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Professor Francois DURET,
Department of Oral and Maxillofacial Imaging,
School of Dentistry, University Park,
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Los Angeles, CA 90089-0641 USA.

Dear Sir,

Thank you very much for your kind letter of May 1,1993.

I would like to inform you that a precis of your lecture is published in our '' Dandanpezeshkan ''.

We are looking for a special occasion to publish your lecture as deliewered in the Convention.

We are looking forward to receive more literatures on dentistry from you in the near future.

Sincerely Yours,

Dr. M.Reza Taherian,

Chief Editor.

The Sopha CAD CAM

F . DURET, DSO, PhD , MS

IRAN

For over three years it has been possible to find commercially available dental CAD/CAM devices, that is , machines capable of producing dental prostheses using robotised and computerized methods. These systems can use sensor devices or some camera to make the impression in a unique way . Such devices will either transmit this information directly manufacture a die , the counter part of the cavity or certain intermediary elements, or they will use the resources of the computer to design the restoration on the monitor. Such restorations may be very simple , or the most sophisticated prosthesis . In the latter instance the CAD-CAM[1] systems in the purest sense of the term will use a modeling process on the computer screen before the milling process.

This study shows that if the systems are part of a same family , their performances, their price, or their testing time vary and requires a detailed study.

Nevertheless, today, it remains the only known alternative for the future.

Traduction de mon article Iranien
du "Dandanpezeshki"

Key Words:

-Prosthesis
-computer Science
-CAD CAM
-Classification
-Handling
-Performances

[1]Computer Assisted Design and Computer Assisted Manufacturing.

1-principe:

The dental CAD-CAM is the application of the Computer Assited Design and Computer Assisted Manufacturing technologies to dentistry to which the first stage of capturing three dimensional informations or impressions has spefically been added.

Twenty years after it invention by Duret (1) , it is a complex device at the technological level and its operating mode implies three distinct stages: the data acquisition, the designing of the product, and the manufacturing.

The first stage ,which has for a long time been the most specific of the dental application of the CAD-CAM aims at collecting the maximum of information from the patient' s mouth and asociating with it certain diagnostic elements of the therapist. This garantees the smooth functioning of the software and also the designing of a prosthesis of good quality.

After finishing the preparation of the zone to be treated, the dentist then proceeds to the reading with the help of an electro-mechanic sensor or electro-optic probe (camera) directly in the mouth or on the model. Even if certain systems have substituted a micro sensor for optical reading and if others have substituted a second CCD[2] (2) for a laser beam, the outlines of these systems remain very close.

The second part of his first stage consists in indicating on the object appearing on the screen, a certain number of points and informations whose specific identification is crucial to some zones of the prothesis(contacts, marginal limit, occlusal elements...). This interactive operation is in general followed by a calculation of three dimensional surfaces.

The second stage derives more or less from the industrial CAD system (3) . Based on some general 3D[3] computed programs, some specific applications for each branch of odontology will be developed and used.

The one that seems the most important among the originalities of this stage is the capacity to produce a part (prothesis) unknown at this stage, relying uniquelly on the buccal data, some specific programs and a certain skill in the manipulation of the objects displayed on the screen. That implies an adaptive program to comply with all the cases that the user may encounter and at the same time a very professional program in order to avoid the big errors when designing.

Very few dental systems come out with this stage of designing; it is present only in sophisticated devices. Many systems (wrongly called CAD-CAM systems) just reproduce a negative of the shape of the cavity to which a homothetic variation is added or subtracted so as to ensure the ciment space.

Finally the third and last stage of this system corresponds to the milling of the previously designed object. In general it is a conventional milling based on solutions ranging through different levels on the technological scale (4) i.e. starting from the simple pentographic reproduction device duplicating a handcrafted model, upto a genuine 4 axes milling machine with automatic changing of tool and automated control.

In any case, the finishing of a prothesis produced by dental CAD-CAM is done manually before it is fitted in the mouth. This finishing can last anywhere from a few minutes to an hour.

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[2] Charge Coupled Device

[3] or program working in the three dimensions of the space

2-The systems

As everyone has in the professional journals , there are a number of systems available or are on their way, if we are still to beleive the authors. We do not want to select a few or establish an order of preference.This is your chose. That is not the role of a member of one of the teams (we work on the Soha) favoring a device, that was derived from my thoughts, in comparison to another. This king of position is much " against the most elementary ethic". This to short description is therefore, strictly analytical:

21-The Celay system (5) :

As already stated , the celay system is a pantographic system, and it des not pretend to be a CAD-CAM system, but which clearly presents an idea of robotisation. It was invented by a Swiss dentsite, Dr Eidenbenz, from Zurich dental school and has being used in that school for over two years. It was introduced for the first time at the exhibitionat Munich in 1990 by the Swiss company Mikona, which manufactures and commercializes it..

The Celay system is composed of two parts, the one that tracers all of the all the surfaces of the patern - a mechanical sensor - and the other that mills a ceramic block by manually following the movements of the sensor through a pantographic arm having 8 directions of freedom.

This device produces inlays and onlays, including their occlusal surfaces.

22-The Procera System (6):

The Procera system invented by Dr Anderson and developed by Nobelpharma, is similar to the Celay process, but more complex. It was intorduced for the first time in 1987.

This system combines the mechanical sensor reading and milling with a second milling by electro-erosion. The machines are extremely large. There is also a welding device that allows to making an intermediary titanium bar between two ceramic copings. The Procera system permits the production of a titanium coping for a metal ceramic crown.

23-DCS TITAN (7) :

The DCS Titan system is the result of the work of Dr Schlegal, Tavor and Zaborsky, that we saw for the first time at Berlin in 1989. The DCS Titan was also presented at Munich in 1990 for the first time.

With this system, we are entering into the devices that can digitize the information . The Titan System is a system which wants to use the data issuing from the reading tool for creating numerical information that can be used by a computer and not for directly guiding the milling tool.

25-CEREC (8) :

The Cerec system, invented by Pr. W. Moermann and M. Brandestini, and developed by the Siemens Company, was introduced for the first time in 1985, i.e. about five years after it s invention. We are there fore dealing with a device which, although it has not changed a great deal, has largely proved itself.

This interesting device can be classified with the devices using the optical impression technique. It consists of a camera (about 65 000 pixels) ,, an image processing station (currently in 2.0 version), assocaited to a Macintosh type monochrome monitor and to an hydraulically drive 1 1/2 axis micro-milling machine . This was recently changed to an electronically driven system in the new version.

In spite of what we first thought, we can classify this device with the CAD-CAM system. The modeling does not use surfaces, but use lines called iso-planes. The aim of Cerec is to produce the internal part of the inlays, onlays or ceramic veneers.

26-Sopha Dental CAD-CAM (9-12):

This french system was invented by Pr F. Duret and developed by several companies before being taken over by the Sopha Bioconcept Corp . This company is the dental branch of the Sopha Development Corp , one of the chief leaders in computerized medical equipment, accliamed world-wide in the imaging field for over 20 years.

Needless to say, the system which took over 20 years to perfect, contains the three stages of a dental CAD-CAM device.

- optical impression capturing, with multiple images, using a CCD camera of about 250,000 pixerls associated with an image processing system (3.1 version). This is caled the Opticast.
- design and modeling of the future prosthesis, with a surface modeling and also of the preparation, of the adjacent and opporite teeth on a color monitor. This is the BioCad .
- milling with the help of a numerically controlled machine tool. This is the DMS .

The aim of this device is (will) the production of posterior and anterior crowns (1989-1990) single and multiple inlays (1991), ceramic copings (1991), and probably fixed partial dentures (1993 - ?) with static (1990) and dynamic (1993 ?) occlusion, in composite (1985) ceramic (1991) and titanium (1992)

Clinical procedure:

After having carved a preparation depending on the material that is used , the practitioner takes a classical impression and casts it in a lambertian plaster and allows him, after a few minutes, to leave the CAD-CAM operations to the technician. The operator of the CAD-CAM, i.e. the technician or assistant, will place the model on the Opticast in order to take the required pictures and to

characterise, on the screen, certain points that are essential for the achievement of the crown (3 to 7 mn). After the modelization stage, the operator will work on the BioCAD screen. In the process, he will have the option of either letting the automatic procedure go on, after controlling the finish line, till the design of a complete crown, including the static occlusion in gnathologic concept (3 to 4 mn) or he will have the possibility of intervening and controlling each of the modelization stages (10 to 15 mn). In both cases he will be able to proceed to the necessary final touches at the end of the process. He only has to place his bar of material in the machine and wait for the end of the milling (between 50 and 80 mn). Meanwhile, he can characterize and finish the prosthesis that was previously produced, and he can take other impressions or perform crown designs.

We are now going to review the different stages in detail.

-the impression:

This impression is divided into two phases, the picture acquisition itself, and the interactive indication of certain elements that are necessary to ensure that the BioCAD station will work at its best.

-picture acquisition:

It is undoubtedly the most important moment of the realization of the prosthesis. Here we are still confronted with the need for exactness which is necessary for any data capturing system. After having placed the model on the mechanized stand of the Opticast, the practitioner takes views after moving the model in different positions with the help of small buttons which activate small motors for rotation and translation.

-interactive action:

The operator indicates a certain number of clinical points, the points which the BioCAD station will use for constructing the crown. It is necessary to indicate the position of the three spheres of correlation by moving a circle on the screen with the help of the mouse. On the occlusal view, which is the most important of all, the operator will indicate the cusps, two external points, one on the buccal and the other on the lingual side (which permit to retrieve the height of contour), the contact points that we need for the future crown, and the general sketching of the occlusal groove. On the occlusal opposite view, that of the bite, the positions of the cusps and the grooves will be defined. Finally the finish line can be drawn in the most precise way on all the views (a zoom on the screen can be used). All these actions do not require more than 4 mn.

-Computer assisted design (CAD):

The work on the BioCAD screen is a decisive moment, for it permits to construct the future crown from the optical impression and a library of theoretical teeth.

In order to make his work easier, the operator has the possibility to

- either design his crown automatically
- or proceed interactively.

-automatic work:

On the screen appears the preparation with the finish line that was chosen and drawn, based on the partial drawings which were done in the interactive stage of the impression. If we accept the drawing, this choice will permit us to obtain on the screen, a few minutes later, a crown that is ready to be milled. If necessary, we may do some final interactive alterations by using the menu "correction". We did not have to intervene as the design was done blindly. In order to understand how the software has worked, let us follow the stages of the interactive method.

-the interactive work:

The use of a specifically dental software gives an unquestionable clinical character to the handling of the operator. The menu must be followed from top to bottom and each stage

consists of a sub-menu that allows to precise or modify the general result obtained in the previous stage.

-internal: Being the first stage in the realization of the future crown, it permits to construct the internal surface of the crown. . If the dentist clicks on the "internal" line, he can have access to a sub-menu through which he can modify this finish line (redefine completely, partially modify or going back to the initial finish line) and chose a cement space.

-environment: During his interactive work, just after the impression, the operator defined a certain number of points other than the finish line. These points will automatically appear in their exact position on the adjacent teeth. However, he may wish to modify their initial position. This work is possible during the stage called "environment".

-framing: It is a strictly visual stage permitting to extract the theoretical tooth from the data-base of the computer, to control it in reference to the lines defining the reshaping box .

-modeling: This is a very important stage in the process. Although the modeling stage is entirely automatic, it allows us to see the reshaping of the theoretical tooth into a tooth that is clinically adapted to the morphology of the patient. This stage provides the second surface of the prosthesis, i.e. the external surface in a very short time. Finally, let's mention again that the crown was reshaped in reference to the general adjacent cuspidian lines. The arcade line will be ideal in the absence of opposite teeth ; when the opposite teeth are present, it will be necessary to go to the next stage, i.e. the occlusal stage. Of course we suppose that it is the case here.

-occlusion (optional): Being the second main stage of the CAD session, the static occlusal fit of the tooth obtained so far will be done in two phases, one being the overall matching of the cusps and opposite fossa with the central fossa and cusps of the crown , and the second phase being their exact displacement . Eventhough we find a certain analogy between this software and the Wax up works of Lundeen , which makes us call it "optical Wax up", the use of a CAD software helps us to ameliorate the inter-arcade relations by controlling the respective positions of each centric stop through successive cross-sections or by modifying them interactively.

-correction (optional): One of the first menus perfected in the marketed CAD software (in 1988) was the "correction" menu. In this menu we find many possibilities for modifying the crown that is thus obtained, from the slightest displacement of a surface point in order to increase or diminish the curve of the crown as if we added or took away some of the wax (where its original name in french "matière" comes from) to the modification of the cuspidian angle of the crown (very useful in the cases of Bruxism). It is impossible to detail this menu in such a short article but its handling is simple for a man of dental art.

-check thickness (optional): This menu allows to define the minimum space that can be accepted between the external and internal surface of the prosthesis.

34-the milling of the prosthetic part (CAM):

The second last stage in the production of the prosthetic part corresponds to its milling in a material that was specially developed for this purpose. It is performed by a numerically controlled machine tool. For this purpose, we have at our disposal, some ceramic bars _ Dentspley, Duceram or Ivoclar, that we place in the machine tool. We do not have to choose the bar, for there is only one

size ; but we have to verify if the tools are not worn out. In that case, a special menu at the BioCAD station will warn us about it by indicating the tools that need to be changed. The machine tool will first carve the internal surface, which most needs accuracy, in a bar that is still very rigid. Then it will mill the external surface up to the point where only two lugs remain, which are situated in the disto-facial and mesio lingual areas in order to respect the the contact-area surfaces.

This process is automatic and is performed under lubrication with water in a closed circuit.

35-characterization and finishing:

The last stage, called the finishing stage, has no specific character, which means that if we have a crown in Duceram, we will use the Duceram characterization technique, if we deal with Ivoclar (EPS Empress) we will use its kit, same principle for Dicor, ...etc. Every practitioner will use his own method, i.e. the one he usually practices without having to go through any specific training.

3-CONCLUSION

The CAD/CAM method which appeared around 1970 enters our dental offices twenty years later. The battles that were waged against the technique and the skeptics were numerous and very often discouraging. Today we know that nothing will be the same in dentistry and that our concept will have a very important impact in the next few years.

The battle between the ancients and the moderns in dentistry, so celebrated in romantic literature, is coming to an end. No one can have any doubts about this new technology. It has just begun to shake up our professional habits and allows us to review some of our research and associated techniques. It offers a tool that allows our researchers and clinicians to forget this postulate that has always shocked us and which made our profession that of a knowledgeable parakeet: good manual dexterity in working with wax was more important than making a beautiful prosthesis.

In our opinion it is more important to know why we use an occlusal concept rather than to know how to work with wax.

A dental revolution, a conceptual revolution, or a materialist revolution, CAD/CAM must now prove itself in our dental offices. What good is research if it is only used by one person? CAD/CAM must prove itself on site.

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