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COMPUTERIZED ORAL SURGERY

SUMMARY

Computers have become more and more involved in diagnosis, planning and surveillance of therapy in both medicine and dentistry. They are increasingly becoming an integral part of researches in dentistry and we are obliged to get the best insight possible into their function and their capabilities in order to make the best possible use of their capacity. In oral and maxillofacial surgery the use of computers is constantly expanding, especially in the field of digital imaging, and CT, CBCT, MRI and 3D ultrasound are of special importance in that regard. Moreover, various computer applications are used in the clinical management of patients, education, and research, such as the screening methods for oral lesions, involving brush biopsy and computer-assisted analysis of histological sections, oral surgery software packages and interactive programs enabling students of postgraduate specialist studies and specialists to build up their knowledge and to apply their knowledge and critical thinking in oral surgery decision-making. Within interventions themselves, computerization is evident in the planning and simulation of the course of operation, navigation of surgical instruments and postoperative patient monitoring. Diagnostic proceedings and associated interventions relying heavily on computerized oral surgery are extractions of impacted teeth, assessments and revisions of the maxillary sinus, assessments of the strength of the mandible, and especially, computer-guided dental implantations. In order to make more use of computers in oral surgery, in addition to the provision of adequate equipment and software, which is the easier part, appropriate education of specialists in oral surgery is mandatory, as well as the education of students of dentistry within the oral surgery course or within the course termed „computerized dentistry", the introduction of which is planned.

Key words: **computerized dentistry; computerized oral surgery, CBCT, 3D**

INTRODUCTION

Computers are more and more present in diagnosis, planning and surveillance of therapy in both medicine and dentistry. They are increasingly becoming an integral part of researches in dentistry, and we are obliged to get the best insight possible into their function and their capabilities in order to make the best possible use of their potentials. However, we must bear in mind also their negative effects, on both the patients and doctors. In oral and maxillofacial surgery, the use of computers is constantly expanding especially in the field of digital imaging, and computerized tomography (CT), magnetic resonance imaging (MRI) and 3D/4D sonography are of special importance in that regard. Taken all together, they brought about a sudden and decisive improvement of the visualization of

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anatomic structures, facilitating the apprehension of problems at hand (1-9). Various computer applications are used in the clinical management of patients, education and research, such as the screening methods for oral lesions, involving brush biopsy and computer-assisted analysis of histological sections, allowing for the screening of more patients on early, premalignant or malignant lesions. There are also packages for oral surgery interventions and interactive programs enabling specialist-candidates and specialists to build up their knowledge and to apply their knowledge and critical thinking in oral surgery decision-making (10).

3D vs 2D imaging

There is a tendency in almost all surgical specialties towards the use of less invasive procedures whenever possible. At the same time, efforts are made to get over the limits of conventional surgical methods in the field of oral surgery, starting from periapical lesions, remaining teeth roots, impacted teeth, then in dental implantology and treatment of malformations, all the way to advanced tumors in complex anatomic regions, etc.

Three-dimensional (3D) imaging techniques such as CT, MRI and 3D sonography can show almost all anatomic and pathologic structures in high resolution and quality. The development in the field focuses on the reduction of artefacts and process automation in the fusion of various image modalities and segmentation of anatomic details, which is the basis of the future of computerized surgery (11-13).

Panoramic radiography is two-dimensional (2D) and one of the most utilized radiographic techniques in oral surgery, including dental implantology. Panoramic radiograms are able to give a global view of both dentition and the shape and height of jaw bones. These are extremely useful in initial treatment planning; however, though widely used, they are associated with numerous limitations. For instance, they cannot provide us with the data on jaw bone thickness, teeth depth within the bone, and are associated with a factor of deformity, which is usually around 25% (14,15).

Compared to panoramic radiography, CT can provide precision of less than 1 mm, without image distortion or tissue superposition, with precise image evaluation with measurements of shapes and distances. CT is in fact 3D software reconstruction of a series of cross-section images of the target area. Higher resolution implies better, more detailed imaging and better quality data, enabling measurements of heights, widths, alveolar ridge angulations, distances between the alveolar top and mandibular channel or the floor of maxillary sinus and nasal cavity. Certain information is sometimes missing, such as the data between two layers (cross-sections), and projections are then mathematically calculated (with the potential for errors). CT scanning has been extensively used in dentistry, since spatial 3D data about the jaws and their content provide the comfort to oral surgeons impossible with other radiographic techniques used in the past. Software processing is here the key factor providing precision of the method as a whole.

Superiority of 3D imaging to 2D imaging (prone to parallactic errors) is best shown in the diagnosis of periapical pathology. Assessment of this pathology heavily relies on radiologic methods, and 3D technology can produce high quality and precise data of periapical lesions, e.g. about the location (e.g. involving trabecular or cortical bone) and size of defects (bone volume involved with destruction related to jaw dimensions in a region) (16). Several studies have demonstrated diagnostic precision regarding periapical defects at least the same as conventional films, and almost always exceeding films.

However, CT suffers from higher radiation doses compared to conventional radiography. In one in vitro experiment simulating combined high resolution CT of the mandible and maxilla, 19mGy was the absorbed dose measured in parotid glands. On the other hand, with conventional methods, the absorbed dose was 1mGy (17,18). CT scanning doses can even be much higher, e.g. maximal doses of 38mGy and 31mGy on the skin surface and in parotid glands (19). New volumetric CT scanners have been introduced recently especially for dental application, termed *cone beam* CT (CBCT). These scanners should have radiation doses 15 to 20 times lower compared to standard spiral CTs, with better visualization, interpretation and measurement of targeted structures.

Intercommunication DICOM data format

Transmission of visual data between devices, health care centers, and doctors, required a standardized data format recognized by all devices and software packages. In 1993, a „golden standard“ was introduced for the transmission of digital images generated by radiological devices, termed DICOM. This data format assists communication between devices and doctors (20). Although it was devised 15 years ago, it has been changed and amended, and now it is able to systematize the data obtained by the latest radiology equipment. All current CT scanners, surgical navigation systems, and CAD/CAM software for medical purposes are able to import DICOM data, but, regretfully, there is no way of converting the data back into DICOM format after changes and planning processes performed by programs such as iPlan and Voxim. Therefore, the transmission of already processed data between surgeons and institutions which do not have identical software packages and hardware is not possible (21).

Planning and navigation

When we have at our disposal 3D geometric models, preoperative planning and simulation of the course of intervention in oral surgery can take place. They could be of practical assistance in:

- computer-assisted planning in dental implantology,
- computer-assisted planning of osteotomies, and
- computer-assisted planning of corrections for malformations.

Planning is done with specialized software packages. Currently, the most renown programs used for CAD/CAM purposes in oral surgery are Armira (Berlin, Germany), Analyze (AnalyzeDirect, Lenexa, U.S.A.), iPlan (BrainLab, Westchester, IL, U.S.A.), MIMICS (Materialise, AnnArbor, MI, U.S.A.) and Voxim (IVS Solutions, Chemitz, Germany); all of these are able to import DICOM data and to perform virtual data manipulations (22).

When there is a plan and 3D model simulation, we may proceed to intervention, using navigational technology. Intraoperative navigational technology has become a universal tool in neurosurgery, otorhinolaryngology, orthopedics, and oral and maxillofacial surgery, being routinely used in many hospitals and clinics. A navigational system is able to track spatial position and orientation of a probe or a surgical instrument (23). Advantages of 3D geometry created by CT data are the basis for further improvement of surgical techniques. It is of crucial importance for a surgeon to know the exact position of instruments and devices intraoperatively. Tracking of instruments in three dimensions on the display and their remote guidance are enabled by a process called surgical navigation. It is based on 3D representation of data slices and reference points most commonly positioned on the patient head, the exact position of which depends on navigational techniques applied. The key requirement in oral surgery is precise recording of obtained data projections and proper analysis of 3D reconstructions of slice sets obtained by scanning of the patient head. Without proper image recording, we cannot achieve spatial identification of structures. The process of navigation involves the identification of structures obtained with preoperative scanning, as well as their current spatial localization relative to intraoperative patient position. The recording techniques can be divided into two main groups:

- marker-based recording, and
- recording without markers (24).

From the technical point of view, the following navigation types exist in oral surgery:

- mechanical (position calculated via gears and movement angles);
- electromagnetic (position detected via field changes with coils);
- sonographic (position determined via real-time sound signal measurement);
- video-optical (calculation of the position via infrared diodes or pattern-recognition with CCD-cameras) (23, 25-27).

Most common, currently available navigation systems are InstaTrak (General Electric Health Care, Buckinghamshire, Great Britain), Stealth Station (Medtronic-Xomed, Jackonville, FL, U.S.A.), Stryker Navigation System (Stryker-Leibinger, Kalamazoo, MI, U.S.A.) i VectorVision (BrainLan, Wetchester, IL, U.S.A.). Each of them has its own advantages and disadvantages.

Computer assistance with impacted third molars

Without 3D tomography a surgeon will have trouble determining the exact spatial position of an impacted tooth. Based solely on panoramic radiogram (and retroalveolar radiogram too) it is not possible, not only because of the missing data of the tooth position in the third dimension, but also because of the insufficient precision of conventional radiograms (prone to distortion) which can present a „false" position of the tooth.

Surgeons are able to plan routine or more complex interventions for impacted teeth with more certainty with CT scans, since precise 3D localization of lower third molars is very important because of adjacent mandibular channel and because of possible mandibular fracture. It is thought that the percentage of damage of neurovascular contents of the mandibular channel is from 0.4% to 5.5%, and irreversible damage ranges from 0.3% to 0.9% (28,29). Two-dimensional radiograms have limitations regarding localization of lower third molars, and Bell et al. in their study of 300 panoramic radiograms of third molars (examined by nine experienced oral surgeons), concluded that the diagnostic accuracy of anatomic details in these images was very low and insufficient in most of their cases (30-31).

The relationship of upper third molars with maxillary sinus is also important in the extraction of third molars. If a surgeon initially knows that the molar in question is not communicating with the maxillary sinus, the flap can be smaller, and if he does know that oroanthral communication will be produced after tooth extraction, he may choose a different, usually wider approach. Panoramic imaging does not provide surgeons with necessary, precise information, and possible communication of molars and the sinus cannot be detected with certainty.

Bouguet et al. confirmed in their extensive study of the precision of establishing the relationship of upper third molars with the maxillary sinus that CT scanning is more precise compared to conventional techniques, by 1.67 mm on the average in the measurement of the impaction level. It is also more precise in the measurements of root lengths, protruding into the sinus by 2.26 mm (32).

Computerized analysis of the maxillary sinus

Maxillary sinus diagnosis is a complex one, and with traditional 2D radiography many problems can be overlooked. CT and CBCT devices facilitate sinus analysis and differentiation of the problems within. A maxilla has bilateral sinuses and a nasal cavity which can be of various dimensions and shapes. An axial section of the maxillary arch can demonstrate significant pathology. CT can further help clinicians to visualize bone volume to be included into the operation field (33).

CT scanning can provide us with better quantitative and qualitative data compared to conventional 2D radiological methods, such as panoramic radiography.

After an adequate 3D reconstruction, the system can also demonstrate soft tissue polyps and even to measure their dimensions. The differences between mineralized masses and polyps can also be well delineated. Three-dimensional images allow for the rotation, magnification, transparency and assessment of axial and transversal image slices.

Whether we have to place implants into the upper jaw in the region prone to perforation (when it is lower than usual), or it is necessary to perform a sinus revision because of the complaints or an oroanthral communication, with 3D technology available, surgeons may use interactive tools allowing for the planning and simulation of graft placement, implant placement, bone volume analysis, or operation course planning. Software packages produce 3D images of the planned intervention, calculating dimensions and shapes of the materials necessary to complete the intervention. Moreover, postoperative CT scans can produce information about the implant position within the sinus and the volume of newly created bone.

Computerized assessment of mandibular strength

Mandible is composed of compact bone tissue and it is much stronger than maxilla. However, in time, atrophy of the mandible can occur as the consequence of edentulism, some disease, or interventions such as tumor resection. Significant bone loss can occur after the formation of cysts, tumors or after surgical extractions of impacted teeth. If significant weakening of the mandible occurs, as a whole or in some region, a fracture may be the result. Situations with increased risk of mandibular fracture can range from usual chewing, then with blows on the mandible, to surgery.

Using 3D reconstructed geometric and biomechanics models of the mandible exposed to masticator forces specific for the patient we treat (taking into account his age, nourishment habits, anatomy), we are able to initially assess the possibility of pathologic fracture of the mandible. Bone stress analysis is done using the finite elements method (FEM).

The process consists of the following steps:

- Production of raw data on the patient's jaw with CT scanning;
- 3D visualization and interaction;
- 3D segmentation of the mandible;
- Automated extraction of 3D mathematical network of the surface of mandible;
- Adaptation of volumetric of 3D network of inner mandible, aimed at adaptation to the FEM software (e.g. Dynel®, IGEOSS).
- Changes to the network in order to simulate surgical bone incision or „natural“ bone resorption;
- Representation of the muscles in 3D images and identification of physical factors of influence on the forces acting upon mandible;
- FEM computerization and 3D visualization of obtained results (34).

Computer assistance in implant placement

The principal help of computer systems in implant placement is reflected in implant visualization to potential patients, preoperative computer planning of the position, size and shape of implants, template production for the implantation process itself, navigational help in that process and teledentistry consultation and education during implant planning and placement. A representative of the software package group aiming to visualize intervention planning to prospective patients is the XCPT®. With this software, oral surgeons/implantologists can explain the procedure and results to the patient, increasing patient consent by around 15% (35).

Preoperative planning of implant placement requires CT or, better, CBCT (with reduced radiation dose and better focusing on the jaw area) imaging and 3D reconstruction of obtained images, with subsequent software marking of the mandibular channel and maxillary sinus. In accordance with the anatomic environment most suitable implant groups are chosen, and the computer itself determines the longitudinal implant placement axis (36-39). With this axis identified, implants are chosen according to their dimensions in order to achieve better primary stability and osteointegration, taking into account the established medical criteria. Current commercially available planning software packages are represented by:

1. SimPlant, Materialise, Leuven, Belgium,
2. NobelGuide, Nobel Biocare, Yorba Linda, CA, U.S.A.,
3. coDiagnostiX, IVS-Solutions AG, Chemnitz, Germany,
4. ImplantMaster, I-Dent Imaging, Ft. Lauderdale, FL, U.S.A.,
5. Med3D, med3D AG, Zurich, Swiss (39).

After the plan has been made, templates are created. These are in fact plastic (or other) moulds with excellent matching with the teeth or jaw surfaces (over the gums or bone after mucoperiosteal flap elevation), fixed and containing guiding holes which would allow passing of the borer and/or the implant itself. These guiding holes agree completely with previous computer planning, so that resultant osteotomies are made in proper places, at the proper angle and depth according to the plan and computer simulation. Commercial representatives are Compu-Guide Surgical Template System and SurgiGuides (40). For the purpose of navigation, the systems used in oral surgery (described above) are used here, too. The significance of teledentistry in the practice of implantology is best illustrated by sending of 3D models to remote locations, distant processing and transferring back to the surgical room where implant placement is to take place. Karl Landsteiner Institute of Biotelematics in Vienna, Austria, has developed a telenavigational client able to function as an independent navigation system, so that each user may choose a 2D or 3D view or cross-section during the operation itself (41).

CONCLUSION

Computerized oral surgery has still not taken its proper place in Serbia, even though it is 2009. Considering the reference oral surgery clinics in Belgrade, Nis, Pristina (temporarily displaced in Kosovska Mitrovica), and Novi Sad, if at all, computers are primarily used for patient data collection and in accountancy departments for billing. Though CT scanning is required in some cases, we cannot speak at all of computer-assisted oral surgery in Serbia. However, in spite of all this, we should mention that a large application system is being built for centralized computer and teledentistry assistance to oral surgeons via the Internet (its working title being *XPA3 Online*). Moreover, Serbia is among the few countries worldwide where all the parts for modern CBCT devices are produced (the manufacturer from Nis was awarded for technologically most advanced export products in 2008). In order to make most of computers, except for investing in the purchase of adequate equipment and software, and it is the easier part, appropriate education of oral surgery specialists should be mandatory, as well as the introduction of education of undergraduate students of dentistry within oral surgery course or within „computerized dentistry" course, the introduction of which is being planned.

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KOMPJUTERIZOVANA ORALNA HIRURGIJA

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SAŽETAK

Kompjuteri postaju sve zastupljeniji u dijagnostičkom procesu, planiranju i praćenju terapija kako u medicini tako i u stomatologiji. Postali su sastavni deo skoro svih istraživanja stomatologije i naša je dužnost da se što bolje upoznamo sa načinom njihovog funkcionisanja i njihovim mogućnostima, kako bi njihovu promoć što bolje iskoristili. U oralnoj i maksilofacijalnoj hirurgiji danas dolazi do posebne ekspanzije kompjutera na polju digitalne imaging tehnologije i od posebnog značaja su CT, CBCT, MRI i 3D ultrazvuk, ali su tu i kompjuterske aplikacije koje funkcionišu u kliničkom zbrinjavanju bolesnika, edukaciji i istraživanjima, poput metoda za skriningovanje oralnih lezija, koje uključuju brush biopsiju i kompjutersku analizu histološkog slajda, pakete za obradu oralnohirurških intervencija i interaktivne programe koji omogućavaju studentima specijalističkih studija ili specijalistima oralne hirurgije izgradnju i praktičnu primenu kritičnog znanja i razmišljanja kod donošenja oralnohirurških odluka. U samim intervencijama, kompjuterizacija se ogleda u planiranju i simulaciji operativnog toka, navigaciji hirurškog alata, ali i postoperativnom praćenju bolesnika. Dijagnoze i prateće intervencije, koje sve više koriste pomoć kompjuterizovane oralne hirurgije, ekstrakcije su impaktiranih zuba, procene i revizije maksilarnog sinusa, procene jačine mandibule i posebno kompjuterski vođene ugradnje dentalnih implantata. Kako bi dobili što više koristi od kompjutera u oralnoj hirurgiji, osim što se mora investirati u kupovinu adekvatnih uređaja i softvera, a što predstavlja lakši deo, mora se izvršiti odgovaraćuja edukacija specijalista oralne hirurgije, kao i uvesti obavezna edukacija studenata stomatoloških fakulteta, bilo u okviru predmeta oralna hirurgija ili u okviru predmeta „kompjuterizovana stomatologija“ čije se uvođenje planira.

Ključne reči: **kompjuterizovana stomatologija, kompjuterizovana oralna hirurgija, CBCT, 3D;**