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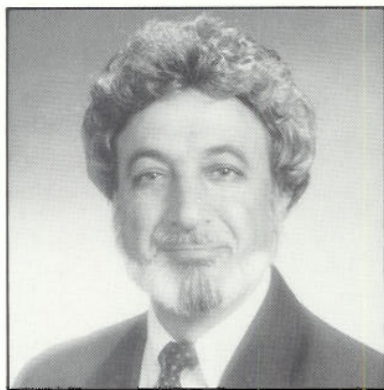
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CAD/CAM: Its Effects on the Practice of Dentistry

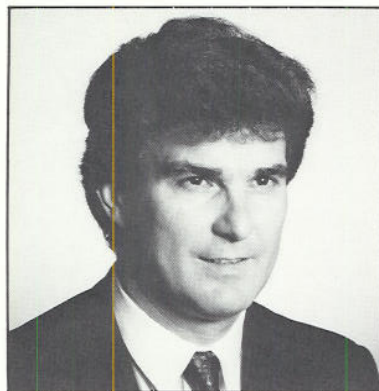
Computers have revolutionized the workplace, and they offer great opportunities for the future. One potential advancement may be the implementation of computer-aided design/manufacture (CAD/CAM) in the practice of restorative dentistry and prosthodontics. The authors of this Point of View share their hopes and concerns for this innovation. Will this technological advancement enable dentistry to make extensive restorations a one-visit treatment? Read on!

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In the industrial world, CAD/CAM (computer-aided design and computer-aided manufacture) is a process which consists of computers used to power an automation process. This process was non-existent 15 years ago. The industry is growing so rapidly that it is projected to have gross sales of over 20 billion dollars in 1990.

Francois Duret, a dentist in Grenoble, France, is responsible for introducing CAD/CAM into dentistry. Knowing that CAD/CAM could produce a highly precise piece of work by information fed into a computer, Dr. Duret imagined a piece of work such as a denture,

crown, inlay, or onlay to be manufactured automatically in a short period of time, perhaps in one visit to a dental office. For 12 years, Dr. Duret worked to enable a computerized laser eye to scan an area in a patient's mouth to receive a prosthesis.

CAD/CAM may be compared with the high-speed dental hand-piece. This process may change the dental delivery system dramatically. It will eliminate the sequential treatment of impressions, temporization and laboratory prescriptions, and the appointment scheduling of patients. There will be a tremendous compression of time and uniqueness in the manner in which the dentist will service the patient!

Using a micro-computer-controlled optical probe of Duret's design, the system translates the three-dimensional form of a patient's mouth into digital information, which the computer then uses to drive a high-precision machine tool to cut the restoration. The entire operation takes less than 30 minutes. The CAD/CAM system will replace the lost wax technique

with the micro-milling machine laser/computer. Through the use of a laser optical probe, the topology of the prepared tooth or teeth, or perhaps a ridge, in the case of a denture, is captured in a 3-dimensional image. The image is then connected by way of digital data and transmitted to a CAD/CAM computer, superimposing the restored tooth or teeth on the prepared tooth by memorized shapes. The CAD/CAM computer directs a digital controlled micro-milling machine to prepare a prosthesis from a block of metal, ceramic, or carbon fiber material in 20-50 minutes. The accuracy of fit for the prosthesis is within 20-30 microns, compared with the 200-micron tolerance limit of today's technology.

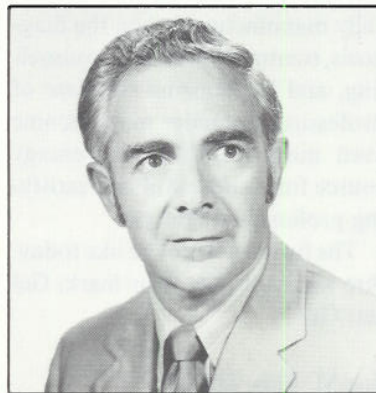
This process offers many advantages for the dentist and patient. Significant reductions of the dentist's operational time, which can be carried out in one visit, will be much more appealing to the person receiving the care. The dentist will find himself serving his patients in a remarkable environment. This will be especially attractive for those patients who value the quality and quantity of their time. The marketing of this service to attract new patients who share these common values is left only to the imagination.

One can imagine the different office designs which will take place in order to truly perform one-visit dentistry. The relationship between the laboratory technician and the dentist will, of necessity, be subject to a wide range of options. The creation of new dental materials to allow the accuracy of cosmetic colorization and durability will greatly enhance the economics of dentistry. The "Good Old Days of Dentistry" have yet to come for all of us who choose to enjoy these exciting times.

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New applications of existing computer technology will impact the cottage industry of Dentistry far more profoundly than have even the most imaginative contemporary usages of electronic bookkeeping, number crunching, scheduling, or data base marketing.

Plastic surgeons today are using computer-assisted design techniques to evaluate proposed cosmetic surgery. With a light pen instead of a scalpel, pretreatment photographs are manipulated on a television monitor to simulate surgery. The doctor and patient together can examine, discuss, and modify the projected results before undertaking treatment, greatly increasing the likelihood of a mutually satisfying outcome. This same system can easily be used to illustrate and evaluate cosmetic restorative dentistry. We can create, with patient collaboration, reversible "before and after" images to facilitate understanding, acceptance, and appreciation. The advantages and limitations of treatment can be seen on a monitor, alternative possibilities can be examined, and the desired result can be recorded for case design and future reference.

Optical and laser scanners will produce high resolution pictures of a dentition to be treated, viewable on a screen in any chosen perspec-

tive. The orthodontist or surgeon can manipulate the "model" to simulate tooth movement, extractions, or orthognathic surgery. The results of various treatment approaches can be instantly and simultaneously viewed and compared with ease and clarity. The pictures can be then digitalized and used to fabricate solid digitalized and used to fabricate solid diagnostic models, or stored on disk or tape as a permanent record for reproduction at a later time or in a different location.

Prototypes of pressure-sensing devices are now available to detect and map the location, timing, and intensity of occlusal contacts. The screened map is viewed chairside as an aid to occlusal equilibration procedures or in evaluating temporomandibular, joint disturbances. Hardcopy printouts can be included in the patient's written record.

Currently in experimental use is a color probe which reads reflected light from selected areas of a tooth. By comparing wave lengths with that of programmed standard color chips, an objective prescription can be produced for the technician to use in selecting porcelain shades.

Among the most significant developments are several imminently available computer-assisted manufacturing systems for restorative dentistry (called CAD/CAM). These systems can scan a prepared tooth, display the preparation on a chairside screen, and guide a milling machine to fabricate a restoration in one appointment. Impressions, bite registrations, temporizations, and conventional laboratory procedures and errors are totally eliminated. The scanning probe can be connected to the milling apparatus using telephone lines and a modem for the office preferring an off-site location, shared facility, or commercial laboratory. Once the preparation and relationships are recorded, provisional restorations (if desired), remakes, or modifications are a matter of a few key

strokes. Restorations requiring individualized coloration will involve a skilled technician, either in-office or at an outside location, with subsequent delivery. The dentist will be able to produce crowns, inlays, and bridges of metal, plastic, ceramic, or materials not yet created. These restorations will have excellent fit, predetermined morphology, precise occlusal interdigitation, and almost instant delivery. This will have monumental effects on the management and economics of private practice and on public health policy.

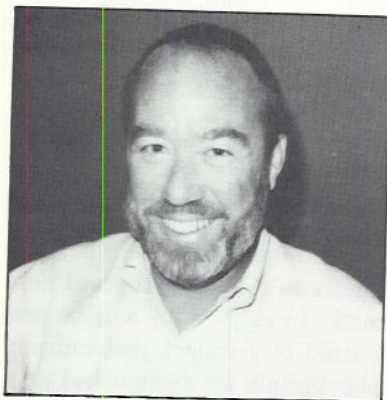
Historically, paradigm changes have involved applying concepts before their ramifications have been completely analyzed and clarified. The revolution of computerization is underway before it is understood. The early users of these CAD/CAM systems will have remarkable marketing and practice-enhancing advantages to reward their initiative and investment. Case presentation, patient involvement and acceptance, single visit restorations, and delegation of procedures to human and electronic auxiliaries will create rapid growth in the pioneer practices. Computer technology will have created the better mousetrap!

What happens when the dental followers join the leaders? A computer system will produce similar restorations for any user. Dentistry delivered by the most experienced and conscientious craftsman, by the youngest graduate, by "Doc in a Box," by a public service clinic, or by a third party-sponsored facility will look, fit, and serve equally! Will the proponents of cost containment demand equal fees? With caries and periodontal disease already problems of choice, soon to be controlled with public health measures such as fluoridation, vaccines, antibiotics, and therapeutic rinses, and with crowns being perceived as commodities, will fine restorative dentistry become price sensitive? "Mrs. Smith, your endodontic and periodontic treatments

are now completed. If you will select the smile of your choice, the parts department will have your crowns this afternoon!" If the hardware of dentistry is to become increasingly identical and robotically manufactured, then the diagnosis, treatment planning, counseling, and humanizing software of professional practice must become even more positively the energy source for a successful and satisfying professional lifestyle.

The future will not be like today. Are we ready? On your mark. Get set! Go!

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CAD/CAM systems will allow the artist in Dentistry a better way to serve those more discerning people who come for private care. CAD/CAM will reduce inconvenience to the patient by producing finished restorations in one visit—providing the object(ive) to the subject(ive) faster. CAD/CAM will extend the service time of the dental artist into his nineties and beyond, as he will be less dependent on his hands (objective) and more dependent on his mind (subjective). CAD/CAM will allow master dental artists to easily consult and design from anywhere on or off our planet.

CAD/CAM will free the dental artist to examine the relationship of periodontal ligament movement and meniscus compression. He will be

able to measure these movements until he finds the "Golden Average." Then he will discover that no one is either "golden" or "average," but, rather, is changing (why does my tooth hurt now? It's been that way for years.). CAD/CAM will lead to the discovery that, if subjective intent (knowledge, skilled, and loving care server) is good and the care is given to a values-aligned care receiver, the object (crown) is good.

CAD/CAM will provide the bionics, but the subjective cure comes through the magic channel of the care server. For this reason, CAD/CAM will have different impacts on private health care and public health (disease) care. Public health officials now project that there will be over one million people in the U.S.A. over 100 years old by 2050. That means that our 37-year-old patients have an excellent chance of being healthy, happy, productive 100-year-olds. How will that affect our commitment to excellence?

Dentistry has some new problems to solve. We must know more about the longevity of both human physiology and bionic technology. Expert systems and CAD/CAM will unite to help find solutions. Private health care will be dramatically impacted, as expert systems provide philosophy-driven models for health and wellness systems. They could be matched to one's felt needs as he enjoys his independent journey to wellness and health. Could these expert systems provide a smorgasbord of sound cures for obstacles in the path of wellness and health?

CAD/CAM may provide an opportunity to develop an holographic approach to patient care. There is a relationship between teeth, mind, person, doctor, family, work, play, love, and worship. Could the relationship be a hologram? Suppose we had a dynamic hologram, a kinetic model of this system? Would this be called psychoneuroimmunology?