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Software applied to oral implantology: Update

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Abstract

Software in combination with imaging techniques is used increasingly for diagnosis, planning and treatment in oral implantology.

Computer-aided surgery allows a great accuracy in implant positioning to be obtained, taking advantage of the amount of bone available and facilitating minimally invasive surgery. It is a significant aid in determining implant number, location, angle and characteristics. A CT with a radiographic template positioned in the mouth is made for the patient. Data are stored on a CD in DICOM 3 format and then introduced in the computer where implant treatment will be planned, using the chosen software.

Navigation improves surgical accuracy through the aid of software based on the images captured from CT or MRI and a surgical instrument tracking system. Infrared light-emitting diodes are connected to rotatory instruments and to the patient's template. Information is collected by special-purpose cameras, allowing the procedure to be viewed in real time on a monitor. It is useful in situations where an exact implantation is demanded, such as anatomical limitations, little space, atrophic maxillae, sinus lifts or zygomatic implants.

Articles reviewed agree in emphasizing the reliability and accuracy of the planning and computer-assisted navigation systems available in the market. Nevertheless, many applications are still in the development phase.

Key words: *Surgical template, computer-assisted navigation, implant planning, augmented reality, 3D planning.*

Introducción

Computer software is increasingly used as a tool for implant diagnosis, planning and treatment. Firstly, it is used in connection with imaging techniques, such as computed tomography (CT) or magnetic resonance imaging (MRI) (1). The present development of clinical computer applications allows us to obtain three-dimensional models to plan virtually real situations. Secondly, we can construct surgical templates carrying the information necessary to transfer that planning to the mouth of the patient. In most cases, this procedure is based on stereolithographic models (2,3).

CT data are recorded on CD and later processed in DICOM 3 format, creating a three-dimensional image. Using the data, accurate planning of the implant treatment can be made (4). From this planning, surgical templates are manufactured to place the implants in selected areas (5).A variety of programs are available, such as: Implametric®, SimPlant® (2,6), Nobel Guide® (7), med3D® (4), etc. Most programs show an axial cut and a panoramic cut with multiple buccolingual cuts and panoramic images shown sequentially below (6). In the 3D image, bony structures are visualized with the possibility of incorporating other anatomical structures or even soft tissues.

Computer-aided implant treatment is a technique developed in recent years thanks to advances in computer programs in combination with CT. The basic principle of computer-guided implant planning in oral surgery is the visualization of the real anatomical situation in three spatial planes. It is hoped that in the near future its application in oral implantology will increase improving surgical navigation systems. Systems currently available (RoboDent®, DenX IGI®, VISIT®, CADImplant®, LITORIM®, Virtual Implant®, Vector Vision®, etc) offer greater security (avoiding damage to the adjacent structures) and improving the results (3).
This article reviews the experimental and clinical results published on the utility of different software in computer-aided planning and placing of implants. The literature was reviewed using the data base MEDLINE, limiting references from 1997 to June, 2006. The following key words were used, in different combinations: surgical template, computer-assisted navigation, implant planning, augmented reality, 3D. Articles included in the update were those directly related with implant planning and surgical navigation, using the preoperative CT of the patient and specialised software or related procedures.

Planning by means of image data

- *Historical development*

In recent years CT, the reformatting of images and visualization in three dimensions of the collected data has been increasingly used in many surgical specialities (8). It has contributed towards establishing a better diagnosis and planning precise treatment, for example in craniofacial deformities (8). In oral implantology, guided planning allows us to obtain highly precise implant positioning, taking advantage of the maximum amount of bone available, and facilitating minimally invasive surgery (9).
Currently, the tendency is towards prosthodontic-driven implant placement, taking into account the later prosthetic restoration (10). The incorporation of an ideal prosthetic design in treatment planning is important in achieving the complete integration of anatomical, biomechanical and esthetic factors (10). To this end, surgical guides have become another part of implant treatment. They allow the transfer of the diagnostic waxup of the prosthodontic restoration into the actual implant planning (11). Among the advantages found by Ganz (2) in using these guides were: the increase in precision of implant positioning, and the reduction in operating time and surgical errors; as well as the better prognosis for the patient since the surgery was minimally invasive. Nevertheless, this system also has certain disadvantages (12). The use of these templates does not allow the use of techniques such as alveolar ridge expansion does not consider the conditions of the mucosa, tactile reference is lost (friction between the template rings and the burs and implants masks the real torque applied) and in most cases the precise milling depth is not given.

- *Procedure*

The procedure is as follows: a template with radiopaque position markers (gutta-percha or calibrated balls of known diameter) or a special radioopaque template (with a barium sulphate coating) is made for the patient (6,13). A CT with the template placed in mouth is made. Data are stored on a CD in DICOM 3 format (4) and subsequently transferred to the computer. Using the chosen software, treatment is planned based on the implant position in the axial, sagittal and panoramic sections, and on the 3D image. The radiographic template can be modified with this information to be used as a surgical template; otherwise a new one is manufactured (2).
Different kinds of templates are found according to the supporting surface. They can be supported by teeth, teeth and mucosa, mucosa, or directly on the maxilla bone (6,14). Different methods can be used to stabilize the template: either by placing pins directly into the bone through soft tissues, thus achieving atraumatic surgery (6,15); by raising a flap and placing into the bone; by using wires as a guide and support (2); by transitional implants (16); or simply by placing over soft tissues (6,13).
Almog et al (17) presented 4 kinds of templates as a tool to use with the CT during implant planning, vertical lead strip guides, circumference lead strip guides, gutta-percha guides , or guides with a system of disks. All except the first can be used as a radiographic as well as a surgical template, and are a great aid to implant treatment. These authors (18) found that surgeons felt more confident using the template and CT than using only CT in a series of 1640 implants placed in 630 patients using the templates described above. Guides provided the surgeons with important prosthetic and diagnostic information.

- *Clinical application*

Three-dimensional image reconstruction of data obtained by CT is of great help in determining implant number, location, angle and characteristics (6). Functional and esthetic outcome will be good if the template is made based on the final shape of the tooth (shape, emergency profile, occlusion and contact areas) and not only on the bone characteristics (2).
It is an appropiate method for use in situations with anatomical limitations, such as inferior alveolar nerve (13), nasal fossae or maxillary sinus (4,8). It makes it possible to use the sinus lift technique and place implants in one step surgery: pre-operatorive planning is made easier by the three-dimensional models of the maxillary sinus (8). Its utility has also been proved in treatment of atrophic maxillae (10,15). It allows the visualization of the amount of available bone in each area and to choose the ideal donor site for osseous grafts (19): graft location, shape and volume (8,10). Another indication is complex surgical procedures (10), such as placing transzygomatic implants. In these cases, three-dimensional planning will help to follow the critical anatomical structures along the implant

trajectory (20). In a study of 29 patients with severe maxillary atrophy, 18 transzygomatic implants were placed, 6 pterygoids and 24 standard platforms. Vrielink et al (21) found 92% of accumulated success for transzygomatic and 71% for pterygoid implants during a mean follow-up period of 15 months.

Surgical navigation. Guided surgery

- *Historical development*

Minimum invasive surgery techniques are being applied to an increasing number of interventions, with the aim of reducing costs and patient healing period. Image guided navigation implies an improvement in surgical accuracy with the aid of a program based on the images captured from CT or RNM and a tracking system of ("tracker") for the surgical instruments (22).

Image guided navigation requires a means of registering anatomical points in the medical image (CT or RNM) and a program to locate the surgical instruments. Knowing the exact position of the instruments is the key to the success of the surgical intervention. CT or RNM images are used as a map and provide the surgeon with a real-time representation of the surgical instruments in relation to the images of the patient. It allows the following of the instrument position during the surgery and their visualization on the computer (23).

During the surgical phase, the surgeon is given interactive support with guidance through the operation and control of potential dangers (1,24). The techniques of virtual reality and computer-assisted surgery are increasing in importance in medical applications. Nowadays they are useful in odontology not only for placing implants, but also in arthroscopy of the temporomandibular joint, osteogenic distraction, biopsies, tumour treatment, deformities and foreign body extirpation (24).

Navigation is made possible through a series of sensors attached to the rotatory instruments, to the surgical template and to a cap fixed on the patient's head, and captured by different systems. Data obtained are transferred immediately to the computer, and enable the surgeon to see the real situation (1). These systems have developed over time from stereotactic systems, used firstly in neurosurgery (mechanical) (1,23), from systems based on ultrasounds (connected by satellite) (1), and electromagnetic systems (based on the localization of the instruments by measuring the changes produced in the magnetic field intensity) (23,24) to optical navigation systems, based on infrared light (based on the localization of infrared light emitting diodes on the instruments captured through cameras mounted in the operation room) (23,25). Siessegger et al (25) found accuracy with a margin of error of less than 1mm in the optical systems (placing 18 implants), results similar to those obtained by Wanschitz et al (26) (in 15 implants). Wagner el al (27) found a mean deviation of 1.1 (range de 0-3.5mm). These are currently the most-used systems (23), although more recently a new kind of sensor has appeared, based on surface detection by a laser scanner (1).

- *Procedure*

Once implant treatment planning has been made, infrared light emitting diodes are connected to the rotatory instruments and to the patient's template (3,25). Stereoscopic cameras registering infrared light are used to know the exact position of the bur and the patient in their respective reference frames (3,25). The information recorded by the camera is displayed in real time on a screen / monitor and is compared to the pre-established planning (25).

There are certain factors that modify the accuracy of guided surgery, such as image quality (28), the navigation system used (29,30), data acquisition (1), interaction of the surgeon with the system (29) and technical errors (29).

Precision varies according to the navigation system used, if it is optical, camera precision (29) influences the localization of position markers. It determines the spacial relationship between the bur and the patient's jaws (30). The infrared camera is the most used, with a precision of approximately 0.3mm (29). According to Wanschitz et al (26), this precision is between 0.96-0.72mm, or has a margin of error less than 1mm according to Siessegger et al (25) (although the experience is limited to maxilla due to mandibular mobility and the impossibility of correctly fixing the sensors). With respect to optical systems, in a study on a series of 240 implantations, Hoffmann el al (30) found a mean recording error of 0.86mm and the deviation between the planning and the point of perforation was 0.95mm. Regarding influence of registration (1), there can be inaccuracies in the transfer of data from planning to surgery (24). The surgeon's ability and his interaction with the system also influences accuracy. A possible source of error may be not paying attention to the indications from the monitor (29). And finally, technical failures such as camera calibration are also important considerations(29).

If these factors are adequately controlled, computer guided navigation has a better accuracy than manual implantation (29), finding no significant differences between the different commercial systems (RoboDent® (31), DenX IGI® (32), CADImplant® (11), VISIT® (22) LITORIM ® (33), Vector Vision® (25,26,28), etc) (27,29). Nevertheless, there are studies (34) in which, although an in vitro application of a navigation system resulted in a better implant placing, they affirm that final conclusions could not be made until more clinical studies on the subject were published.

Exact treatment planning decreases the possibility of complications, it minimizes the total time needed, reduces the postoperative period, improves the esthetics and functional outcome of the prosthetic restoration (27). The main disadvantage of image-guided systems is the use of the CT, which is expensive and produces a large amount of radiation. For this reason some studies (5,11,35) use a cone-beam tomograph that decreases both cost and radiation dose.

- *Clinical application*

In most clinical situations, the accuracy achieved with manual implantation is sufficient (29). Nevertheless, there are certain situations where a very precise implantation is required, as in situations with anatomical limitations, little space, atrophic maxillae, sinus lifts, transzygomatic implants, etc. In these cases, systems to guide the surgeon are of great help (29).

Conclusions

The importance of dental implant treatment planning by means of a three-dimensional view of the data obtained by CT is increasing. This is brought about by the possibility of a less traumatic surgery thanks to a good previous treatment planning, to the possibility of accurately placing the implant in the selected site and to the precise anatomical knowledge of the area to be worked, avoiding possible intraoperative complications deriving from the anatomical limitations (inferior alveolar conduct, maxillary sinus, etc).

The articles reviewed agree in emphasizing the reliability and accuracy of the planning and computer-assisted navigation systems available. Nevertheless, many applications are still in the development phase.

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