Surgical Stents in Implant Dentistry : A Review

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Abstract

Various techniques have been proposed for the fabrication of surgical guide templates in implant dentistry. The objective of this paper is to review the associated literature and recent advancements in this field, based on design concept.

Introduction

A new era of Restorative Dentistry has evolved with the newer generation of Biomaterials which has proven to be a boon for the Dental fraternity. Dental Implants have proven to be a new horizon and a field of speciality where the horizons have been broadened with different treatment modalities both surgically and Prosthetically. Recent studies on clinical success of dental implants have indicated a high survival rate. Also the association of surgical and prosthetic complication with improper diagnosis and placement of implants have also been documented. These factors play a crucial role in the long-term predictability and success of implant prosthesis. Surgical guide templates not only assist in diagnosis and treatment planning but also facilitate proper positioning and angulation of the implants in the bone. The surgical template dictates the implant body placement that offers best combination of support for repetitive forces of occlusion and aesthetics. Moreover, restoration- driven implant placement accomplished with a surgical guide template can decrease clinical and laboratory complications. Hence, increasing demand for dental implants has resulted in the development of newer and advanced techniques for the fabrication of these templates.

Historical Overview

Since 1952, extensive experimental and clinical studies which have constituted the basis for permanent tissue integration of prosthesis, have been performed at the Laboratory for Vital Microscopy, Department of Anatomy, University of Lund, Sweden since 1960 at the Laboratory Of Experimental Biology, University of Goteborg, Sweden and since 1978 at the insitiute for applied Biotechnology in Goteborg, Sweden.

The concept of osseointegration is based on research that began in 1952 with microscopic studies in situ of bone marrow in rabbits fibula.

- Pure titanium was used instead of tantalum which had been used previously for.
- Titanium seemed to have better mechanical & surface charachteristic for implantation in biologic environment.

Theses studies in early 1960's indicated possibility of establishing true osseointegration in bone tissue, because the optical chambers used could not be removed from the surrounding bone once they had healed.

During the course of early 1980's it was realized that placement of implants and angulations lead to a better prognosis of the implants and prosthetics which lead to development of surgical guides which were most of the time laboratory made.

As the research developed a logical community between diagnosis, prosthetic planning and surgical phases use of a transfer device is essential which lead to development of Cad Cam based surgical guides in combination with CT scans and CBCT.[1]

Surgical guide template fabrication involves a diagnostic tooth arrangement through one of the following ways[2]:

A diagnostic waxup and A trial denture. (Fig. 1 & 2)

The fabrication of the surgical guide templates is then based on one of the following design concepts[3]

1. Nonlimiting design .
2. Partially limiting design.
3. Completely limiting design.

Non Limiting Design

Nonlimiting designs only provide an indication to the surgeon as to where the proposed prosthesis is in relation to the selected implant site.[3] This design indicates the ideal location of the implants without any emphasis on the angulation of the drill, thus allowing too much flexibility in the final positioning of the implant. Blustein et al[4] and Engelman et al[5] described a technique in which a guide pin hole was drilled through a clear vacuum-formed matrix . This hole indicated the optimal position of the dental implant. However, the angulation was determined by the use of adjacent and opposing teeth. Almoget al[6] described the circumference lead strip guide in which a lead strip was attached to the external surfaces of the diagnostic waxing. This was used to outline the tooth position over the implant site. (Fig. 3A & 3B).

Partially Limiting Design:

In such designs, the first drill used for the osteotomy is directed using the surgical guide, and the remainder of the osteotomy and implant placement is then finished freehand by the surgeon.[7] (Fig. 4)

Techniques based on this design concept involve fabrication of a radiographic template, which is then converted into a surgical guide template following radiographic evaluation.

Completely Limiting Design

Completely limiting design restricts all of the instruments used for the osteotomy in a buccolingual and mesiodistal plane.[7] Moreover, the addition of drill stops limits the depth of the preparation, and thus, the positioning of the prosthetic table of the implant.

As the surgical guides become more restrictive, less of the decision-making and subsequent surgical execution is done intraoperatively. This includes 2 popular designs: cast-based guided surgical guide and computer-assisted design and manufacturing (CAD/CAM) based surgical guide and Sterioloithiography.

Cast-based Guided Surgical Guide

The surgical guide is a combination of an analog technique done along with bone sounding and the use of periapical radiographs in a conventional flapless guided implant surgery.[7] The periapical radiograph is modified using digital software to help in transposition of root structure onto the cast. The cast is then sectioned at the proposed implant site, and bone-sounding measurements are transferred to help in orientation of the drill bit to perform a cast osteotomy. A laboratory analog is placed in the site, and a guide sleeve consistent with the implant width is modified to create a framework und the teeth. Guttapercha can be used to confirm the bone height and width for accurate placement when considering the flapless placement considering this technique. Once confirmed the same surgical guide made on cast can be used as a stent. (Fig. 5)

CAD/CAM-based Surgical Guide

CT/CBCT scanners allow the dentist and surgeon to visualize a patient's anatomy in 3 dimensions.[8] Visualization of the height and width of available bone for implant placement, soft tissue thicknesses, proximity and root anatomy of adjacent teeth, the exact location of the maxillary sinuses and other pertinent vital structures such as the mandibular canal, mental foramen and incisive canal are possible. Once images are imported into proprietary software programs (eg, Simplant, Nobel Clinician) the clinician can then virtually treatment plan the placement of implants for an individual patient's anatomy and case plan. The type and size of the planned implant, its position within the bone, its relationship to the planned restoration and adjacent teeth and/or implants, and its proximity to vital structures can be determined before performing surgery. Computer-generated surgical drilling guides can then be fabricated from the virtual treatment plan. These surgical guides are used by the doctor to place the planned implants in the patient's mouth in the same positions as in the virtual treatment plan, allowing more accurate and predictable implant placement and reduced patient morbidity.[9] (Fig. 6A & 6B)

Steriolithography

This technique uses advanced computer software (Surgi Case, Leuven, Belgium) along with a rapid prototyping technology called stereolithography to achieve this. It permits graphic and complex 3D implant simulation and fabrication of computer-generated surgical templates (Surgi Guides, Materialise, Leuven, Belgium) that seat directly on the bone and are pre-programmed with the individual depth, angulation, mesiodistal, and bucco-lingual positioning of individual implants as planned during the 3D computer workup.[13]

Other commercially available software packages allow similar 3D planning-

1. SIM/Plant, Columbia Scientific Incorporated, Columbia, MD.
2. Nobel Guide, Nobel Biocave, Yorba Linda, CA.
3. I-Dent Imaging Ltd., Hod Hasharon, Israel.
4. Co Diagnosti X, IVS Solutions AG, Chemnitz, Germany.
5. Im Placer, Pacific Coast Software Inc., CA.

Technique[14]

1. Diagnostic Waxup

Diagnostic study casts are properly articulated on a semi-adjustable articulator. After a comprehensive clinical and roentgenographic examination, a sound treatment plan is formulated and a diagnostic wax-up is completed. An impression of the wax-up is made using irreversible hydro- colloid impression material and a duplicate cast is made in Type IV dental stone. A radiographic template is fabricated on a duplicate study cast. For complete dentures, a duplicate of a previously fabricated complete denture can also be used, if the denture contains correct relationships.

2. Radiographic Template

Radiographic templates fabricated using barium sulfate as the radio opaque marker are most suitable for this technique. In cases where a duplicate denture is being used for the radiographic template, radio opaque markers can be placed in the center of the occlusal surfaces of the teeth corresponding to the screw access holes of the the patient can be instructed to use denture adhesive to stabilize the template during the scanning procedure. Alternatively, barium sulphate denture teeth such as Vivo TAC/Ortho TAC (IvoclarVivadent, Amherst, NY) can be used for the radio graphic template for more precise planning. The barium teeth are a more accurate representation of the intended restoration as they appear on the reformatted CT data. This would preclude the possibility of deviating from the confines of the intended restoration while moving the simulated implants or using angulation correcting abutments. (Fig. 7)

3. CT Scan Procedure/ Data Acquisiton

The CT scanning procedure is performed with the radiographic template in place. The spiral CT (also referred to as helical or volume-acquisition CT) is preferred. It involves simultaneous translatory movement of the patient while the X-ray source rotates, so continuous data acquisition is achieved while scanning the entire volume of interest. A conventional scanning protocol is followed however, some additional instructions to the radiologist should be included on a roentgenographic prescription.

Use a bone or high resolution image reconstruction algorithm to get sharp reformatted images where you can locate internal structures such as the inferior dental alveolar canal.

4. Reconstruct the images with a 512 × 512 matrix and a field of view between 140 and 170 mm to include the entire arch.
5. Only the axial images are required, no dental reformatting has to be

made.

6. The slice thickness, table feed per second and reconstructed slice increment should be 1.0 mm.
7. Gantry tilt should be 0°.

The images should be saved as a ".sim" file format on a suitable data storage medium like a ZIP disc or CD. If other software packages are used, the data should be stored in a file format compatible with that software.

3D Computer Simulation [15]

Using the software, the surgeon and prosthodontist can simulate implant placement on the 3D model in conjunction with the parasagittal views. The dental team can select implants of specific length and diameter from a database of most commercially available implants and reproduce a 3D replica of exact dimensions in the desired location on the computer model of the patient's jaw. The simulated implants can be bodily translated or tilted about their long axis until their ideal location within the bone is finalized. Another unique feature of the software is that it allows the user to make the surface rendering of the bone transparent. This allows complete visualization of all anatomical structures situated within the bone. Otherwise, these structures would be invisible. It is also possible to interactively rotate the 3D model along with the simulated implants in all directions. Once the computer simulation is completed, it is saved as a ".sim" file and sent to the processing center via e-mail. This file transfers geometrical information, consisting of numerous triangles, to another workstation which describes a volume by its boundary surface. Triangles have exactly three sides and vertices so they are always planar. This allows them to accurately define the surface topography of the bone without gaps or overlaps. This triangulated data is the interface to the stereolithographic apparatus (SLA).

Fabrication of Stereolithographic Templates [16]

At this stage, a rapid prototyping machine using the principle of stereolithography is employed to fabricate the stereolithographic models. (Fig. 8)

The SLA consists of a vat containing a liquid photo-polymerized resin. A laser mounted on top of the vat moves in sequential cross- sectional increments of 1 mm, corresponding to the slice intervals specified during the CT formatting procedure. The laser polymerizes the surface layer of the resin on contact. Once the first slice is completed, a mechanical table immediately below the surface moves down 1 mm, carrying with it the previously polymerized resin layer of the model. The laser now polymerizes the next layer above the previously polymerized layer. In this manner, a complete stereolithographic model of the patient's jaw can be created. Approximately 80% of the total polymerization is completed in the vat; the remaining 20% can be completed in a conventional ultraviolet light curing unit. The surgical templates are fabricated in a similar manner. The precise depth, angulation, and mesiodistal and bucco-lingual positioning of each im- plant as planned during the computer simulation is preprogrammed in the template. The template itself is fabricated of Stereocol resin (Zeneca Specialties, Blackley). (Fig. 9)

Metal sleeves of varying diameters accurately guide the osteotomy drills. Windows on the buccal aspect allow access for external irrigation used in surgical procedures. The templates can be sterilized using most common techniques without the loss of properties. These include low temperature steam and formaldehyde at 80°C. There are windows on the buccal surface to allow for irrigation with saline. Because the template is precisely shaped to the unique surface topography of the bone, the template is extremely stable without the need for any external fixation. Also, the unique fit forms a peripheral seal allowing water from irrigation to escape only through the irrigation windows on the buccal aspect of the template or from the superior aspect of the guiding sleeves. In effect, there is a constant pool of water created at the osteotomy site, thereby providing more efficient cooling of the bone.

Summery

Although the completely limiting design is considered a far superior design concept, most clinicians still adopt the partially limiting design due to its cost effectiveness and credibility in the field. In addition, it has been observed that most clinicians use surgical guide templates that are based on cross sectional imaging to facilitate accurate planning and guidance during the surgical phase. Evidence based research still needs to be conducted to evaluate the applications of the completely limiting design and its effect on the treatment outcome in oral implantology.

Reference

References are available on request at editor@healtalkht.com

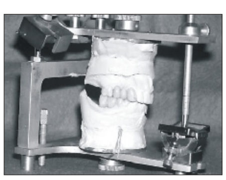

Fig. 1

Fig. 2

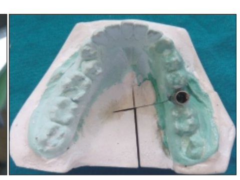

Fig. 3A

Fig. 3B

Fig. 4

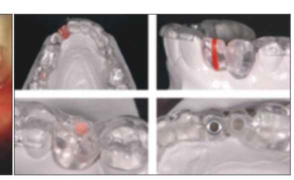

Fig. 5

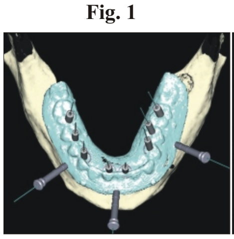

Fig. 6A

Fig. 6B

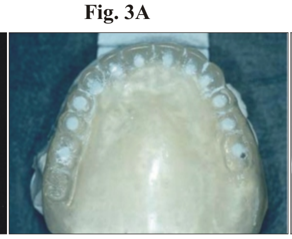

Fig. 7

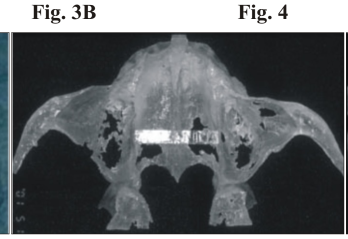

Fig. 8

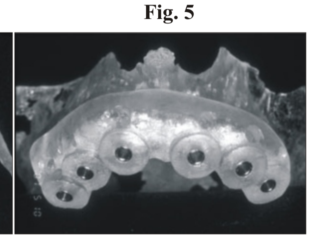

Fig. 9