrire comporte – hélas – des bugs, c'est-à-dire des erreurs qui l'empêchent de fonctionner correctement.
BULLE	Surface de 3 microns environ constituée d'un matériau qui a la propriété de se magnétiser très localement sous l'action d'un champ magnétique. Les mémoires à bulles sont des mémoires permanentes de grande capacité.
BUREAUTIQUE	– Utilisation conjuguée de nouvelles techniques pour faciliter les travaux de bureau : traitement de texte, courrier électronique, tableurs, gestion de fichiers, graphiques. – Etude des changements ainsi apportés dans les secrétariats.
BUS	Ensemble de signaux permettant au processeur* de converser avec ses mémoires et ses périphériques. Ils sont véhiculés dans le canal.* Certains bus sont normalisés et utilisés par de nombreux micro-ordinateurs : S-100, IEEE 488, ... (Voir CANAL).
BYTE	Ensemble de 8 bits correspondant à 1 caractère (voir OCTET).

C

CAHIER DES CHARGES	Document à caractère contractuel définissant précisément les fonctions d'un système informatique à installer. ((Voir Fiche I.5).
CANAL	Appareil assurant l'échange de données* entre la mémoire centrale et les périphériques (Voir BUS).
C A O	Conception Assistée par Ordinateur. Matériel et logiciel orientés vers l'assistance à la conception pour les bureaux d'étude.
CARTE	Plaque supportant des «composants électroniques»* assemblés en circuit.
CASSETTE	«Bande magnétique»* de petite et moyenne capacité, enfermée dans un container facilitant sa conservation et sa manipulation.
CATALOGUE	Voir LIBRAIRIE
C C D	Composant photo-électrique utilisé dans les caméras reliées à des ordinateurs.
CENTRE SERVEUR	Ordinateur* pouvant être interrogé par un utilisateur éloigné disposant d'un terminal*. (Voir Fiche Videotex).
CHAINE DE CARACTERES	Succession de caractères formant un ensemble intelligible. (Voir CONCATENATION).
CIRCUIT IMPRIME	Dépôt métallique conducteur placé sur un support isolant pour constituer des éléments plans de câblage ou pour créer des éléments plans de circuit dans un schéma général de câblage.

CIRCUIT INTÉGRÉ	Se présente sous la forme d'un petit boîtier muni de deux rangées de pattes métalliques. Dans ce boîtier se trouve une pastille de silicium de quelques millimètres carrés dans laquelle sont diffusés des transistors*, des diodes* et des résistances formant une fonction électronique complexe miniaturisée. (Voir PUCE).
CLE D'ACCES	Critère de recherche dans un «fichier indexé»*. Ex. : dans un fichier indexé sur le code client, la clé d'accès sera le code client.
COBOL	Langage* de programmation* très orienté vers les applications* de gestion.
CODE	Système* de symboles* permettant de représenter une information*. Ex. : code ASCII, code client.
CODE BARRES	Code* décryptable par lecture optique, basé sur l'utilisation de barres de largeur et d'espacement divers imprimées sur des étiquettes, permettant l'identification d'un objet.
COMPATIBLE	– Un périphérique* est compatible avec un ordinateur* si on peut les connecter sans difficulté. – Deux ordinateurs* sont compatibles si les programmes* écrits pour l'un fonctionnent correctement sur l'autre.
COMPILATEUR	Programme permettant de traduire en «langage machine»* (binaire*) un programme écrit en «langage évolué»* (Basic, Cobol ...) et ainsi de l'exécuter. Il traduit le «programme source»* en «programme OBJET»* exécutable. Il y a donc dans les fichiers deux programmes : le programme SOURCE écrit par le programmeur et proche du langage humain, le programme OBJET traduit par le compilateur et exécutable par la machine.
COMPOSANT ELECTRONIQUE	Constituant élémentaire d'un circuit (Transistor*, diode* ...).
CONCATENATION	Assemblage de plusieurs «chaînes de caractères»* constituant un ensemble intelligible.
CONFIGURATION	Ensemble des matériels* constituant l'infrastructure d'un système informatique de traitement des informations. (Voir Fiche I.3).
CONFLIT D'ACCES	Lorsque deux utilisateurs veulent intervenir simultanément sur la même donnée, il y a conflit d'accès.
CONTROLE DE PARITE	Bit de position 1 rajouté lors de l'écriture d'un caractère lorsque le nombre de bits de position 1 correspondant à celui-ci est impair. A la lecture, un contrôle basé sur la vérification de la parité des bits de position 1 permet de déceler toute anomalie. (Voir BYTE, BIT).
CONTROLEUR	Organe permettant à l'ordinateur* de contrôler un périphérique*. Ex. : le contrôleur de disquettes* est un ensemble de circuits permettant à l'ordinateur de commander «l'unité de disquettes»* et de dialoguer avec elle.
CONVERSATIONNEL	Voir INTERACTIF
CORRESPONDANT INFORMATIQUE	Personne, dans une entreprise, assurant la liaison entre les informaticiens et les utilisateurs.
CP/M	«Système d'exploitation»* de disquettes» très répandu (SED) : les ordinateurs individuels utilisant CP/M sont, en principe, compatibles, même s'ils sont de marques différentes.
C P S	Caractères Par Seconde
C P U	Control Processing Unit : Unité centrale comprenant le micro-processeur et la mémoire centrale.
CRASH	Panne Système (= panne de matériel)
CRYPTOGRAPHIE	Chiffrage des informations pour en assurer la confidentialité.

D

DATA	Mot anglais = DONNEE
DATA BASE DBMS	«Base de données»* (Voir SGBP).
DEBIT	Vitesse de transfert dans un canal*
DESSIN D'ENREGISTREMENT	Définit, dans l'enregistrement, une place précise et inaliénable à chaque zone (voir ZONE).
DIDACTICIEL	Logiciel* spécialisé pour l'enseignement.
DIGIT	Elément d'information* qui peut prendre un nombre fini de valeurs différentes. Ex. : code binaire*.
DIODE	«Composant électronique»* à base de semi-conducteurs = Redresseur de courant. (Voir SEMI-CONDUCTEUR).
DIRECTORY	Voir LIBRAIRIE.
DISQUE AMOVIBLE	Disque interchangeable
DISQUE DUR	Disque magnétique de grande capacité (10 à 300 millions de caractères) tournant à vitesse élevée (2.400 t/m).
DISQUE FIXE	Non interchangeable (Voir WINCHESTER).
DISQUE SOUPLE	Disquette*
DISQUETTE	Disque souple, amovible, de petite taille (3,5, 5,8 pouces*), de faible capacité (100.000 à 3 millions de caractères)' enfermé dans une enveloppe de protection fixe à la manière d'une cassette* de bande magnétique.
DONNEE	Forme donnée à l'information*, lors de la saisie, destinée à faciliter son traitement par l'ordinateur. (Voir SAISIE).
D O S	Disk Operating System. — Est un «système d'exploitation»*.

E

E A O	**E**nseignement **A**ssisté par **O**rdinateur. Utilisation pédagogique de l'ordinateur où celui-ci joue le rôle de répétiteur ou de simulateur permettant de tester les différentes réactions de l'élève.
E B C D I C	Table de traduction. Le code EBCDIC permet de définir des caractères en les codant sur 8 bits*.
ELECTRONIQUE	Technique utilisant les variations de grandeur électrique pour capter, transmettre et exploiter de l'information.
EMULATEUR	Dispositif permettant de simuler, sur un appareil, le fonctionnement d'un autre appareil.
ENREGISTREMENT	Est constitué par un ensemble d'informations élémentaires ayant un lien logique entre elles. Ex. : Code client, raison sociale, adresse : cet enregistrement regroupe 3 informations de ce type (Voir ZONE, DESSIN, FORMAT, LONGUEUR). N.B. — Il est plus exact de dire : «données»* à la place d'informations, lorsqu'on parle du contenu d'un enregistrement.
EPROM (ou REPROM)	**E**rasable **P**rogrammable **R**ead **O**nly **M**emory — Mémoire électronique reprogrammable et effaçable.

EXPLOITATION	Ensemble des opérations liées à l'utilisation d'un ordinateur.

F

F A O	Fabrication Assistée par Ordinateur.
FICHIER	Ensemble de données* de même nature stockées sur un support quelconque: fiches cartonnées, cassettes, disques... Un fichier est caractérisé par la nature de son support, son volume, ses modes d'accès*, sa fréquence d'utilisation. Les données sont réparties dans les enregistrements*.
FICHIER ALEATOIRE	Voir ALEATOIRE
FICHIER DIRECT	Fichier à «accès direct»* grâce à la connaissance de l'adresse* (ou localisation) exacte de l'enregistrement.
FICHIER INDEXE	Fichier à «accès indexé» grâce à l'adjonction au fichier d'un index*, sorte de table des matières permettant de retrouver l'adresse* de l'enregistrement.
FICHIER RELATIF	Accès par la position de l'enregistrement* par rapport au début du fichier*.
FICHIER SEQUENTIEL	Fichier à «accès séquentiel»*, qu'on lit intégralement depuis le début jusqu'à ce qu'on rencontre l'enregistrement* cherché.
FILE D'ATTENTE	Données* provenant des terminaux*, stockées en attente de traitement par l'ordinateur (ordinateur multi-poste, télématique*). (Voir CENTRE SERVEUR).
FIRMWARE	Mot anglais : «logiciel de base»* du constructeur.
FLOPPY	Mot anglais : disquette*
FORMAT D'UN ENREGISTREMENT	Constitué par le dessin et la longueur de l'enregistrement. (Voir DESSIN, LONGUEUR).
FORMATER	1ère opération à effectuer lors de l'utilisation d'un disque vierge : consiste à demander à l'ordinateur de préparer le disque afin qu'il soit utilisable par celui-ci en fonction de son propre système d'exploitation.
FORTH	Langage* de programmation* très structuré.
FORTRAN	Langage* de programmation* évolué adapté principalement aux utilisations scientifiques.
FRONTAL	Ordinateur* gérant les terminaux* et les «files d'attente»*.

G

GENERATEUR	Programme* permettant de créer plus facilement d'autres programmes.
GESTIONNAIRE D'APPLICATION	Progiciel* directement utilisable pour réaliser une application* sans faire appel à un programmeur.
G P A O	Gestion de Production Assistée par Ordinateur. Matériel et logiciel adaptés à la Gestion de Production.

H

HARDWARE	Mot anglais : quincaillerie. Employé pour : matériel* informatique. (abr. : HARD).

HEXADECIMAL	Système de numération en base 16 dans lequel on utilise les chiffres de 0 à 9 puis les lettres de A à F. Par exemple 10 en décimal s'écrit A en hexadécimal; 17 en décimal s'écrit 11 en hexadécimal.
HORLOGE	Dispositif électronique permettant de synchroniser le fonctionnement du micro-processeur*.

I

INDEX	Table classée permettant un accès rapide aux données* d'un fichier*.
INFORMATIQUE	Traitement* automatique et rationnel de l'information* considérée comme support de la connaissance et de la communication.
INFORMATION	Indication permettant la connaissance d'une chose.
INITIALISATION	Procédure* de mise en route.
INPUT / OUTPUT	Mot anglais : Entrée / Sortie
INTÉGRÉ	– Se dit d'un système de traitement* où toutes les applications* sont reliées les unes aux autres. – Se dit d'un logiciel* contenant tableur*, gestion de fichiers, traitement de texte*, graphiques.
INSTRUCTION	Ordre, consigne, précis exprimé dans un langage* de programmation*.
INTERACTIF	Se dit d'un traitement* permettant une conversation entre l'ordinateur* et l'utilisateur. Les informations* sont traitées pas à pas grâce au dialogue homme-machine. Ex. : saisie d'une commande. (Contraire : BATCH*). (Synonymes TEMPS REEL*, CONVERSATIONNEL*).
INTERFACE	– Ensemble matériel* et logiciel* nécessaire pour assurer la communication entre un périphérique* et un ordinateur*. – Programme* permettant de relier deux applications*. Ex. : facturation et comptabilité.
INTERPRETEUR	Programme* qui traduit un programme écrit en «langage évolué»*, au fur et à mesure du déroulement de celui-ci, en langage machine, permettant ainsi son exécution (Comparer avec COMPILATEUR).
ITEM	Mot anglais : ARTICLE*

K

K (ou Koctets ou Kbytes)	Unité de capacité mémoire : 1024 octets.
K UTILISATEUR	Capacité mémoire du matériel réellement disponible pour l'utilisateur.

L

LANGAGE	Mode de transmission de l'information*.
LANGAGE ÉVOLUÉ	Langage* proche de la logique humaine (traduit en langage machine par un compilateur ou un interpréteur. Exemples : Basic, Fortran, Cobol, Pascal, APL, Pilot, Forth, Lisp, Logo, LSE ...). (Voir Fiche I.2).
LANGAGE INFORMATIQUE	Ensemble de caractères, de symboles* et de règles permettant de les assembler, utilisé pour rédiger les instructions* à donner à un ordinateur*.

LANGAGE MACHINE	Le langage machine est le seul que comprenne directeur un ordinateur*. Il est exprimé en code* binaire*.
LANGAGE SOURCE	Voir PROGRAMME-SOURCE
LIBRAIRIE	Liste du contenu d'un disque magnétique
LIGNE SPÉCIALISÉE	Ligne téléphonique réservée spécialement à l'acheminement des données* informatiques par un seul et même utilisateur. (Voir MULTIPLEXEUR).
LISTE LISTING LISTAGE	Etat informatique imprimé.
LOGICIEL	Programme* ou ensemble de programmes.
LOGICIEL D'APPLICATION	Programme* de l'utilisateur lui permettant d'assurer ses traitements*.
LOGICIEL DE BASE	Fabriqué par le constructeur et livré avec l'ordinateur*, il permet de faire fonctionner celui-ci.
LOGICIEL INTÉGRÉ	Voir INTÉGRÉ
LOGICIEL SPÉCIFIQUE	Se dit de programmes* conçus spécialement pour une application*, par opposition à PROGICIEL*.
LONGUEUR D'UN ENREGISTREMENT	Se calcule en nombre de caractères par addition des caractères contenus dans chaque zone de l'enregistrement. (Voir ZONE, VOLUME).
LUDICIEL	Logiciel* de jeu.

M

MATÉRIEL	Ce terme revêt une signification précise dans le contexte informatique, par opposition à son autre composante : le logiciel*. Il désigne l'ensemble des pièces mécaniques et des «composants électroniques». (cf. HARDWARE et SOFTWARE).
MÉMOIRE	Organe qui permet de stocker, dans l'unité centrale* ou en dehors d'elle, une information* afin de l'utiliser ultérieurement.
MÉMOIRE AUXILIAIRE	Est constituée par toutes les «mémoires rémanentes»* externes à «l'unité centrale»*, capables de stocker des données* : bandes magnétiques, cassettes, disques, disquettes ... (voir Fiche I.2).
MÉMOIRE CENTRALE	Mémoire électronique, volatile (voir MÉMOIRE VOLATILE) installée dans «l'unité centrale»* de l'ordinateur*.
MÉMOIRE ELECTRONIQUE	Constituée de «composants électroniques» susceptibles de présenter deux états : chargé, non chargé, traduisant ainsi le code binaire* et représentant un bit*. Toute coupure électrique ramène les composants à l'état neutre et vide la mémoire (Voir MÉMOIRE VOLATILE).
MÉMOIRE MAGNÉTIQUE	Constituée d'éléments microscopiques de matière magnétisable par aimantation sous l'effet d'un champ magnétique. Chaque élément est susceptible d'avoir deux états : aimanté, non aimanté, traduisant ainsi le code binaire* et représentant 1 bit*. Un élément reste aimanté après coupure de l'alimentation électrique (Voir MÉMOIRE RÉMANENTE).
MÉMOIRE DE MASSE	Voir MÉMOIRE AUXILIAIRE
MÉMOIRE MORTE	«Mémoire électronique»* que l'on ne peut que lire (voir ROM et EPROM).

MÉMOIRE PERMANENTE	Voir MÉMOIRE RÉMANENTE.
MÉMOIRE RÉMANENTE	Caractéristique d'une mémoire composée de supports magnétiques : les données qu'elle contient ne sont pas détruites par la coupure de l'alimentation électrique. C'est une mémoire permanente. (Contraire : MÉMOIRE VOLATILE).
MÉMOIRE VIRTUELLE	Se dit d'une technique de gestion dynamique de la «mémoire centrale»* permettant l'exécution rapide de plusieurs programmes* simultanément. La mémoire centrale est partagée en cadres de taille égale qui recevront chacun un bloc correspondant extrait de chaque programme. Une «mémoire auxiliaire»* stocke momentanément les autres blocs (ou «pages») des programmes. Chaque bloc exécuté est remplacé dans la mémoire centrale par le bloc suivant. «L'unité centrale»* travaillant beaucoup plus rapidement que les périphériques*, l'utilisateur a l'impression que les programmes s'exécutent simultanément alors qu'en fait, ils s'exécutent par intercalements successifs des blocs. La mémoire nécessaire au stockage de tous les programmes, s'ils s'exécutaient simultanément, étant beaucoup plus grande que la mémoire réelle centrale, cette technique donne l'illusion d'une mémoire virtuelle.
MÉMOIRE VIVE	«Mémoire électronique»* que l'on peut lire, effacer, charger à volonté.
MÉMOIRE VOLATILE	Caractéristique d'une «mémoire électronique». Les données qui s'y trouvent sont détruites par toute coupure de l'alimentation électrique. C'est une mémoire temporaire. (Contraire : MÉMOIRE RÉMANENTE).
MICRO-ORDINATEUR	Ordinateur* de faible volume dont l'unité centrale* de traitement arithmétique et logique est constituée par un micro-processeur»*;peut être multi-poste. (Comparer ORDINATEUR INDIVIDUEL).
MICRO-PROCESSEUR	«Circuit intégré»* très complexe regroupant les logiques de traitement*, qui a permis l'apparition des «ordinateurs individuels»*. C'est un processeur très miniaturisé (voir PROCESSEUR). (Voir MICRO-ORDINATEUR).
MINIDISQUETTE	Voir DISQUETTE.
MINITEL	Terminal*, standard permettant d'accéder à des «centres serveurs»*. VIDEOTEX
M.O.	1 Million d'Octets.
MODEM	Abréviation de : «modulateur - démodulateur». Appareil permettant la transmission des «données» par une ligne téléphonique ordinaire. Voir Fiche I.3).
MODULATION	Convertit les données informatiques codées en langage numérique, en données codées en langage analogique* seul accepté par les modes de transmission des réseaux.
MONITEUR	Programme* créé par le constructeur, chargé de surveiller le fonctionnement de la machine et des programmes. (logiciel de base).
MONITEUR VIDEO	Ecran cathodique relié à l'ordinateur*, et permettant de visualiser les instructions* ou les informations*.
MONO-PROGRAMMATION	Un micro-processeur* ne peut exécuter qu'une seule instruction à un instant donné, et donc un seul programme* ou une seule séquence de programme : c'est la mono-programmation. Par opposition, la multi-programmation est une technique d'exploitation* permettant d'exécuter simultanément plusieurs programmes.
MOT	Groupe de caractères ou de bits* occupant une seule position mémoire dans l'ordinateur* (8, 16 ou 32 bits).
MOT-CLÉ	Mot caractérisant sans équivoque l'information* contenue dans un texte d'une «banque de données»*.

MOT DE PASSE	Code personnel autorisant l'accès à certains traitements.
MS - DOS	«Système d'exploitation»* standard sur micro 16 bits.
MULTIPLEXEUR	Permet de connecter plusieurs utilisateurs sur une même ligne de transmission spécialisée. (Voir LIGNE SPÉCIALISÉE).
MULTI-PROGRAMMATION	Voir MONO-PROGRAMMATION.

N

NANO-SECONDE	1 milliardième de seconde.

O

OCTET	Ensemble de 8 bits*, permettant de stocker des valeurs entières de 0 à 255. Correspond à un caractère. (En anglais : BYTE).
ONDULEUR	Appareil permettant de pallier les incidents d'alimentation électrique (coupures et micro-coupures).
O E M	Original Equipment Manufacturer. Sociétés spécialisées dans la vente de solutions clés en main (matériel* + logiciel*) faisant souvent appel à l'assemblage de matériels d'origines diverses.
ORDINATEUR	Au sens restreint, l'ordinateur est une machine programmable de traitement* de l'information* composée uniquement de «l'unité centrale»*. Il a besoin, pour être exploitable, de périphériques* divers selon l'utilisation que l'on veut en faire.
ORDINATEUR INDIVIDUEL	Ordinateur monoposte (1 seul écran clavier) construit autour d'un microprocesseur*. (Voir MICRO-ORDINATEUR).
ORDINOGRAMME	Traduction graphique d'un algorithme*, de l'expression d'une suite logique d'actions. Plus précisément : schéma représentant graphiquement le déroulement d'un programme* au moyen de symboles* normalisés.
ORGANIGRAMME	Même sens que ordinogramme, en informatique.

P

PACK	Concerne uniquement le chargement d'informations numériques dans les enregistrements* : consiste à mettre deux chiffres dans un seul octet pour gagner de la place. La zone de l'enregistrement concernée est dite packée.
PACKAGE	Voir PROGICIEL.
PARTITION	Partie de la «mémoire centrale* réservée à un utilisateur ou un programme*. Il peut y avoir plusieurs utilisateurs ou programmes, donc plusieurs partitions. (Voir MULTI-PROGRAMMATION et MÉMOIRE VIRTUELLE).
PASCAL	Langage* de programmation évolué.
PÉRIPHÉRIQUE	Appareil permettant d'entrer des informations dans l'ordinateur* ou de les en sortir (ENTRÉE / SORTIE) : clavier, «moniteur vidéo»*, imprimantes, «mémoires auxiliaires»*. (Voir Fiche I.2).

PLAN INFORMATIQUE	Projet d'informatisation d'une ou plusieurs applications* décrivant le système de traitement souhaité et l'évolution des moyens informatiques à mettre en œuvre dans le temps, accompagné du budget correspondant.
PL 1	Langage* de programmation* IBM.
PORTABLE	Micro-ordinateur transportable, mais sans alimentation électrique autonome.
PORTATIF	Micro-ordinateur de taille et de poids réduits alimenté par piles ou batteries.
POUCE	Mesure anglo-saxonne : 25,4 m/m.
PROCÉDURE	Méthode utilisée pour atteindre un certain résultat.
PROCESSEUR	Organe capable d'assurer le traitement* complet d'une série de données*. (Voir MICRO-PROCESSEUR).
PROGICIEL	Logiciel* complet et documenté conçu pour une application* concernant un certain nombre d'utilisateurs différents, acheteurs potentiels. Ex. : progiciels de comptabilité, progiciels de gestion de stock de quincaillerie, progiciels de gestion de pharmacie... Moins chers qu'un logiciel spécifique, ils mettent l'informatisation à la portée du plus grand nombre. Certains progiciels peuvent recevoir des adaptations leur permettant de correspondre au plus près aux besoins des utilisateurs. (En anglais : PACKAGE).
PROGRAMMATION	Rédaction des programmes* d'instructions destinés à obtenir de l'ordinateur* les résultats demandés par l'utilisateur.
PROGRAMME	Ensemble des instructions* rédigées dans un langage* donné (en «langage évolué»* la plupart du temps), et que doit exécuter l'ordinateur. Ex. : programme en basic calculant les payes d'une entreprise. Par extension, on parle d'un «programme de paye».
PROGRAMME OBJET	Programme en langage machine directement exécutable.
PROGRAMME SOURCE	Programme, en langage évolué, non directement exécutable par la machine. Le compilateur* ou l'interpréteur* le traduisent en programme objet *.
PROLOGUE	«Système d'exploitation»* français.
PROM	Mémoire PROM (**P**rogrammable **R**ead **O**nly **M**emory). Livrée vierge, cette mémoire, une fois programmée par l'utilisateur, devient une mémoire ROM. (Voir ROM).
PUCE	Petite surface de silicium incorporée dans un «circuit intégré» et dans laquelle a été réalisée la logique du circuit. (Voir CIRCUIT INTÉGRÉ).

R

RAM	Mémoire RAM (**R**andom **A**ccess **M**emory). (Voir MÉMOIRE VOLATILE).
RACK	Meuble ou boîtier permettant d'enficher des cartes. (Voir CARTE).
RANDOM	Signifie : aléatoire.
RÉALISATION	Regroupe «analyse organique»* et programmation*. On parle de la réalisation d'une application.
RÉPERTOIRE	(Voir LIBRAIRIE).
RÉSEAU	Ensemble des lignes de transmission connectant des terminaux* à un ordinateur* central.

RÉSEAU LOCAL	Connexion de plusieurs ordinateurs ou micro-ordinateurs au sein d'un même établissement.
RÉSEAU COMMUTÉ	Lignes téléphoniques normales. Peuvent être utilisées pour transmettre des données* si elles passent par des centraux automatiques. (Voir LIGNE SPECIALISÉE).
RÉSEAU TRANSPAC	Réseau spécifique des transmissions de données constitué d'un ensemble d'ordinateurs spécialisés reliés entre eux par des liaisons à grande vitesse.
RÉSIDENT	Tout ce qui est à l'intérieur de la «mémoire centrale»* à un moment donné.
ROBOTIQUE	Ensemble des études et des techniques tendant à concevoir des systèmes* capables de se substituer à l'homme dans ses fonctions motrices, sensorielles et intellectuelles. (Voir AUTOMATISME).
ROBOT	Appareil capable d'agir de façon automatique pour une fonction donnée. (Voir AUTOMATISME, ROBOTIQUE).
ROM	Mémoire ROM (**R**ead **O**nly **M**emory). Ne peut être que lue.
ROUTINE	Terme anglais francisé désignant : programme ou sous-programme.
RS 232 C	Norme fixant les caractéristiques du type de transmission utilisé pour relier un ordinateur* à un périphérique.

S

SAISIE	Transcription des informations sous forme codée sur un support normalisé (carte perforée, disque...) en vue de leur traitement : la saisie transforme une information en donnée*. (Voir DONNÉE).
SAISIE DIRECTE	Appelée aussi «ON-LINE».* Met directement en relation l'appareil de saisie* avec le fichier-maître.
SAISIE INDIRECTE	Appelée aussi «OFF-LINE». Met l'appareil de saisie en relation avec un fichier intermédiaire de stockage (cartes perforées, documents à lecture optique, disquettes, bandes magnétiques) qui sera lu ensuite par l'ordinateur principal et stocké dans le fichier maître.
SAUVEGARDE	Les supports magnétiques étant effaçables accidentellement, ou destructibles, il convient d'effectuer périodiquement des copies de leur contenu et de sauvegarder celles-ci dans un lieu adéquat.
SEMI-CONDUCTEUR	Les matériaux semi-conducteurs ont une conductibilité qui se situe à mi-chemin de celle des conducteurs et celle des isolants. Par l'apport de corps étrangers, ils acquièrent des propriétés spécifiques qui permettent de réaliser transistors*, diodes*, circuits intégrés*.
SEQUENTIEL	Consécutif
SERVEUR	Ordinateur gérant une «banque de données»* accessible par MINITEL ou par d'autres ordinateurs.
SÉLECTION	Signifie CHOIX (ne pas confondre avec TRI).
S G B D	**S**ystème de **G**estion de **B**ase de **D**onnées. Pour une «base de données»*, c'est le logiciel* qui permet d'introduire les données*, de les mettre à jour et d'y accéder. (En anglais : DBMS : **D**ata **B**ase **M**anagement **S**ystem).
SOFTWARE	Mot anglais : logiciel (abr. SOFT).
SOURIS	Dispositif s'apparentant à une poignée et permettant de désigner un point de l'écran en positionnant un curseur sur l'emplacement désiré.

SPÉCIFIQUE	Voir LOGICIEL SPÉCIFIQUE
SPOOL	Fichier d'édition différée, sis en «mémoire auxiliaire»* et généré par le «système d'exploitation»*. Stocke les données* issues d'un traitement*, en attention, d'impression
S S I I	Société de Service d'Ingénierie Informatique
SYMBOLE	Signe conventionnel abréviatif.
SYSTEME	Combinaison d'éléments qui se coordonnent pour parvenir à un résultat.
SYSTEME EXPERT	Intelligence artificielle. Ordinateur capable d'exploiter l'acquis historique qu'est l'expérience associée à la mémoire chez l'homme. Le système appelé aussi ordinateur de la 5e génération, en est au stade de la recherche.
SYSTEME D'EXPLOITATION	Voir LOGICIEL DE BASE et Fiche I.2.
SYSTEME GÉNÉRAL DE TRAITEMENT DE L'INFORMATION DANS L'ENTREPRISE	Ensemble cohérent d'applications* reliées entre elles. (Voir APPLICATION).

T

T A F	Travail A Façon.
TABLEUR	Programme* spécialisé de création et de manipulation interactive de tableaux visualisés utilisables pour différents suivis. (Ex. : Balance règlements) ou simulations.
TÉLÉTRAITEMENT	Mode d'exploitation d'un ordinateur* qui traite des données* qui lui sont transmises par voie téléphonique, télégraphique, hertzienne.
TÉLÉMATIQUE	Techniques et services association télécommunications et informatique.
TEMPS RÉEL	Voir INTERACTIF et Fiche I.9 – Un robot fonctionne en temps réel pur.
TEMPS PARTAGÉ	Voir TIME-SHARING.*
TERMINAL	Appareil qui permet, à distance, d'avoir accès à une «unité centrale»*.
TEST	– Essai d'un programme* avant sa mise en œuvre opérationnelle. – A l'intérieur d'un programme*, examen d'une information conduisant à une de ces 2 réponses : vrai ou faux.
TIME-SHARING	Partage du temps d'utilisation d'une «unité centrale»* entre plusieurs utilisateurs. (cf. MULTI-PROGRAMMATION).
TRANSISTOR	«Composant électronique»* amplificateur, modulateur, détecteur de courants.
TRAITEMENT	Ensemble des opérations exécutées pour obtenir un résultat (en informatique : calcul, contrôle, stockage, édition...).
TRAITEMENT PAR LOTS	Voir BATCH. *
TRAITEMENT DE TEXTE	Une machine de traitement de texte est un «ordinateur individuel»* doté d'une imprimante qualité courrier et d'un support d'archivage des textes (disquettes* en général). Le logiciel de cet ordinateur est un programme* spécifique spécialisé qui permet de créer un texte, de le modifier, de l'imprimer. Son utilisation pour la création de rapports, textes, lettres, documentations, ou leur correction, conduit à un gain de temps important.

TRANSPAC	Société privée chargée de la télécommunication entre ordinateurs utilisant un réseau spécifique.
TRI	Classement selon certains critères. (Ne pas confondre avec SÉLECTION).*

U

UNITÉ CENTRALE	C'est la partie de l'ordinateur*, pris au sens large, qui contient processeur* et «mémoire centrale»*. (Voir ORDINATEUR et Fiche I.2).
UNITÉ DISQUES ou DISQUETTES	Périphérique* permettant lecture et écriture sur les disques ou disquettes.
UNIX	Système d'exploitation* multi-poste standard.

V

VIDEOTEX	Utilisation des téléphones et des téléviseurs comme terminaux* de télé-informatique. (Ex. Antiope, Télétel).
TELETEX	Communication inter-entreprises utilisant les réseaux* de transmission de données. (Ex. : TRANSPAC) *.
VOLUME	– Quantité d'informations à traiter. (Ex. : Nombre de clients, nombre de factures...). – Volume d'un fichier : longueur d'un enregistrement* multiplié par le nombre d'enregistrements que le fichier sera susceptible de contenir. (Voir LONGUEUR) *.

W

WINCHESTER	Type de «disque dur fixe»*.

X

X - 25	Procédure normalisée de transmission utilisée par TRANSPAC*.

Z

ZONE	Dans un enregistrement, c'est l'emplacement réservé à une information élémentaire. Ex. : code client, raison sociale, adresse : cet enregistrement comporte 3 zones contigües. (Voir ENREGISTREMENT, DESSIN).