Computer-Guided Surgery in Implantology: Review of Basic Concepts

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Abstract: The aim of the present study was to conduct a critical literature review about the technique of computer-guided surgery in implantology to highlight the indications, purposes, immediate loading of implants and complications, protocol of fabrication, and functioning of virtual planning software. This literature review was based on OLDMEDLINE and MEDLINE databases from 2002 to 2010 using the key words "computer-guided surgery" and "implant-supported prosthesis." Thirty-four studies regarding this topic were found. According to the literature review, it was concluded that the computer-assisted surgery is an excellent treatment alternative for patients with appropriate bone quantity for implant insertion in complete and partially edentulous arches. The Procera Nobel Guide software (Nobel Biocare) was the most common software used by the authors. In addition, the flapless surgery is advantageous for positioning of implants but with accurate indication. Although the computer-guided surgery may be helpful for virtual planning of cases with severe bone resorption, the conventional surgical technique is more appropriate. The surgical guide is important for insertion of the implants regardless of the surgical technique, and the success of immediate loading after computer-guided surgery depends on the accuracy of clinical and/or laboratorial steps.

Key Words: Prostheses and implants, tomography, osseointegration

(*J Craniofac Surg* 2010;21: 1917–1921)

Virtual planning allows better visualization of bone morphology previous to the positioning of implants and improves the fabrication of implant-supported prostheses according to a predictable planning of the implants for treatment success.[1–4]

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Received April 20, 2010.
Accepted for publication June 20, 2010.

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The authors report no conflicts of interest.

ISSN: 1049-2275
DOI: 10.1097/SCS.0b013e3181f4b1a0

This planning enhances a high success rate for flapless surgery,[2,3,5–7] but it may present postoperative complications and limitations when it is counterindicated.[8–12]

In addition, an implant-supported fixed prosthesis can be fabricated in the laboratory using a cast based on the surgical guide and immediate loading of the implants attached to the abutments can be conducted.[13] Although this procedure may be advantageous, special care is required, and some difficulties may occur for prosthesis insertion.

Some studies about computer-guided surgery in implantology were carried out to valorize the reverse planning for positioning and angulation of the implant according to a prosthetic-driven position. However, some inconclusive topics should be highlighted, mainly regarding the advantages and limitations of the flapless surgery.

According to this, the aim of the current study was to conduct a critical literature review about the guided surgery in implantology to highlight the indications, purposes, immediate loading of implants and possible complications, protocol of fabrication, and functioning of the virtual planning software.

MATERIALS AND METHODS

The present literature review was based on OLDMEDLINE and MEDLINE databases from 2002 to 2010 with the keywords "guided surgery" and "implant-supported prosthesis." The research was limited by studies written in English containing all or some of the keywords.

LITERATURE REVIEW

Description of the Studies Evaluated

Thirty-four studies on guided planning in implantology were found including 12 clinical evaluations,[7–9,11,14–17,19–22,34] 11 case reports,[1,2,4,6,12,23–27] 6 technical notes,[3,10,28–31] 4 literature reviews,[4,11,13,32] and 1 laboratorial study[33] (Table 1).

Indications and Purposes of the Computer-Assisted Surgery

The guided surgery was indicated for complete[1,2,4–8,11,12,14,15,23,25–28,33] and partially edentulous patients,[3,9,17,21,24,30] and some authors reported both clinical situations[10,16,19,20,22,34] (Table 1).

Most of the authors described that the guided surgery was indicated for both maxilla and mandible.[8–10,12,14,16,17,19,20,22,29,32,34] However, some authors indicated the technique only for maxilla[5–7,15,21,24–26] or mandible[1–4,11,23,27,28,30,33] (Table 1).

Two purposes are reported for computer-guided surgery. The first one allows accurate planning for better positioning of implants according to a tomographic image. The second one consists in fabrication of the surgical guide for accurate placement of the

TABLE 1. Summary of Available Articles

Reference	Type of the Study	Edentulism	Arch	Software
Campelo and Camara (2002)[22]	Clinical evaluation (359 patients)	Total; partial	Maxilla; mandible	—
Van Steenberghe et al (2002)[15]	Clinical evaluation	Total	Maxilla	Litorim
Sarment et al (2003)[33]	Laboratorial study	Total	Mandible	Simplan software
Tardieu et al (2003)[1]	Clinical report	Total	Mandible	SurgiCase Dental program
Ewers et al (2004)[16]	Clinical evaluation (55 patients)	Total; partial	Maxilla; mandible	MedScanII–Virtual Implant
Holst et al (2004)[28]	Technical note	Total	Mandible	—
Becker et al (2005)[8]	Clinical evaluation (57 patients)	Partial	Maxilla (n = 32); mandible (n = 47)	—
Casap et al (2005)[2]	Clinical report	Total	Mandible	Image-guided implantology system
Ewers et al (2005)[32]	Literature review	Total; partial	Maxilla; mandible	MedScanII–Virtual Implant
Marchack (2005)[5]	Clinical report	Total	Maxilla	Medicim
Kupeyan et al (2006)[6]	Clinical report	Total	Maxilla	Procera NobelGuide software
Lal et al (2006)[9]	Technical note	Total; partial	Maxilla and mandible	SurgiCase Dental program
Widmann and Bale (2006)[10]	Literature review	—	—	—
Bedrossin (2007)[29]	Technical note	Total; partial	Maxilla and mandible	Procera NobelGuide software
Cannizzarro et al (2007)[7]	Clinical evaluation (33 patients)	Total	Maxilla	—
Holst et al (2007)[23]	Clinical report	Total	Mandible	Implant3D
Malo et al (2007)[14]	Clinical evaluation (23 patients)	Total	Maxilla (n = 18); mandible (n = 5)	Procera NobelGuide software
Marchack (2007)[3]	Technical note	Partial	Mandible	Procera NobelGuide software
Ozan et al (2007)[17]	Clinical evaluation (12 patients)	Partial	Maxilla; mandible	3D SENTCAD software
Sherry et al (2007)[30]	Technical note	Partial	Mandible	Procera NobelGuide software
Xiaojun et al (2007)[31]	Technical note	—	—	Image guided oral implant system
Wittwer et al (2007)[34]	Clinical evaluation	Total	Mandible	Stealth station
Abbo and Miller (2008)[24]	Clinical report	Partial	Maxilla	Procera NobelGuide software
Allum (2008)[11]	Clinical reports	Total	Maxilla (n = 1); mandible (n = 1)	Simplan software
Azari and Nikzard (2008)[12]	Literature review	—	—	—
Balshi et al (2008)[13]	Clinical evaluation (23 patients)	Total	Maxilla; mandible	Procera NobelGuide software
Cheng et al (2008)[25]	Clinical report	Total	Maxilla	Procera NobelGuide software
Mandelaris and Rosenfeld (2008)[4]	Review and case report	Total	Mandible	—
Yong and Moy (2008)[18]	Clinical evaluation (13 patients)	Total (n = 11); partial (n = 3)	Maxilla (n = 9); mandible (n = 5)	Procera NobelGuide software
Becker et al (2009)[19]	Clinical evaluation (57 patients)	Total; partial	Maxilla; mandible	—
Fortin et al (2009)[20]	Clinical evaluation (11 patients)	Partial	Maxilla	EasyGuide Protocol
Oyama et al (2009)[26]	Clinical report	Total	Maxilla	Procera NobelGuide software
Tahmaseb et al (2009)[27]	Clinical report	Total	Maxilla; mandible	Exe-Plan software
Valente et al (2009)[21]	Clinical evaluation (25 patients)	Total (n = 10); partial (n = 17)	Maxilla (n = 15); mandible (n = 12)	Simplan software

implants based on a previous planned position for immediate prosthesis insertion.[18]

Virtual Planning Software

The software based on computed tomography allow volumetric reconstruction of several transversal slices of data obtained by sagittal, coronal, and axial slices. The advantages of this radiologic technique make it the most accurate and indicated for planning of dental implants.[35,36] However, its accuracy depends on the thickness of the slice obtained during the tomographic examination, movement of the patient during the examination, and presence of artifacts in the restorations.[11,37]

The software used in the present review were Procera Nobel Guide (Nobel Biocare, Yorba Linda, CA), Simplan (Columbia Scientific Incorporated, Columbia, MD), Surgicase (Materialise, Leuven, Belgium), MedScanII–Virtual Implant (Artma Medical Technologies AG, Vienna, Austria), image-guided implantology (IGI; Denx Advanced Dental Systems, Moshav Ora, Israel), image-guided oral implant system, Litorim (Leuven Information Technology, Leuven, Belgium), Medicim (Sint-Niklaas, Belgium), Implant3D (med3D, GmbH, Heidelberg, Germany), 3D SENTCAD software (Media Lab Software, La Spezia, Italy), Stealth station (Spine 3Ds; Medtronic Inc), EasyGuide Protocol (Keystone-Dental, Burlington, MA), and ExePlan software (Brussels, Belgium).

It is important to simulate the three-dimensional positioning of the implant in the sagittal view of the tomography for precise planning. After selection of implant length and diameter according to the bone anatomy, angulation should be assessed to visualize the emergence of perforations in the denture teeth. Alterations in angulation can be made to improve biomechanics and favor stress distribution toward the implant long axis. If the ideal angulation is not achieved, an angled abutment can be selected according to the implant depth and its relation with the denture teeth to provide excellent aesthetic results.[10] Other biomechanical considerations include horizontal distribution to prevent rotation of the implants, achieving the tripodism[37] and decreasing the cantilever.[38]

DISCUSSION

Flapless Surgery

The advantages of the flapless surgery include reduced operative period, less invasive surgical technique, reduced postoperative complications and discomfort, and minimized bone loss.[2,3,5,6,8,9,19,34] Besides, the computer-guided surgery is less affected by human precision in comparison to the conventional technique.[11]

In contrary to other authors reporting about the flapless surgeries, Becker et al[9] stated that this technique presents surgical complications due to raising the soft tissue as infections, dehiscence, and necrosis. For cases with bone resorption, Cannizzarro et al[7] reported that flap is important for positioning of the implant to increase bone contact. However, when bone quantity is enough for implant insertion, flap is unnecessary because of its higher morbidity and patient's discomfort.[7]

Becker et al[20] stated that the patient should present at least 4 mm of bone thickness and 12 mm of bone height in relation to the mandibular canal and maxillary sinus as inclusion criteria for flapless surgery.

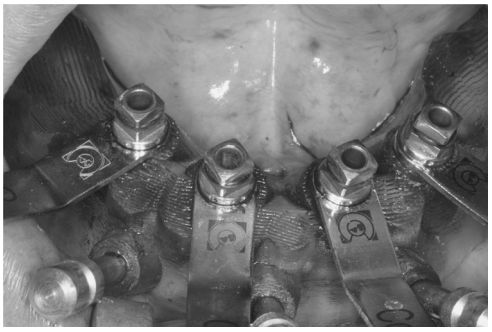

FIGURE 1. Surgical guide fixed by fixation screws with the washers in position.

FIGURE 2. Patient occluding on the record of silicone to stabilize the guide during perforation of the fixation screws.

Campelo and Camara[34] conducted a retrospective study (Table 1) evaluating flapless surgeries and found a success rate of 74.1% in the first year and 100% after a 10-year follow-up.

Similarly, Becker et al[9] evaluated partially edentulous patients (Table 1) and found a success rate of 98.7% after 2 years, with loss of 1 implant among 79 implants inserted. Furthermore, the bone loss was clinically insignificant (0.05 mm). This high percentage may have occurred because most (n = 67) of the implants were inserted in bone without resorption and with bone quality type II (70 implants).

Surgical Guide

According to Sicilia et al,[39] the need of surgical guide for treatment of mandibles is not frequent, but it is important for maxillary rehabilitations. However, most authors agree that the surgical guide is essential for accurate execution of the planning.[28] Several types of surgical guides are described in the literature but its major disadvantage is instability for complete edentulous patients, mainly when only remaining soft tissues are used for support.[28,39]

This limitation can be minimized by fixation screws to stabilize the guides and decrease the movement during perforation and insertion of the implants at the surgical step (Fig. 1). The patient should be asked to occlude bilaterally an occlusal record fabricated on the antagonist arch to help insertion of the fixation screws and stabilize the guide (Fig. 2).

Besides this disadvantage of the guided surgery technique, it is also limited for cases with appropriate bone quantity and quality (Fig. 3) and counterindicated for patients with reduced mouth opening that jeopardizes positioning of surgical instruments on the guide.[5,8] A minimum of 5 mm of mouth opening is suggested.

FIGURE 3. Bone quantity clinically satisfactory for guided surgery. Mouth opening appropriate for guided surgery.

Immediate Loading for Guided Surgery

The protocol of immediate loading after guided surgery provides all benefits of a treatment with implants with short time and maximum comfort for the patient.[14] Some authors[30] reported that the insertion of a removable implant-supported prosthesis after guided surgery may cause some biologic disturbances between the mucosa and the abutment and may be painful for the patient. In addition, removal of the abutment may generate a microgap between the implant and the abutment that influence bone remodeling in the region.[14]

Yong and Moy[19] evaluated cases of guided surgery with immediate insertion of fixed prosthesis (Table 1) to assess early and late complications. The early surgical complications were related to bone interference during insertion of the implants that can be minimized with Morse taper implants and abutments with platform switching. The early prosthetic complications included loss of the prosthesis, problems with phonetics, and lack of bilateral contact. The late surgical complications were related to persistent pain in the region of the implants and defects in soft tissue, whereas the late prosthetic complications were occlusal overload, fracture of the prosthesis, and unsatisfactory aesthetics.

Literature reported a medium of deviation of 0.9 mm and 4.5 degrees between the planning before surgery and the condition obtained after surgery in relation to implants positioning.[11,15,33] The main causes of this deviation were unstable fixation of the surgical guide, imprecise impressions, and/or incorrect pouring of the casts.[11] If this deviation is transferred to the immediate loading of a previously fabricated prosthesis, misfit between the components will probably occur and compromise the long-term treatment success.

Mistakes in Guided Surgery

The computer-guided surgery consists in a sequence of diagnostic and therapeutic steps, and mistakes may occur in different stages. The most common mistakes are as follows:

1. Acquisition of tomographic image and incorrect processing (mean of error <0.5 mm)[22,40]
2. Fabrication of the surgical guide with deviation from 0.1 to 0.2 mm[15,22]
3. Inaccurate positioning of the guide resulting in displacement during perforation[22]
4. Mechanical errors caused by angulation of the drills during perforation that may cause lateral deviations[22]
5. Reduced mouth opening that jeopardizes positioning of the surgical instruments[22]
6. Human mistakes as not using the whole length of the drill during perforation.[22]

Although the guided surgery in implantology exhibits some limitations, Ewers et al,[16,32] with clinical experience during 7 and 12 years with virtual planning, described that this technology is essential for evolution of clinical safety and treatment success with implants.

Concerns for Success

Some concerns are necessary for accuracy and quality of fixed prostheses when flapless surgery technique is used through virtual planning.[10,11,14]

1. Proper fabrication of the removable complete denture with accurate functional impression and adequate determination of maxillomandibular relations and dental positioning.
2. Adequate positioning of the complete denture in relation to the antagonist arch and the anatomy of the soft tissues during computed tomography (Fig. 4). The patient can be asked to use an adhesive to improve stabilization of the denture during the scanning. This denture can present radiopaque marks of barium sulfate.
3. The virtual relationship of the surgical guided superposed to the bone anatomy during the planning of the implants.
4. Detailed and meticulous laboratorial technique.
5. Fit of the surgical guide to the arch and uniform biting force on the occlusal record of the guide (Fig. 2).
6. Placement of the implant in the whole length planned in the washer of the guide.
7. Proper torque and connection of the abutment attached to the implant.

FIGURE 4. Stable occlusion for computed tomography.

CONCLUSIONS

According to the literature review, it was concluded that

1. The guided surgery represents an excellent treatment alternative for patients with satisfactory bone quantity for implant insertion and can be indicated for complete and partially edentulous arches in the maxilla and/or mandible.
2. Procera Nobel Guide (Nobel Biocare) was the most common software used by the authors evaluated.
3. Although the flapless surgery is advantageous for implants positioning, it presents precise indication for situations with appropriate bone quantity and quality.
4. For cases with severe bone resorption, the guided surgery is helpful for virtual planning, but the flapped surgical technique is better recommended.
5. The guided surgery is essential for insertion of the implants regardless of the surgical technique.
6. The success of an immediate loading prosthesis fabricated previously to the surgery depends on accuracy of all clinical and/or laboratorial steps of the virtual planning.

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