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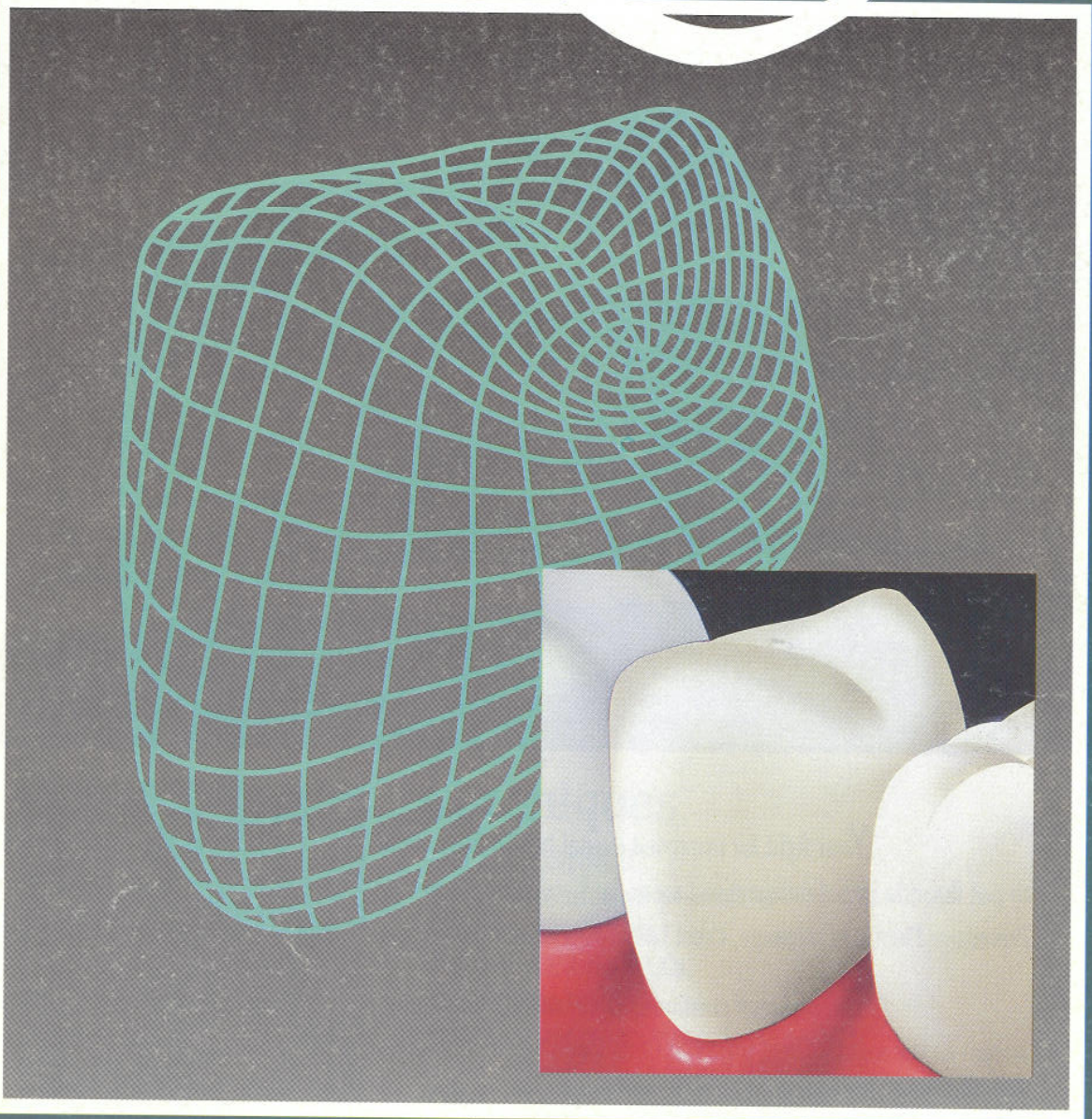

▲Computers in Dentistry

▲L'informatique en médecine dentaire

La prothèse dentaire, le progrès et la prudence

En prothèse dentaire comme dans tout autre domaine scientifique, le progrès est une suite de réalisations qui s'échelonnent dans le temps. Chaque découverte, chaque innovation en suit une autre, chacune ajoutant au bagage des connaissances acquises. Et chacune contribue — du moins nous l'espérons, car autrement pourquoi nous en soucier? — au bien-être de nos patients.

Qui peut dire que telle découverte en prothèse dentaire a été plus importante qu'une autre ou qu'elle constitue la plus grande contribution? Est-ce le premier porte-empreinte mis au point par Delabarre en 1820? la découverte (par hasard) de la vulcanite par Goodyear en 1851? le composé élaboré par Stent en 1857? Ou plutôt ne seraient-ce pas les alliages de Black, l'appareil de coulé inventé par Taggart en 1907, l'articulateur de Gysi ou les expériences de Pollar avec la gélose qui, en 1925, ont donné naissance aux hydrocolloïdes? On se souviendra sûrement du Branemark des années 1980 et, dans cent ans d'ici, le nom de Duret sera sans doute associé à la mise au point de la CFAO.

Aujourd'hui, les scientifiques de la robotique proclament bien haut que l'ordinateur changera la prothèse dentaire comme on ne l'a jamais fait auparavant. Songez donc, la prothèse dentaire sans empreintes salissantes, l'occlusion numérisée avec une précision infinie, plus de prothèses temporaires, — et tout cela en un seul rendez-vous. Ah, la prothèse dentaire! Ah, le progrès!

Mais prudence, chers dentistes, prudence! D'après le *Webster*, la prudence est une vertu: ''la faculté d'agir avec mesure et discrétion, la sagesse mise en pratique''. Les inventions et les innovations passent et s'oublient. On se souvient seulement de celles qui rendent service. En médecine dentaire, tout ce qui est mécanique est toujours susceptible de changer. C'est le facteur humain, les échanges de personne à personne, l'intégrité du dentiste envers son patient, ''la sagesse mise en pratique'' qui ne doit jamais changer.

Le dentiste doit tirer parti des connaissances nouvellement acquises seulement pour améliorer les soins qu'il donne au patient. Certes, si une nouvelle méthode soulage les malaises, fait épargner du temps, améliore la santé dentaire et allège la corvée du praticien, utilisez-la. Mais jamais aux dépens du patient. C'est là un simple principe de la règle d'or, c'est là ce qu'on appelle faire preuve de professionnalisme.

Dans les Prairies, est philosophe celui qui garde les choses en perspective, sachant que les actions d'un homme envers ses semblables ne doivent jamais être gouvernées par des possessions non humaines. . . En effet, une machine, un fusil, un cheval ne seront jamais meilleurs que la personne qui les utilise. △

Le rédacteur en chef,
P. Ralph Crawford, DMD

Computers in Dentistry

L'informatique en médecine dentaire

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Computers in Dentistry

Ralph Crawford, DMD

• PART ONE •

CAD/CAM: The computer moves chairside

The Computer Moves Chairside!

For years the computer has been well established in the dentist's reception area and business office. Now it has moved into the operatory.

In this issue, the Journal staff endeavors to inform its readers of some of the recent technology which undoubtedly will influence the practice of dentistry in the future.

In describing certain products and methods, the Journal does not necessarily advocate one over the other, or ascribe that it is the only one available. The Journal wishes to thank Dentsply International, York, Pennsylvania and Tekscan Inc. of Boston for their assistance in the preparation of the material. We are also grateful for the opportunity granted to attend the CAD/CAM Symposium in Vancouver and for the interview with Dr. Francois Duret.

On March 19, last, in Vancouver, a bit of history was made in Canada. For the first time, leaders in the field of CAD/CAM met in one room and presented a clinic to a group of interested dentists and technicians, outlining a system of prosthetic fabrication that will revolutionize dentistry as we know it today.

For years, dental office personnel have utilized computers at their desks and in their business offices. Now the computer is also in the operatory and directly transmitting information from the oral cavity to the computer-assisted design (CAD) and computer-assisted manufacturing (CAM) phases. A micro-milling machine will produce a finished crown or bridge of prepared teeth, ready to be cemented in less than one hour.

Dental prosthetics will never be the same again.

CAD/CAM is the first major change in technology since 1907, when Dr. Taggart demonstrated the casting of gold inlays. Certainly the lost wax technique was known to the ancients; a recent Toronto exhibition of Holy Land artifacts displayed such metal ornaments created 20 centuries before Christ. Now, however, Vancouver's March audience was told that impressions, models, wax and casting machines may well be exhibited as historic relics in the next century.

Dr. John Nasedkin, a Vancouver prosthodontist who mentors TEST, the Esthetic Study Team, arranged the one-day symposium that brought together Dr. James P. Duncan, Mechanical Engineering Professor Emeritus from the University of British Columbia; Dr. François Duret of Grenoble, France, originator of the application to dentistry of the CAD/CAM system; Dr. Diane Rekow of Minneapolis, an instructor in Orthodontics and a Post Doctoral Fellow in Biomechanical Engineering at the University of Minnesota; and Dr. Reggie Caudill, Professor of Mechanical Engineering and Director of Robotics and Computer Graphics at the University of Alabama in Tuscaloosa, U.S.A.

Dr. Duncan, who graduated in 1941 from the University of Adelaide, Australia, Mechanical Engineering and holds a Doctor of Science degree from the University of Manchester, traced the early involvement of computers in industry, particularly in the automobile sector. He has had a lifelong interest in shape reproduction, including the first uses of computers in that field back in 1954.

Dr. Duncan gave a graphic demonstration of optics engineering by displaying a perfect plaster replica of his own head – a remarkable likeness – which was computer designed and milled in minutes at a cost of $100.00.

He indicated that for dentistry there are special added concerns and problems. Industry is used to working with simple equations such as spheres and cones, but dentists are working with natural shapes where God the Creator, He alone, knows the equation. ''If we want to design it (i.e. the natural shape) then we have to have some means to equate it.''

Dr. Reggie J. Caudill, who began his work independently of Drs. Duret and Rekow, is involved at the University of Alabama with developing DESS, a Dental Expert Support System, where three-dimensional imaging data of the dental arch will lead the dentists through the appropriate design

Left to right are: Drs. James P. Duncan, mechanical engineering Professor Emeritus, University of British Columbia; Dr. François Duret of Grenoble, France, originator of the application to dentistry of the CAD/CAM system; Diane Rekow, of Minneapolis, an instructor in Orthodontics and Post Doctoral Fellow in Biomechanical Engineering at the University of Minnesota; John Nasedkin, a Vancouver prosthodontist who monitors the Esthetic Study Team, and Reggie Caudill, Professor of Mechanical Engineering and Director of Robotics and Computer Graphics at the University of Alabama.

sequences and automatically manufacture dental prostheses utilizing computer controlled milling machines and robotics.

Dr. Caudill initially worked with robotics in industry attempting to decrease the time interval between design and production – leading to his work relating to the elimination of the dental impression phase and then automating the production stage. He emphasized that in attempting to achieve a one hour turnaround in the production of a crown, the quality must be maintained. Dentistry must take its lesson from the automobile industry. It doesn't matter what it costs, if it isn't quality it isn't going to survive. He indicated that in dentistry they are talking quality and precision in the range of 25 to 50 microns. The key, according to Dr. Caudill, falls back on the imaging system; can the computer actually get the data with the precision we need?

When questioned whether the future dentist will need an engineering degree, Dr. Caudill replied that certainly the dentists would have to be computer-oriented but the computer programs and the software would need to be developed in an ''expert-friendly-interphase'' manner.

Dr. François Duret, originator of dental CAD/CAM, outlined how he had toiled for 20 years to bring his system to the commercial market stage. It was in 1970 that he first conceived the idea that the combination of physics and the computer could revolutionize dentistry. (See below, ''François Duret – a man with vision'')

Following the preparation of the tooth, or teeth, Dr. Duret's CAD/CAM system is essentially a three-step procedure. The teeth are prepared traditionally, but feather edge margins are avoided. Chamfers and butt-edges reproduce better in the computer system. Dr. Duret is quick to point out that there is no substitute for excellent preparations. ''The computer'', he said, ''cannot make a poor preparation better.''

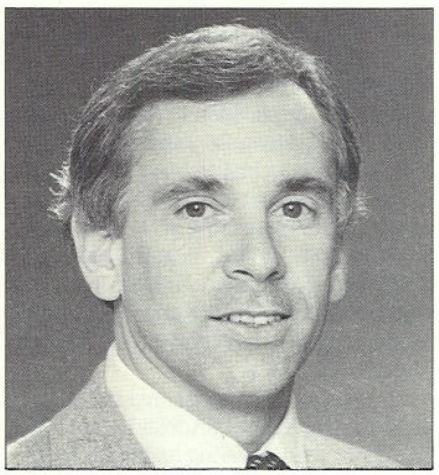
The first step is the Optical. The system utilizes a laser-diode scanner and a charge-coupled-device (photo receptor) to produce images of preparations and surrounding areas. As the scanner is passed over the teeth, the signals are relayed into the computer and displayed on the video monitor. A foot control allows the image to be fixed on the screen for examination, and a series of acceptable images are selected for the second step – Design. An experienced operator can complete this step in three minutes or less.

Step two, CAD, or design phase, determines the internal and external shapes of the required prostheses, right down to the exact micron space needed for the luting agent. The internal crown configuration has already been decided by the scan of the preparation. The external requirements calls upon the computer library to select a particular morphology to be placed in the optical impression. A scan of the area before the preparation can be used to 'place' the patient's own tooth morphology back into the required space. Individual, specific anatomy and contact points can be designed as required.

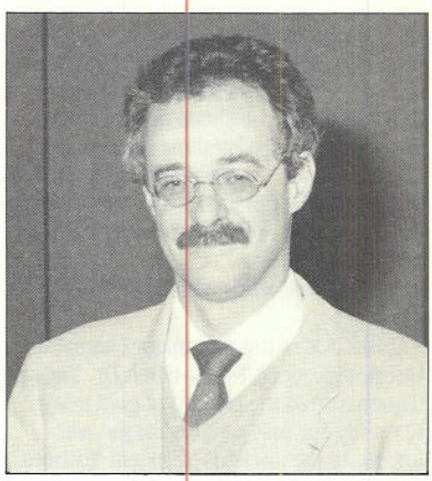
The success of any prosthesis is the occlusion. Intrinsic within the Duret system is a computer recording device which follows the movements of the mandible in order that the surface of the crown or the bridge is in harmony with centric occlusion and excursive movements. The complete design requirements – selection of prosthesis and its articulation – is achieved in under ten minutes. ''And'', says Dr. Duret, ''it is not necessary for the dentist to know the physics, just be familiar with the computer software.''

Step three is CAM, the manufacturing of the prosthesis. A three-axis micro-milling machine controls automatically, from a blank of pre-selected material, the internal/external shapes of the crown or bridge to a tolerance of 50 to 80 microns, all within 15 to 20 minutes. The audience was reminded that Dr. Duncan's and Dr. Caudill's lectures indicated that industry had been auto-milling for years, just in larger dimensions.

Dr. Duret's original material of choice was Dicor, and it produced quality results. Although it was possible to select the shade via the computer, the Dicor crowns have to be hand finished and glazed by a technician before insertion. He is currently working on new materials and cements specific to CAD/CAM. The micro-milling machines cut from a solid block of material and is not dependent upon the variables of chairside mixes. Thus, new vistas of material technology



Dr. Reggie Caudill of the University of Alabama.



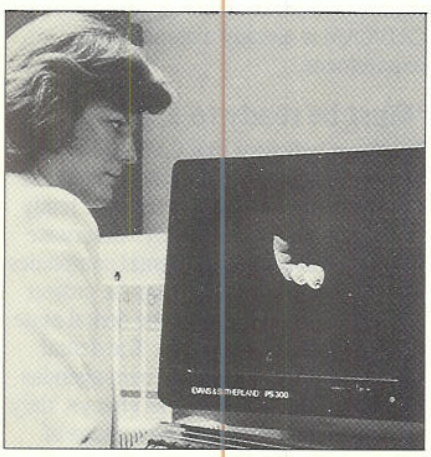
Dr. François Duret, of Grenoble, France.

are opened. Dr. Duret proposes that new material "configurations" could be aligned much like tooth substance itself.

As to integration into the dental office, there are, in Dr. Duret's opinion, three possible scenarios:

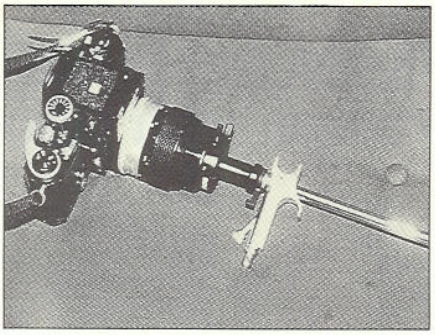
1. Complete integration: the design (CAD), and manufacturing (CAM) phases are controlled by a single dentist. A technician would be required for the CAM and subsequent color shading and polish.
2. Group office: two, three or more dentists could have an optical scanner each with one CAD and one CAM serving all.
3. Laboratory integrated: the laboratory has the CAM (most expensive component) and also the CAD which can be connected to the dentist's CAD by a modum.

When questioned as to the time frame for production, Dr. Duret said there are already systems functioning in France that are producing two crowns per day per unit. 1988 has been the target for commercial marketing. When asked about the total cost of the system, Dr. Duret replied, "I never answer this question. I am a scientific man, not a marketing man." The reported cost for the total Duret package, a scanner, CAD and CAM is said to be around $150,000 to $200,000.



Dr. Diane Rekow of the University of Minnesota

Dr. Rekow's background truly blends the knowledge of engineering and dentistry. For 12 years, she was an engineer, and at one time she headed a pacemaker development program. This was followed by a degree in dentistry, a certificate in orthodontics, a degree in Business Administration and a PhD. The wife of a dentist and mother of two children, she currently is developing a system of CAD/CAM that will construct restorations of gold, other metals, porcelain and



Modified 35mm camera views tooth preparation three dimensionally.

ceramic. The impression stages will be eliminated and the finished product micro-milled to a perfection fit. "The bottom line," she said, "is you must be able to produce restorations which are the equivalent to what you can now cast. If you can't do that, then you have no business releasing the system."

Dr. Rekow's experiments, (she has not yet reached the commercial stage), are designed to create a crown by first photographing the prepared tooth with a 35 mm camera containing a specially modified lens. In order to "see" the preparation three dimensionally, stereophotogrammetry is achieved by having two cameras mounted on the same system so each half of the stereo pair view the area simultaneously . . . much as it is achieved with human vision.

The lens system needs 25 mm clearance above the tooth (about two fingers width which is similar to the distance now required for conventional dentistry). The optic system records data from the top view down onto the tooth, buccal-lingual and takes information from the cheek side to record occlusion of the upper teeth. It can take dynamic information of centric occlusion, lateral excursions and protrusive paths.

The images are recorded on standard film (Ektachrome ASA 400) and developed by commercial processing. The color slides are then digitized to produce three-dimensional computer images. When the coordinates from all the images have been reconstructed and the paths of motion of the opposing dentition established, a computer based equivalent of perfectly mounted casts on an infinitely adjustable articulator is provided.

The external surface of the crown is automatically designed, taking into consideration the actual preparation, contact points, occlusion and anatomical contours, much like the Duret system. The data base has stored within it "ideal" crown forms for all 32 teeth and these are automatically modified to fit the unique requirements of any specific case. Upon commands generated by a CAM package, the Minnesota system, using a five-axis micro-milling machine, produces a gold crown in minutes.

It is Dr. Rekow's objective that the dentist's investment will be in the neighborhood of $5,000 US, which will provide the optic system and design software necessary to obtain the prosthesis impression and design. The information will then be sent to another location for machining. Once the system is perfected to produce quality metal full-coverage crowns, then there is the potential for partial frameworks and complete denture bases.

Truly the scientist, Dr. Rekow answered her own question, "Why bother? We have a good system now. Consider," she said, "the exciting possibilities."

- one appointment crowns.
- eliminate the need for impressions.
- no need for temporaries.
- no adjustments necessary.
- exciting opportunities for materials: new alternatives. Consider stainless steel crowns that will fit like gold. What if you could use a thinner, stronger material like titanium and have to reduce less tooth substance?

Her expectation is that the clinician can sit down with the data input within the system and say:

- this is the tooth.
- this is the occlusal scheme.
- this is the material.
- Now do It!

Although not represented at the symposium, there is a third CAD/CAM system about to emerge upon the dental market. Often referred to as the Swiss system after its developers, Dr. Werner Mörmann a dentist, and Dr. Marco Brandestini, an engineer, it trades under the name of CEREC. First demonstrated in Zurich in May 1986, their CAD/CAM is designed to produce only porcelain inlays which are reported to have excellent margin integrity. Utilizing Vita porcelain blocks, an inlay can be milled in five to seven minutes. The system does not however design the occlusal surface. This must be accomplished at chairside.

What then of the dental office of the future? CAD/CAM is here. It is not a question of when or where. It is a matter of marketing and money. The participants at the symposium varied as to their "guesstimates" of practical office systems and costs – one to two years and $5,000 to $200,000 – but there was no doubt that it will eventually be a dental office routine. △