Bites for the computer

Speech

presented by
Jef M. van der Zel
on the occasion of his acceptance
of the endowed chair of Computerized Dentistry
of the Faculty of Dentistry at the Universiteit van Amsterdam
on Wednesday, 15 September 2004

Rector,
board members of the Stichting Bijzondere Leerstoel DeguDent,
ladies and gentlemen,

On the thirtieth of October two thousand and three, the Board of the Universiteit van Amsterdam approved the establishment of the endowed chair of Computerized Dentistry within the Faculty of Dentistry. With this inaugural speech, I publicly accept this chair, which entails:
'Research into the integration of hardware and software in the context of dentistry and, to subsequently promote the development of user-friendly, efficient and cost-effective computer applications for diagnosis and treatment of patients for dental health care'.

BITES FOR THE COMPUTER

You are assuming that as a professor computerized dentistry I will address the wonderful potential of computers in dentistry. Taking into consideration the rapid pace of change within this field, however, the prefix ‘computerized’ may soon become redundant. I will indeed be discussing computer applications this afternoon, but I will focus also on how dentistry is developing within current ICT trends and responding to the dominance of the Internet and other computer networks. The primary goal of my speech is to demonstrate that computerized dentistry is much more than a strategic choice. It is a fascinating discipline, due perhaps to the fact that it is still in its infancy. Great developmental strides remain to be taken in this field; a fact that continually demands new research. This specialization also continually demands a new orientation of dentistry.

This afternoon, I will try to impart my fascination with CAD-CAM, which is short for computer-aided design and computer-aided manufacturing. Pioneers in this field, such as François Duret, Dianne Rekow, Lars Anderson, Sadami Tsutsumi and Werner Mörmann, share my long-standing interest in the potential of computers in the automation of the dental restoration process. The initial steps towards automated prosthetic production were taken in nineteen seventy-two with François Duret’s doctoral research. Few will forget how, in nineteen eighty-nine, Duret first presented a live demonstration of a chairside restoration before an audience of several hundred during the annual Chicago Mid-winter Meeting. The procedure, which at the time lasted four hours, can now be performed in less than a half hour. My interest in dental CAD-CAM was piqued several years earlier by an article in *Dentist News*, which was written by François Duret. I was immediately hooked. In nineteen ninety, when we were first able to grind ceramic crowns, Dianne Rekow, mechanical engineer and dentist from Minnesota, visited our CAD-CAM development team in Hoorn. She watched for at least twenty minutes until the crown milling process was completed. Sadami Tsutsumi, Professor of Bioengineering at Kyoto University, also visited our group. I also paid him a visit in Japan. Meanwhile, the individuals I have named have become a close-knit circle of friends on the technological battlefield that is the extremely young discipline of computerized dentistry. Despite being a relatively new field, software solutions have already changed several of the old paradigms with regard to fit, aesthetics, clinical longevity and functionality of restorations produced using CAD-CAM technology. In addition, we are at the dawn of a revolution in restorative and prosthetic dentistry.

State of affairs

Before I describe our current research projects, I would like to present a general overview of the state of affairs. The research addresses issues derived from restorative dentistry, using a technical approach that focuses on the interaction between user and the resulting computer applications. A key research objective of restorative and prosthetic dentistry is to gain insight into and thus optimize the processes involved in the restorative process of lost hard dental tissues. To date, these processes are largely the domain of the dentist. One research area highlights the developments that slowly, but surely, will lead to the replacement of restorative processes currently performed by the dentist with computer technologies. This can be attributed in part to the fact that prosthetic dentistry increasingly uses digital information technology, such as imaging and CAD-CAM technology, and the associated introduction of new materials. Five years ago, the Dental Materials Science section established a research project in close collaboration with the Department of Oral Function and the business community to investigate the development and application of CAD-CAM systems in restorative dentistry. The seeds for this project were initially sown during the implementation of a university research effort funded by the STW Technology Foundation, conducted by the Dental Materials Science section and the Utrecht University Department of Oral-Maxillofacial Surgery, Prosthodontics and Special Dental Care. As part of the joint venture between the Dental Materials Science section and the Department of Oral Function, several trainee assistants and visiting researchers are actively working on computerized dentistry at the Academic Centre for Dentistry. With this study in the field of clinical materials science, the section aims to support the clinical activities of the Academic Centre for Dentistry Amsterdam in providing state-of-the-art restorative and prosthetic dental care.

BITES FOR THE COMPUTER

Internet

The subtitle of the doctoral thesis I defended fifteen years ago was ‘The essence of knowledge is, having it, to apply it’; this being a two thousand five hundred-year-old saying of the Chinese philosopher Confucius. As you already know, the Western world currently has high grade information and communication networks at its disposal. These networks are home to an infinite amount of knowledge, which individuals can access simultaneously anywhere in the world. An incredible achievement, but I would like to raise a rather serious question: Do we know how to optimise the application of this wealth of knowledge?

Meanwhile, billions of pages of information are available online. Fortunately, sorting through this information has become child’s play due in part to such online search engines as Google. Available online since nineteen ninety-eight, this search engine derives its name from the number googol, which is equal to a one followed by one hundred zeros. It is the brainchild of Muscovite Sergey Brin and Larry Page, the son of an American computer sciences professor. Finding information on the Internet using search engines such as Google is still in its infancy. Meanwhile, search engines can already sort through image files, and this will soon be extended to include audio and video files. And in response to a spoken query about restaurants, a mobile phone will soon display the location of the nearest one. The PC, which we can refer to as the device, and the Internet, which we can refer to as the network, have been under development since the nineteen eighties. In just under a decade, the PC made its way into most Western households. The Internet required only five years to become a mass medium. This record pace has already been surpassed by that of the mobile phone, which needed only three years to gain mass acceptance. You have to be pretty sure of yourself to publicly doubt the pending social acceptance of mobile Internet.

Traditionally, dentists work alone. As a result, they rarely come across information about the experiences colleagues have with treatment methods, equipment, materials and pricing methods. Those dentists who are skilled in networking are already well aware of the benefit of exchanging information with colleagues online. Moreover, external databases containing specialist information and, for instance, photos depicting oral diseases, can expand dentists’ horizons and are being consulted to an ever growing degree. There is no shortage of information networks. There is a growing array of networks available. The speed of access to the Internet continues to rise. We are surrounded by local networks and global communication satellites. We use both fixed and mobile infrastructures. There is nothing preventing a dentist from accessing a constant flow of information. Life is becoming a never-ending download. Although the idea of enabling dentists to design their own restorations and devices online may seem trivial, the underlying idea is truly revolutionary. After all, to date, dental technicians have produced close approximations of what they thought dentists generally expected. Patient care, however, has become increasingly individualized. This involves meeting the unique wishes of each patient quickly and for the most attractive price.

Through the Internet the dental practice ‘owns’ the interface with the patient. The patients outsource their demand for goods and services to the information network, which enables us to closely approximate the essence of ‘provision of care’. Patients can increasingly be compared to small companies, approaching dental practices with a description of what they want, a list of specifications and conditions and a request for the most attractive offer. They will outsource their dental care needs to the information network, just as dental laboratories increasingly outsource their business processes. Laboratories were already accustomed to this before the advent of the Internet, albeit to a limited degree. In nineteen eighty-nine, already fifteen per cent of all restorations were outsourced abroad. This approach is new territory for the patient. This is the first time that patients are confronted with a reversal in the chain of care. Despite this fact, it is naive to assume that this reversal signals the beginning of the end of patient loyalty. After all, patients will continue to consult the dentist offering the best quality service. This requires that dentists familiarize themselves with their patients and, preferably, that they anticipate their needs. An effective relationship is fertile ground for a high degree of patient loyalty, conditional as it may be. Dentists who jeopardize the trust their patients have placed in them can be ‘replaced’ with the click of the mouse. The information networks offer sufficient alternatives.

Patient smart card

As it is, patients don't want any kind of fuss. What they want is to receive fast and convenient treatment during a single appointment. The push-behavior of dental care providers prevails. Not only do they offer a limited package of products and services, they also determine the patients treatment plans, the patients' method of payment, the security systems used to protect patients and what patients can expect from treatment. So genuine chain reversal is still a long way off. A patient smart card is badly needed. Each card includes information about the patient's preferences in terms of method of payment, transaction security and identification. No longer will the patient have to meet the needs of the dentist. In fact, these roles will be reversed. Representing a crucial step towards true reversal of the chain of care, the smart card will contain information about the medical and dental treatments previously performed and an overview of dental health status, substantiated with X-ray images. This portable information will facilitate the patients' ability to outsource their dental care needs via the information network. A patient smart card offers advantages to everyone involved. Stand-alone solutions in dental care are a thing of the past, increasingly replaced by a system which integrates administration, image processing and equipment. To date, systems have impeded the co-ordination of information and image material. The development of an open communication standard and a patient smart card obviates duplication of effort in entering data, as well as the subsequent errors this may entail. Computerized patients have a much greater say in things. Dentists who refuse to accept digital smart cards will be sidelined. Patients will also place ever increasing demands on privacy and integrity. The transition from paper-based to digital archiving increases the care sector's dependence on ICT, particularly in terms of research activities and patient treatment. Reliability, availability and continuity are guiding principles. The information that should always be available for health care purposes demands powerful and secure storage capabilities, for which the patient lays down the rules. Anyone who would like access to these patients will have to play by their rules.

The change

Dentistry is developing along several different tracks. Special and new treatment methods are becoming increasingly important. More dental practices will focus on an area of speciality. As a result, more information will need to be made available for more critical patients. A dental practice that does not provide anything less than visualizing patient information will likely fall out of favour.

Dental laboratories will have to fundamentally adapt on several fronts. They, too, will have to admit what their well-developed and less-developed qualities are. Dental laboratories that refuse and want to maintain their very traditional value chain in an integrated manner being horizontal or vertical will lose. They will not only find their core competencies coming under fire through the networks, but they will be assailed on several fronts at once. It seems to me that computerized outsourcing will play an increasingly important role in the production of dental restorations. The cost savings it already realizes, will only increase in the near future. Maximizing the use of information networks makes it possible to identify the most advantageous business process, price-quality ratio and supplier at any time of the day. In short, information networks will be used to maximize competitive advantage. Computerized outsourcing is only possible if dental laboratories are comfortable in sharing information about product systems, business processes and logistics with their business partners. Am I comfortable with that? Am I able to do that? Do I even want that? This is the dilemma facing today's dental laboratories.

If not for global information networks, developing nations would have had a reasonable chance of becoming influential regional powers. As it is, the most they can expect to achieve is serving as subcontractors for industrialized countries. Those who can afford to be at the leading edge, can make use of competitive advantages in a wide range of areas. This not only applies to production costs, but also what could be called the most precious commodity of all, information. Market information, distribution and storage information, client and supplier information. Information networks enable industrialized nations to produce goods more quickly, more efficiently and more inexpensively than developing nations.

Research

I would now like to present some information about our current and future research programmes. More specifically, I would like to talk about the SCANdent, ARMeD, CADDIMA and LOCATION projects. Each one directly addresses an aspect of bites for the computer and is motivated by the desire to effect drastic improvements to the user friendliness, efficiency and cost-effectiveness of dental care.

SCANdent (*dental scanner*)

Taking its name from dental scanner, the **SCANdent** project aims to develop a multifunctional intra-oral dental scanner to perform chairside scans of both tooth color and the preparation's geometry and surrounding environment. It is one of the most important strategic aims of computerized dentistry, as it represents the starting point for the computerized production of dental restorations, whether produced chairside by the dentist or at a centralized production facility. It means that dentists can quickly and conveniently provide patients with ceramic restorations, sometimes in a single appointment. Paired with state-of-the-art production technology, the aesthetic quality of these restorations can easily rival that of their hand-crafted counterparts. The intra-oral scanner enables dentists to go online and 'get' on the Internet the best price/quality restorations for his patient.

ARM*e*D (*Augmented Reality Meta-model for Dentistry*)

Nowadays, dental care without computers is difficult to imagine. Although there are legions of examples of computer applications in dentistry, such as digital X-ray systems, intra-oral cameras and chromameters, digital cavity and pocket depth meters, bite impression systems, interactive image processing and planning, CAD-CAM systems and digital patient file management, the computer's true breakthrough in dentistry has still to take place. To date, software to the extent that it was available has been highly device-specific. In ARM*e*D a graphical interface for prosthetics, implantology and orthodontics is being developed, made possible through the integration of various structural components, such as for example the tooth library and the scan and design software, with an open communication standard and central file management. The current approach to software development involves common elements, including iterative development, development of software geared to meeting the needs of users and the continually testing and prioritizing of requirements. The underlying rationale is that projects will enjoy greater success if the development team functions as a unit and the project applies recognized instances of best practice. Architectural risks should be addressed at as early a stage as possible, ensuring the manageability of any subsequent problems. This facilitates the creation of a feasible, stable and future-proof software architecture. The framework is based on Unified Modeling Language, which is a formal language used to describe diagrams, and object orientation. The formal definition of events enables developers flexibility in implementation regardless of platform or architecture without the need for the models to be changed. The ARM*e*D project aims to create a new, sometimes virtual, reality. To this end, it is essential to look at the extent to which the models and flow charts that serve as the basis reflect the experience and context of the dental practice. Ideally, the most adept specialists of our field should develop the models and flow charts, or be closely involved in the preparatory stages of the systems' development. This has so far rarely been the case. The resulting high-tech products did not fit well within the context of a dental practice and ultimately wound up being used only for specific applications in a limited number of dental clinics. Using a user-friendly graphical interface, dentists could navigate in an augmented virtual reality, making it possible to work in a much more effective and confident manner than is presently allowed by the constricting oral environment. User friendliness would, for example, take the form of a program that, after the preferences are entered, would present the dentist or dental technician with a design proposal that would require minimal or no changes. In addition, a program must not leave the user high and dry in the event of errors, offering solutions to foreseeable problems instead.

CADDIMA (*Computer-aided Diagnosis and Design of Implant Abutments*)

The current approach to the implantation and production of prosthetic tools by dental surgeons or implantologists is based on skilled craftsmanship and comprises a large number of steps. The desire to limit the risk of failure has resulted in growing demand for automation for reasons of efficiency, including greater precision and improved reproducibility in combination with high quality. Each year, approximately sixty thousand implants are placed in the Netherlands. This number will double in the next five years. The increasingly demanding patient will more frequently ask for tooth implants, refusing to accept conventional treatment methods. However, if we calculate the number of implants each dentist places annually, this number does come to one hundred. Experienced dentists and implantologists can easily place six to eight hundred or more implants a year. A vast new body of dentists and implantologists will be needed to meet the increasing demand for implants. Several years ago, Massey performed a clinical analysis of hundreds of implants placed by dentists and implantologists and drew the conclusion that a mere seventeen per cent could be categorized as ‘ideal’ in terms of position and orientation. Aided by a three-dimensional reconstruction of the anatomical structures of the upper and lower jaw and computer tomography, dentists could place implants on screen in the ideal position and orientation in terms of anatomy, bone structure and bone quality. This planning information can be sent via the Internet to a centralized production facility, which manufactures an implant navigation drill guide. This is then used to precisely drill the holes necessary for placing the implants. Following implantation, a new scan is performed. The results are sent to the centralized production facility, which manufactures tailor-made implant supra structures. These are then placed in the patient’s mouth. This process approach increases the certainty of proper placement by the dentist. Moreover, the treatment, which usually involves a traumatic, highly invasive procedure involving exposure of the bone, is transformed into a minimal invasive procedure involving only a small bore hole. Consequently, the implant therapy is shorter in duration and much less traumatic for the patient.

LOCATION (*Local Computer-aided Tomography for Implant Ontologies*)

Advanced technological developments are expected to increase the importance of computer tomography in dentistry. The development of X-ray detector arrays currently make it possible to capture an entire projection surface. This principle is already used in cone beam CT scanners. CBCT technology, as it is known, can develop specific dental solutions for a reasonable price, as part of which extremely low radiation levels are used to create detailed three-dimensional images of the jaw and central facial area. This makes it possible to expand the use of CT scanning in design and planning in restorative and prosthetic dentistry in the future.

New materials

It took more than one hundred and twenty years before the computer, invented in eighteen eighty by Jacquard, and the use of ceramics in dentistry, first applied by Land in eighteen eighty-six, were combined to create computerized dentistry. Until recently, aesthetics were the key reason for opting for ceramics. An added criterion has become the tissue-friendliness of metal-free ceramics. The public has made its preference for biocompatibility known. The arrival of zirconium oxide relegated to the past the paradigm that ceramics require a different preparation and modeling approach than metal-ceramics. One of the blessings of computerized dentistry is that it enabled the application of zirconium oxide. The introduction of this material in restorative and prosthetic dentistry is most likely the decisive step towards the use of full ceramics without limitation. With the exception of zirconium oxide, existing ceramics systems lack reliable potential for the various indications for bridges without size limitations. Zirconium oxide with its high strength and comparatively higher fracture toughness seems to buck this trend. With a three-point bending strength exceeding nine hundred mega-Pascals, zirconium oxide can be used in virtually every full ceramic prosthetic solution, including bridges, implant supra structures and root dowel pins. The fact that zirconium oxide has been used in the industrial production of root dowel pins since nineteen ninety reaffirms the belief that its high strength yields clinical durability. The high strength and toughness are the result of a material-specific crystal transformation, specifically from a tetragonal to a monocline crystal structure, which stops cracking at the source. The increase in volume resulting from this transformation inhibits cracking and increases strength by an order of magnitude. In a nineteen ninety-two publication, Garvy compared zirconium oxide with hardened steel. The similarities in material properties proved astounding. The bending strength, modulus of elasticity, thermal expansion coefficient and specific gravity of both materials are comparable. The fact that both materials can attribute their strength to the same martensitic transformation of crystal structure accompanied by a nearly identical volume increase makes the comparison even more striking. In addition, both materials are opaque to X-ray.

BITES FOR THE COMPUTER

Due to its specific material properties, zirconium oxide ceramic, referred to by the abbreviation Y-TZP, has been used for quite some time in orthopaedics as part of hip joint implants. Previous attempts to extend its application to dentistry were thwarted by the fact that this material could not be processed using traditional methods used in dentistry. The arrival of computerized dentistry enables the economically prudent use of zirconium oxide in such elements as base structures such as copings and bridges and implant supra structures. Special requirements apply to dental materials implanted for longer than a period of thirty days. Several technical requirements include high strength, corrosion resistance and defect-free producability at a reasonable price. The primary requirement, however, is biocompatibility, which means that there should be no rejection response, infection or any other problem related to the introduction of material in tissue. In vitro testing of zirconium oxide has thus far elicited no unfavourable responses when combined with cells or tissues. Moreover, short and long-term in vivo testing indicate excellent biocompatibility. This is further substantiated by the results of various clinical trials extending over a period of more than eight years, each of which reveals no unfavourable tissue responses.

Ever more stringent requirements are being placed on the aesthetics of teeth. Metals and porcelain are currently the materials of choice for crowns and bridges. The demand for full ceramic solutions, however, continues to grow. Consequently, industry and science are increasingly compelled to develop full ceramic systems. In introducing full ceramic restorations, such as base structures made of sintered ceramics, computerized dentistry plays a key role. When discussing aesthetics, we must not focus solely on natural colored porcelain inlays, onlays and veneers milled with the aid of a computer, but also the application of various layers of dental glass ceramic on base structures. To increase the aesthetics of zirconium oxide, a glass ceramic layer can be applied onto the structure's surface. Research focuses primarily on the strength of the bond between the zirconium oxide and the glass ceramic and the strength of the entire structure in terms of the difference in thermal expansion coefficient. The application of glass on zirconium oxide is infrequently discussed in the scientific literature. The first aim is to gain a good overview of the functional properties of the glass ceramic-zirconium oxide system in terms of the thermal compatibility of the components, interface integrity, form stability of glass ceramic when used in ceramic shoulders, integrity of the glass ceramic in terms of porosity and in vitro testing of fatigue sensitivity and strength of restorations. These results can be used to assess the risks associated with the clinical application of this type of restoration.

Due in part to the growing demand for aesthetic and biocompatible, metal-free restorations, this research is important to predict an evidence-based estimate of clinical reliability. This will make it possible to evaluate the values found using a mathematical analysis of the designed restoration model based on the finite elements method. A number of international evaluation standards find their use in testing the functional product requirements and validating the production method. These standards, however, do not always respond to questions which are key to long-term in situ performance. At the same time, one of the study aims is to generate more definitive conclusions regarding the guidelines for use in dental indications for this type of restoration. The study will also address how the restoration is produced to determine which parameters are essential for the resulting quality of the restoration. The final aim is to improve the quality of the crown or prosthetic elements.

Aesthetics

Digital color measurement using an intra-oral scanner is an objective and predictable method to record the color distribution on the surface of a tooth. The digital color map, however, has not yet been used to produce computer-generated layering involving translucent layers. Instead, dental technicians use this to manually build up the layers for a restoration. To produce a natural-looking crown using one or more layers of colored glass ceramic, a generic layering model will have to be developed, enabling the computer to control the interaction between the various layers involved in the restoration to approximate the digitally recorded color scan as closely as possible.

Future

Having reached the conclusions of my speech, the time has now come to again go through this vision of the future and its relevant elements. ICT developments in the field of medicine has proceeded much further than those seen in dentistry. It is clear that our field has a lot of ground to make up in terms of ICT. A thorough analysis, focusing on identifying what dentistry truly needs, reveals that we have still a long way to go. We will have to validate every computer application and see how to increase their user friendliness and how they can be incorporated into the context of dental care. Although acceptance, which in this context means bites for the computer, will not be easy to achieve in our fairly conservative field, there are signs of change.

The aim of our research is to promote discussion about the future models for the user-friendly, efficient and cost-effective use of computer applications in dentistry. The resources, time and expertise currently available offer extremely interesting prospects for innovative research. I am convinced that the Academic Centre for Dentistry Amsterdam can play a key role in this. As a knowledge centre for computerized dentistry, it will add a new group of researchers to its fold.

The endowed chair for computerized dentistry focuses on promoting the application of computer technology and identifying treatment methods and materials by means of independent analysis. In addition, it addresses the need for thorough basic knowledge of the available computer technology in dentistry. Practical training in computerized technologies will play a key role in scientific education. The department expects that in the next decade ICT will have a tremendous impact on the management and operation of dental clinics and on the quality of the dental restoration process.

While a lot of what has been said this afternoon can be termed a vision of the future, there is no more doubt about the direction that developments in dentistry are taking. The old mechanistic rules of traditional dentistry, which required little documentation, no longer apply. The tools needed to achieve future aims are already available or under development. In any event, computerized dentistry is no longer a dream.

I have outlined why the computer's true breakthrough in dentistry still has to take place. The integration of various structural components with an open communication standard in a shared file management architecture and optimum use of the Internet can change this. In the future, research into generic models that fit seamlessly into and can be validated within the context of the restorative process and the application of new materials will almost certainly compel us in dentistry to offer bites for the computer.

Word of thanks

Having come to the end of my speech, I would like to express a few words of thanks. The contributions of many individuals have led to my standing before you now. I am truly grateful to them.

I would like to take the opportunity to thank the Board of the University van Amsterdam, as well as the former dean, Professor Robert Bausch, and the current dean, Professor Wouter Beertsen, of the Academic Centre for Dentistry Amsterdam. Without their support, I would not be here today to give impetus to the improved co-ordination of research in the field of computerized dentistry.

I would also like to thank Jan Slor of Elephant Dental B.V. and Rudi Lehner of Dentsply International for their ceaseless efforts in establishing the endowed chair. I would also like to thank John Jaakke, master of laws, for making time, in addition to his busy schedule at Van Doorne and as President of the Ajax Amsterdam football club, to attend the board meetings of the Stichting Bijzondere Leerstoel DeguDent.

My scientific past is closely linked up with the Academic Centre for Dentistry Amsterdam. With gratitude, I can look back not only on my doctoral research under Professor Carel Davidson, but I am since involved in the doctoral programmes of Catherine Begazo, Alma Đozic, Guiseppe Isgro, Niek de Jager and other visiting researchers.

I would like to give special thanks to my wife, Tineke. Like no other, she can appreciate the importance of time and attest to the fact that time management is not my greatest skill. After all, I continually promised to take it easier...

I, of course, would like to thank Professor Albert Feilzer, as colleague and head of the Dental Materials Sciences section, which has opened its doors to the endowed chair of Computerized Dentistry, for his inexhaustible dedication. Albert and I complement each other well and share the same vision regarding computerized dentistry.

As holder of the endowed chair of Computerized Dentistry, I hope to make a contribution to education and scientific research in a field that continues to gain in importance.

Finally, I would like to thank you for being here and for your attention.

Summary of inaugural speech

Although there are legions of examples of computer applications in dentistry, such as digital X-ray systems, intra-oral cameras and colour chromameters, digital cavity and pocket depth meters, bite impression systems, interactive image processing and planning, CAD-CAM systems and digital patient file management, the breakthrough for computers in dentistry has failed to materialise. The integration of various structural components with an open communication standard in a shared file management architecture and optimum use of the Internet can change this. Research into generic models that seamlessly fit and are validated within the context of the restorative process with the application of new materials will no doubt lead to a revolution in dental care.

Jef van der Zel holds the endowed chair of the Faculty of Dentistry (Academic Centre for Dentistry) of the Universiteit van Amsterdam. He is a pioneer in the field of restorative computerized dentistry and, since 1987, has been working on the development of CAD-CAM dental systems. He is a founder and chairman of the Dental CAD-CAM special interest group of the International Association of Dental Research.