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Current status of digital dental surgery

Aktuelni status digitalne dentalne hirurgije

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ABSTRACT

At the end of the 20th century, the introduction of computer technology into oral surgery created great expectations. In almost two decades of the 21st century, computer technologies entered deeply into the pores of oral surgery and we witnessed their full expansion there. Computer technologies extend across different areas and offer support to oral surgeons in patient management. This paper represents a review of the most recent advances of computer-assisted dentistry in the domain of oral surgery. The paper is intended to inform the reader about the advantages and shortcomings of computer-assisted oral surgery in both research and clinical practice.

Key words: surgery, oral; dentistry; computer systems; surgery, computer-assisted; technology, dental.

APSTRAKT

Krajem dvadesetog veka postojala su velika očekivanja od uvođenja kompjuterizovanih tehnologija u oralnu hirurgiju. Za skoro dve decenije dvadeset prvog veka kompjuterizacija je duboko ušla u pore oralne hirurgije i tu doživela pravu ekspanziju. Prostire se kroz različite oblasti i pri tome značajno pomaže oralnom hirurgu kod zbrinjavanja pacijenata. Ovaj rad pruža pregled dosadašnjih maksimalnih dostignuća kompjuterizovane stomatologije u oralnoj hirurgiji. Rad informiše čitaoca o prednostima, ali i nedostacima do sada razvijene kompjuterizovane oralne hirugije, kako u istraživanjima, tako i u praksi.

Ključne reči: hirurgija, oralna; dentalna medicina; računarski sistemi; hirurgija, računarima-podržana; tehnologija, dentalna.

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Introduction

At the end of the 20th and the beginning of the 21st century, great expectations related to a rapid development of dentistry were associated with the introduction of computer technologies into dentistry. Perhaps the greatest expectations were based on the ever-increasing availability of personal computers, the implementation of microcomputers and their integration into machines, the development of telecommunication technologies enabling computerized integration of smaller parts as a whole, and management and control systems integrating artificial intelligence software and algorithms. Predictions of rapid growth in the nearest future were made in all fields of dentistry and oral surgery; for instance, it was expected that robots would replace oral surgeons in oral surgery interventions.[1] Even before surgical intervention, computer-assisted equipment was expected to administer and control anesthesia in an attempt to make it painless, rapid and always successful [2] Fully automated dental replacement production was also expected to occur, with appropriate software programs capable of planning and subsequently directing the placement of dental implants.[3,4] It should be mentioned that there were many realistic, but also many unreasonable expectations.[5]

Nowadays, after almost 20 years in the new century, we may be able to offer a more comprehensive review of the maximum reach of computerized oral surgery and to get a realistic insight into its possible future advances in this field full of potentials.

Computerization of local anesthesia

Classical local dental anesthesia represents a challenge as to the selection of agents, administration techniques and our approach to dental patients in order to eliminate the fear of anesthesia and to achieve painlessness in the targeted area.[6] Computerization here represents modern computer-controlled local anesthetic delivery devices (CCLAD), directed to the painless administration of anesthetic agents, achieved by computer-controlled injection speed. In a series of 13 studies on children, 7 studies have demonstrated CCLADs were more effective in terms of less pain caused, while in 6 studies almost identical pain has been produced by both methods. The level of success is the same and the administration time is longer with the computer-controlled method.[7,8] Further research is needed so that completely painless anesthesia administration could be achieved, eliminating thus the inconvenience and fear in dental patients.

Cone beam computerized tomography (CBCT)

When dental radiography is concerned, computerization has completely taken primacy in this field . First, in the first decade of the 21st century, digital orthopantomography almost completely replaced analogue full mouth radiography, and in the second decade 3D computerized radiography had its fullest expansion.[9] In particular, the first computerized tomography (CT) devices were introduced in 1973, and the first modified forms of the so-called Cone Beam CT for dental use were introduced in 1998.[10,11] However, real revolution in the use of this kind of 3D radiography has occurred in the last ten years when Cone Beam technology successfully reduced the level of irradiation during radiographic exposure, improving the visual field and image resolution at the same time.[12] Then it could be fully integrated into the software packages for the analysis of anatomical structures.[13] Advances made on the side of entry digital information obtained using high-resolution CBCT machines with the error margin of less than 1 mm in 3D image restoration, enabled the creation of precise virtual 3D digital anatomical models.[14]

These models have had multiple possible uses, providing precise insight into anatomical and pathoanatomical structures and positioning them precisely in three dimensions, and delineating their relationships with one another.[15] This improved 3D precision enables much better software analysis and planning.[16] In particular, instead of just the information available to the naked eye, a highly precise 3D model is an ideal resource for processing in Computer-Aided Design (CAD) softwares. The effectiveness of CAD softwares is based on the performance of the computer processing unit and/or graphic card. Since the speed of processing of mathematical calculations of new generation processing units has been greatly improved, analytical and CAD softwares for dental applications are nowadays able to detect in real-time any area of reduced bone density or to make the 3D plan for an ideal bone defect reconstruction.[17,18] We should bear in mind that these CAD planning processes have not yet been automated; these are still largely based on the human factor of reasoning, analysis and guidance.[19]

The development of the system towards automation is directly connected with the development of artificial intelligence able to control and manage these services, and it has not been sufficiently developed to respond to a challenge like this.[20] Artificial intelligence has been demonstrated to be effective in certain situations; for instance, several authors reported automatic detection of the mandibular nerve and mandibular bone from CT information in 3D models.[21,22] However, the level of artificial intelligence potentials in the recognition of anatomical structures from CT and CBCT information is far from the level required for any reliable automated analysis and planning. Certain advances have been reported in the area of algorithms of semi-automated software segmentation of the mandible, as well as the attempts of a digital reconstruction of CT information based

on a pre-existing mapping of key anatomical points of reference.[23,24] It is our opinion that further research is certainly warranted in the area of CBCT information segmentation which would enable adequate recognition and modeling of anatomical elements in the form of independent 3D objects.

Computerization of dental implants

The growth of interest in the last 20 years in the management of dental patients with implants led to the expansion of computer systems which would support the analysis, planning, fabrication and placement of dental implants. In none of the areas of oral surgery has computerization made such an impact as on dental implants.[25] The procedure starts with CBCT imaging of the upper and lower jaw and its computer-aided reconstruction. Thus, a tridimensional model is obtained which is further used in the analysis and planning of implant-prosthetic management of the patients. Since the level of development of these systems currently does not enable high-quality recognition and mapping of anatomical structures, the greatest burden of analysis has to rest on the human factor.

However, the 3D model greatly facilitates this process, allowing the movements and measurements to be made within the model from one to another point of interest defined by the dentist. Based on the measurements of the bone spaces, the computer recommends the dimensions and form of the implant and assists in the placement of virtual implant object upon the 3D model.[26,27] In the process of implant positioning in the bone in three dimensions, the human factor is indispensable. The cause of that is that the assistance of the computer is not satisfactory, which should be expected since the computer is not able to recognize, i.e. „read out" the anatomical structures out of the collected data.[28] Nevertheless, the help from the computer is huge in terms of the free positioning of implant objects on a 3D model, including the selection of the axial angle towards the bone.[29] It would be very useful if we could perform statistical testings of bone load, with implants placed as future dental bridge abutments.

The inability of the software to recognize the anatomy out of a model prevents its routine daily practical use of such a test. Therefore, it is not possible to detect bone density with this mathematical model in an automated way.[30] However, several studies have demonstrated that software assistance in the determination of implant relationships with adjacent structures can markedly optimize geometry and alleviate the chewing.[31,32] Using CAD software, a dentist can design a fixed prosthetic replacement upon the projected implant abutments, fabricated in an automated way with the CAM systems.[33,34] In addition to routine fabrication of prosthetic replacements using CAM systems, these systems also became a reliable tool in the fabrication of surgical guides for the placement of dental implants based on prior computer-aided planning. This provides oral surgeons a valuable tool in performing minimally invasive and maximally precise surgical interventions in the placement of dental implants.[35,36]

In addition to implant guides, there is also and Dynamic Dental Implant Navigation System, based on the 3D model, sensors on the patient's head, on the surgeon's hands, and on the dental handpiece that control the implant placement procedure. Several studies showed that systems such as this may hold a promise for the future.[37] We believe that future research should be oriented towardsthe CAD system capable of precise simulation of dental implant load statics and maximally reduces the necessity of implant placement adjacent to the high risk anatomical sites.

Telemedicine in oral surgery

Perhaps the best and simplest definition of telemedicine is „treatment from a distance".[38] Whether the introduction of phones and television into telemedicine is more of a revolution than the establishment of digital information transfer between computers in their various forms (personal computers, tablets, smartphones, smart TVs) is a matter of personal preference.[39] Using the Internet as a medium of information exchange in telemedicine, computerized oral surgery has had valuable results. Nowadays, digital 2D images, but also 3D models of CBCT data, are routinely transferred to distant smart phones via the wireless HSDPA network, where teleconsultants can review the images and present his own suggestion about the diagnosis and therapy.[40] Based on a series of photographic images of the internal structures of the mouth, facial photographs from different angles and digital full mouth orthopantomography, an oral surgeon may from a distance make the diagnosis of impacted third molars, but also assess adequate conservative or surgical therapy with the same degree of reliability as during a direct examination.[41]

Several successful cases of telemedicine consultations related to the plan of implant management of healthy individuals, as well as those with certain disorders, are presented.[42,43] In a comparative study of distant and direct examination of the patients with dentogenous infections, it has been shown that oral surgeons can make equally reliably as in-person the diagnosis of dentogenous infection and assess adequate therapy.[44] Using the method of telemedicine, oral surgeons are able to reliably inspect temporomandibular joint disorders and offer interspecialist consultation to dentists, prosthetics specialists and endodontists as a part of the interdisciplinary management of edentulous patients.[45,46] We think that further research should be directed

towards telemedicine management of high-risk dental patients. These cases should be managed in an interdisciplinary manner and this is an area where distant consultations between oral surgeons and other specialists is of utmost importance.[47] Here, we have in mind primarily the specialists for internal diseases, but also the other medical specialties involved in the management of high-risk patients.

Other fields

Out of other fields of computer science greatly promising in the sense of development of oral surgery, artificial intelligence and data mining should be mentioned primarily. In this regard, possible advances are the robotization of clinical processes and assistance in scientific research. These systems are able to assist in the detection of currently unknown disease etiologies and in the invention of treatment methods.[48] Artificial intelligence relies on the analysis of ordered data sets, and modern software packages are set in place for computer-aided registration as the basis of its application, i.e. for patient dental records. Advanced patient records represent not only the collections of information for dentists or oral surgeons about the diagnosis or therapy planning.[49] They are much more than that – a resource of information for scientific analyses and conclusion correlations.

Analysis-friendly data in relational databases are organized into objects according to the anatomy of the mouth cavity and face. From these virtual anatomical structures, diagnoses are made and precise therapeutic information is entered, including details about therapeutic procedures and administered medication.[50,51] An ever-increasing number of educational publications and on-line resources should be mentioned as well, with the primacy of educational courses for dental implants.[52] Further research efforts should be invested in artificial intelligence systems which would be able to formulate guidelines for further studies based on the detected correlations between available data.

Conclusion

Computer science is increasingly intermingling with oral surgery. Its different forms can be a valuable assistance to oral surgeons in the phases of diagnostic decision-making and in the analysis of therapeutic options. Various studies have shown the validity of these methods, holding promise in terms of further development of information-robotic systems. Comparing the situation with the last decade of the 20th century, significant evolutionary progress is evident, as well as the increasing presence of computerized systems in oral surgery. In the years to come, the advent of new significant benefits from computer science, as used in the field of oral surgery, can be expected.

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