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Computer-Aided Implant Surgery: A Literature Review

By Lauren Bohner, Rafael Prestes, Eduardo Mukai, Sueli Mukai
& Rogério de Lima Romeiro

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Material and Methods: A literature search was applied in electronic database using the key-words: "Guided surgery", "dental implants", "computer-aided surgery", "stereolito-graphic guides".

Results: The procedure involves the use of diagnostic imaging and CAD – CAM technology with the purpose of obtaining a surgical guide, which transfers the virtual implant planning to the surgical field. The technique allows to couple the desired prosthesis into the anatomical structures in order to determine the implant positioning. Thus, the method provides greater safety during surgery, accurate knowledge about position of anatomical structures and their relationship to the future prosthesis. Besides, it allows a flapless surgery, providing a shorter surgical time and reducing the post-surgical discomfort.

Conclusion: Guided surgery requires specialized knowledge and high standards of care. However, when performed in accordance with patient´s specific needs, it may represent a faster and safety procedure.

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I. Introduction

Dental implant has becoming a common procedure in clinical practice due to the long-term predictability of the treatment (Tortamano et al., 2009). In order to ensure the treatment success, an accurate treatment planning is required, which comprises the association between the surgery and prosthetic treatments.

Treatment planning is usually performed with the aid of radiographic and clinical examinations. In this respect, both the examination of anatomical structures by means of cone-beam computed tomography (CBCT) such as the use of a surgical stent to transfer the prosthetic planning to the surgical procedure are essential aspects to determine an accurate implant placement (Carvalho et al., 2006).

However, the conventional technique does not allow to associate the prosthetic requirements to the bone availability, which may result in errors during the surgical procedure. Furthermore, the manual process of manufacturing may also result in errors inherent to the surgical stent fabrication (Gulati et al., 2015).

Author α: Lauren Bohner, Rafael Prestes, Eduardo Mukai, Sueli Mukai, Rogério de Lima Romeiro. e-mail: lauren@usp.br

Guided surgery allows to overcome the limitations related with the conventional process by associating the surgical and prosthetic treatment planning. The techniquecomprises the digital workflow on which the virtual planning considers both surgical and prosthetic needs of the patient. In addition, by means of a stereolitographic template, it is possible to transfer the virtual planning to the surgical procedure (Aaschen et al., 2012).

The main advantage of the technique is the positioning of dental implants based on surgical and prosthetic requirements, allowing a safety, easiness and faster surgical procedure. Furthermore, it decreases the postoperative discomfort of the patient (Greenberg et al., 2015). Despite of the several advantages provided by the technique, the accuracy of the guided surgery and the success rate of the procedure are still controversial. Hence, the purpose of this study was to update the literature regarding the computer-guided implant surgery.

II. Materials and Methods

The literature search was performed in the electronic database Pubmed/Medline, using the following key-words: "Guided surgery", "dental implants", "computer-aided surgery", "stereolitographic guides".

Inclusion criteria comprised studies evaluating the accuracy of the technique for dental implant placements. Articles containing insufficient information and case reports were not considered for this study. The articles were chosen based on title and abstracts, followed by the full-reading of the paper, from which data were extracted.

III. Results

a) *Initial considerations*

Guided surgery is the digital workflow on which the placement of dental implants is virtually planned based on surgical and prosthetic needs of the patient. The technique associates the location of anatomical structures, bone availability and prosthetic requirements (Bornstein et al., 2014). Thus, it is mainly indicated to complex rehabilitations, on which the bone availability is limited or in cases on which a minimal invasive procedure is required (Yilmas et al., 2015).

The following advantages regarding the guided surgery are described in literature: the integration

between the virtual planning and the surgical procedure; the possibility to guide the perforation according to the bone availability and location of anatomical structures; the possibility to perform a minimal invasive procedure by means of flapless technique and the greater precision provided by the virtual treatment planning (Greenberg et al., 2015).

However, the use of technique is limited due to the complexity, higher costs and the need of learning curve. Furthermore, there are risks inherent to the procedure, as the deviation of implant positioning due to the manufacturing of an inaccurate surgical guide. Therefore, it is not indicated in cases on with the mouth opening is limited, as it may cause the wrong positioning of surgical instruments (Gulati et al., 2015).

b) Virtual planning

The virtual planning begins with a tomographic exam, which allows to determine the positioning and angulation of the dental implant. In this respect, cone-beam computed tomography provides a tridimensional image on which the placement of implant is simulated (Figure 1).

After, the definitive restoration is designed and coupled to the tomographic exam, associating the surgical planning to the prosthetic treatment. In this case, functional and aesthetic aspects related to the prosthesis are provided during the prosthetic planning. Thus, the positioning and angulation of dental implants are chosen based on both bone availability and occlusal relationship (Ganz et al., 2015).

During the prosthetic planning, a diagnostic wax-up is fabricated to obtain a diagnostic model. After, the design of the future prosthesis is added to the virtual planning by scanning a radiographic template containing radiopaque materials. The tomographic scan in performed with the template positioned into the patient mouth, allowing the visibility of tooth position in relation to the underlying bone (Ganz et al., 2015). A second possible approach is to scan the diagnostic model by means of an optical scanner. Furthermore, CAD-CAM (computer-aided design/computer-aided manufacturing) technology allows to virtually plan and design the future prosthesis by direct scanning of the intraoral arch (Figure 2).

The prosthetic planning is associated to the CBCT data to design the surgical guide, which is then fabricated by means of prototyping (Figure 3). The association between these digital techniques increases the accuracy of the technique (Patel et al., 2010; Reyes et al., 2015).

c) Surgical guides

The fabrication of customized surgical guides is possible due to the association between digital technologies. The surgical guide is virtually designed and fabricated by prototyping. Three types of surgical guides are available, and they differ according to the tissue type used as support: bone, mucosa or tooth-supported guides. The bone-supported guide offers a greater precision, as it allows the visualization of the surgical field. On the other hand, by using mucosa-supported guides it is possible to use minimal invasive procedures, as flapless surgical techniques (Gallardo et al., 2016).

IV. Discussion

Guided surgery offers several advantages to implant surgery due to the possibility of transfer the virtual planning to the surgical procedure. The key factor for the implementation of guided surgery is the use of digital techniques, such as CBCT, virtual software and CAD-CAM system (Gulati et al., 2015). Although the technique present some limitations, when correctly performed, it allows a safe and accurate procedure (Katsoulis et al., 2009), presenting a survival rate similar to the conventional technique (Hultin et al., 2012). On the other hand, Schneider and al (2009) claim different errors may occur during the planning and surgical phases. Hence, there is a need of improvement of the technique in order to avoid prosthetic complications.

Arisan et al. (2015) evaluated the deviation of 108 implants placed by mucosa-supported surgical guides when using CBCT or computed tomography for virtual planning. Both technique presented similar deviations. Petersson et al. (2010) evaluated the accuracy of technique by comparing the virtually planned position of implants to the positioning after the surgical procedure. The authors emphasized the need of a rigid protocol to avoid errors during the procedure.

The accuracy of guided surgery relies on the stability of the surgical guide into the patient mouth (Gulati et al., 2015). However, studies are still controversial regarding the fidelity presented by surgical guide to transfer the implant positioning from the virtual planning to the surgical procedure (Petersson et al., 2010; Arisan et al., 2012). According to Sicilia et al. (2012), deviations up to 6 mm on implant positioning may occur due to the instability of the surgical guide, especially in cases of multiple implants.

Arisan et al. (2010) compared the conventional procedure to the computer-aided implant surgery when using bone and mucosa-supported guides. The evaluation was based on surgical duration and postoperative complications. With this regard, the use of mucosa-supported guides for flapless technique decreased the surgical time and postoperative discomfort of the patient. In addition, Vasak et al., (2010) reported the flapless surgery is a reliable technique, as the deviation of implant positioning did not exceed the safety distance recommended by the planning software.

Micromovements of the surgical guide, which occur during the surgical procedure, are the main responsible to the instability of the template. Di Giacomo

et al. (2012) showed a rate of 34,43% of complications resultant from the guided surgery. The implant deviation commonly occurs in posterior region due to the difficult in positioning the surgical guides, especially in cases on which the patient present a reduced mouth opening. Even though, the technique is considered effective for complex rehabilitations and minimal invasive procedures (Fortin et al., 2010).

V. Conclusion

Guided surgery requires specialized knowledge and high standards of care. However, when performed in accordance with patient´s specific needs, it may represent a faster and safety procedure.

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Figure Legends

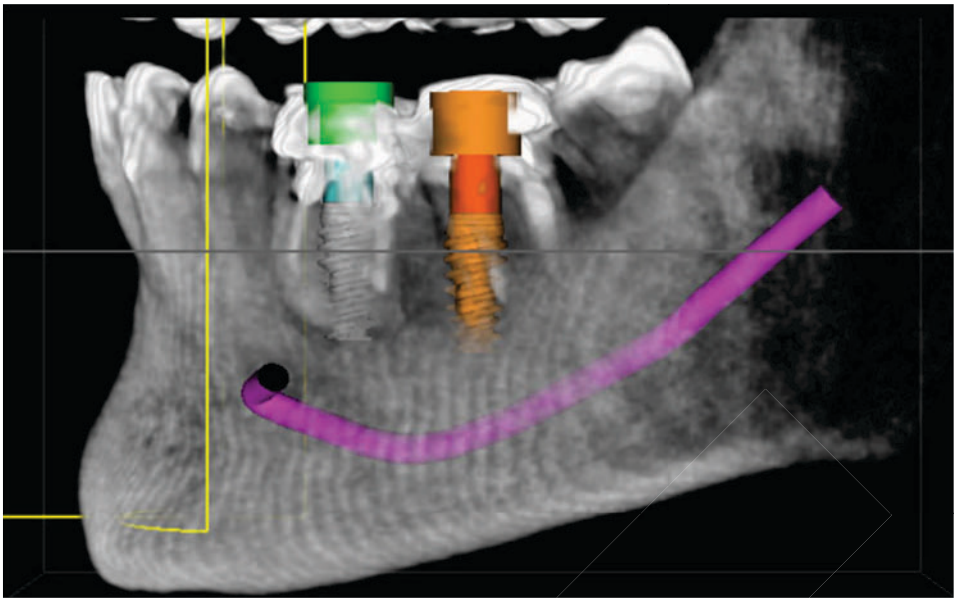

Figure 1: Virtual planning by means of CBCT.

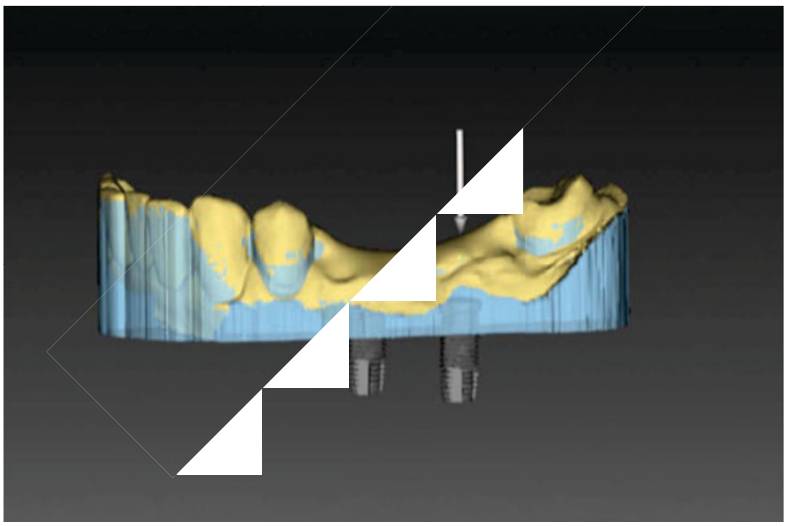

Figure 2: Virtual planning by means of CAD-CAM.

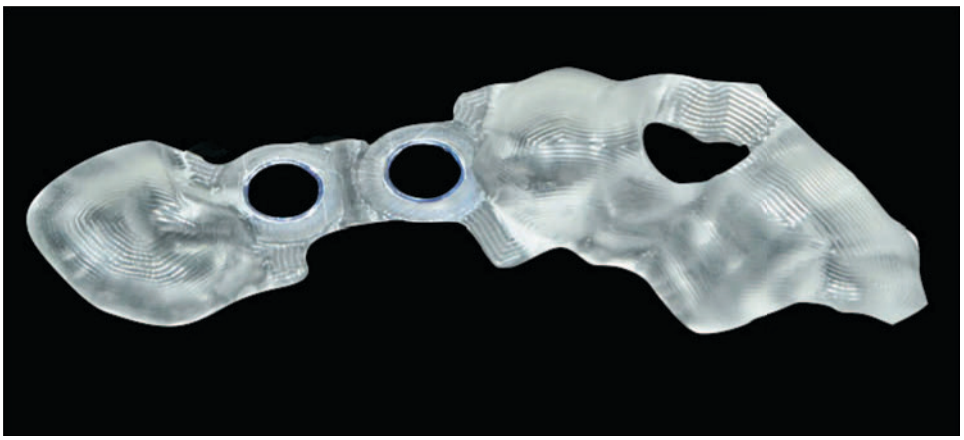

Figure 3: Surgical guide.