

Surgical Templates in Implantology

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Abstract

The clinical success of dental implants has been shown in recent studies to have a high implant survival rate. Nevertheless, it has also been shown that incorrect diagnosis and implant placement are unintentionally linked to the majority of surgical and prosthetic complications. These elements are essential to the success and long-term predictability of implant prosthetics. Surgical guide templates help with proper positioning and angulation of the implants in the bone in addition to aiding in diagnosis and treatment planning. In addition, using a surgical guide template to place implants that are restoration-driven can reduce clinical and lab complications. Due to the rising demand for dental implants, newer and more sophisticated methods for creating these templates have been developed.

Keywords: Computer-assisted design and manufacturing, Implants, Stereolithography, Surgical Guide

INTRODUCTION

Dental implants have emerged as one of the most widely selected options for tooth replacement. Replacement options are wide. However, implants gain more attention of patients as they are more comfortable and efficient compared to other replacement options. Implant-supported oral restorations became the best option for edentulous as well as partially edentulous patients. The osseointegration property exhibited by implants makes them more stable and efficient for the purpose of mastication, speech as well as esthetics. Bone augmentation, regeneration along with soft tissue regeneration made them a convenient and efficient treatment modality in prosthodontics. Designing a prosthesis supported by an implant was still a challenge.^[1,2]

The evolution of osseointegrated implants created revolutionary changes in the treatment of partially edentulous and completely edentulous cases. Even after the introduction of implants there were many advancements in its placements, case selection criteria, angulations. The initial placements were solely depending on the amount of bone present and there was no consideration about a final restoration. An intra-oral periapical radiograph (IOPAR) was the only diagnostic aid in the placement of an implant. Different-sized burs were used to create space in bone for the implant placement. This conventional technique ended up in many complications and failures. The restoration followed by implant placement was

facing a lack of space due to the inappropriate placement of implant. An implant placed closed to the natural tooth, angulated implant placement, nerve injury were the common complications.

An implant placement by a surgeon alone, based on the visual anatomy ended up in complications. Pre-treatment evaluation of a case by a prosthodontist will improve esthetics, tissue contour, lip line, and even extensions of the prosthesis. The newer concept of "Prosthetically guided implantology" improved the position, stability, angulation of the implants. A definitive restoration plan is required for the success of implant-supported prosthesis. Restoration-driven implant placements are the ideal ones which will meet the functional and esthetic needs. This concept can be fulfilled with the help of surgical guides, which can help in an ideal implant placement.

Advancements such as stereolithography, CT imaging along with the use of software can provide us with a 3D implant simulation and proper guidance for the placement of implants

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maintaining depth, mesiodistal, buccolingual position of individual implants.^[3,4] Researches in the field made us to place an implant hassle free. Hence, let's go through various surgical templates and their role in placing implants.

HISTORIC BACKGROUND

A surgical template is defined as a guide used to assist in proper surgical placement and angulations of dental implants (GPT).^[5] Stumpel was one of the first researchers to consider the use of surgical stents. His research led to the identification of three fundamental design concepts for three types of fabrications: (1) non-limiting design, (2) partially limiting design, and (3) completely limiting design. This was based on the degree of surgical restriction provided by the surgical guide templates.^[6,7] Non-limiting designs only provide the surgeon with a rough idea of where the proposed prosthesis is located in relation to the chosen implant site. This design neglects to emphasize the proper drill angulations, which may lead to too much flexibility in the implant's final positioning. In a method demonstrated by Engelman *et al.*, the guide pinhole was drilled through a transparent vacuum-formed matrix. In reality, though, the angulations were set by the use of opposing and adjacent teeth. It was later discovered that these templates might be used as imaging indicators during the implant surgery phase. These radiographic cross-checking procedures confirm the relative parallelism as well as the implant's final positioning.^[8]

Adrian *et al.* created a radiographic cum surgical template using auto-polymerizing acrylic resin. The maxillary and mandibular incisors were covered in lead foil, and he used a lateral cephalogram to cross-check the relevant parameters.^[9] Tarlow made use of an acrylic resin duplicate denture and covered it with a vacuum-formed thermoplastic matrix (0.02 inch). Accurate implant positioning and angulations are required by such designing, with little interference to surgical access.^[10] With a focus on partially missing cases, Espinosa Marino *et al.* demonstrated the first clinical application of heat polymerizing acrylic resin in the creation of surgical templates. They used dual-curing composite resin combined with colored chalk to make it radio-opaque on CT.^[11] Stellino *et al.* showed the use of gutta percha as a radio-opaque marker in acrylic resin provisional fixed restorations. In situations where a temporary fixed restoration spans the implant site in place of a removable radiologic template, this is particularly helpful as an alternative.^[12] Vacuum-formed thermoplastic matrix was used by Pesun and Gardner to modify their diagnostic model.^[13] The idea of combining acrylic resin with radio-opaque material to create surgical templates (rather than using pure acrylic resin) was first proposed by Takeshita *et al.* They mixed acrylic resin in a 4:1 ratio with barium sulfate powder.^[14] While Minoretti *et al.* constructed templates using a vacuum-formed thermoplastic matrix or auto-polymerizing acrylic resin, Sicilia *et al.* used orthodontic wires and auto-polymerizing acrylic resin.^[15,16]

Only the initial drill for osteotomy is permitted by the partially limiting design; the surgeon must complete the remaining

osteotomy and implant placement by hand. This design approach essentially involves creating a radiographic template initially, which is later transformed into a surgical guide template after radiographic evaluation. Ku and Shen used a vacuum-formed thermoplastic matrix with auto-polymerizing acrylic resin to apply the marker, which was later removed with a carbide bur.^[17] Almog *et al.* applied auto-polymerizing resin vertically on the lingual/palatal wall of the buccal access groove along with a vacuum-formed thermoplastic matrix and lead strip (2 mm). The clinical outcomes of this template were dubious because more implant placement errors were made buccolingual.^[18]

Later, Adrian *et al.* presented a straightforward method for creating surgical guides on mounted diagnostic models of patients' mouths. To determine whether there is enough room for a fixed cantilevered implant prosthesis, he also used these mounted models.^[9] On the other hand, Cehreli proposed the creation of a bilaminar dual-purpose stent that makes it easier to place implants and improves implant positioning verification.^[19] Utilizing radio-opaque markers, the outer lamina is intended for use in CT evaluation. A straightforward technique for creating a vacuum-formed matrix filled with clear acrylic resin and a gutta-percha marker was presented by Ku and Shen. The matrix can be used both as a surgical guide during the surgical stage of single implant therapy and as a radio-opaque marker for evaluation.^[17] Solow then demonstrated how a radiographic surgical template can make it easier for a surgeon and patient to consult when implant-supported restorations are being planned. A template that enables precise or altered surgical placement and radiographic evaluation of the implant site is presented.^[20] A modified surgical stent that acts as a guide for proper mesiodistal paralleling of dental implants was described by Aka *et al.*^[21]

Computer-generated surgical templates have been developed to address the drawbacks of traditional radiographic surgical templates. Utilizing information from a CT scan, computer-aided design, and computer-assisted design and manufacturing (CAD/CAM) technology plans implant rehabilitation.^[22,23] According to the original Branemark protocol, an implant's osseointegration took between 3 and 6 months, depending on the implant's location and the quality of the bone, before it was ready for restoration and loading. Surgical guides built using CAD/CAM have many benefits. It has been demonstrated that dental implant planning using CAD/CAM technology is accurate and that the presurgical plan is reliably transferred to the surgical site. A more recent development in dentistry is stereo-lithography, a rapid prototyping technique that enables the creation of surgical guides from three-dimensional computer-generated models for the exact placement of the implants.^[24-26]

CLASSIFICATION

Based on the support they derive that can be either: ^[27]

1. Tooth-supported template
2. Tissue-supported template
3. Bone-supported template.

Based on coverage design: ^[28]

1. The fully edentulous
2. The partially edentulous (removable partial denture design)
3. Partially edentulous tooth-supported design.

Based on the surgical restriction offered: ^[29]

1. Non- limiting design
2. Partially limiting design
3. Completely limiting design.

Based on accessibility: ^[27]

1. Open sleeved
2. Closed sleeved.

Based on utility: ^[27]

1. Pilot guides
2. Complete drill guides
3. Safe guides.

Based on materials: ^[27]

1. Self-cure acrylic
2. Vacuum formed polymers
3. Metal-reinforced acrylic templates.

Flowchart for using a surgical guide

1. Step 1: Planning the diagnosis and treatment.
2. Step 2: Using software to plan virtual implants and prostheses.
3. Step 3: Choosing a specific implant system and its components.
4. Step 4: Planning for the surgical guide that is compatible with a specific implant system.
5. Step 4a: Bone or mucosa- or tooth-borne surgical guide if there are fewer than three teeth.
6. Step 4b: Choosing the anchors (based on the location, number of implants, angulation, and anatomical restrictions).
7. Step 5: Manufacturing of surgical guides (most soft goods allow for online ordering).
8. Step 6: Disinfection of surgical guides that have been received, followed by guide evaluation.
9. Step 6a: For teeth support, assess the patient's mouth and the cast.
10. Step 6b: For a mucosa-supported guide, evaluate the patient's mouth and the cast.
11. Step 7: Checking the accuracy of particular surgical drills and drill keys.
12. Step 8: Anchor pins are used to stabilize the guides in the patient's mouth, and the stability of the guides is then confirmed.
13. Step 9: Drill sequence.
14. Step 10: Installation of fixtures (possible with safe instructions).^[27]

Non-limiting design

Non-limiting designs only give the surgeon a general idea of how close or far away the proposed prosthesis is from the chosen implant site.^[30] This design places an excessive amount of flexibility in the final positioning of the implant because it does not emphasize the angulation of the drill. A method

that involved drilling a guide pinhole through a transparent vacuum-formed matrix was described by Blustein *et al.*^[31] and Engelman *et al.*^[8] Using this, the tooth position over the implant site was indicated. It has been noted that using these guides could lead to unacceptable access hole placement or unacceptable implant angulation. Therefore, during the surgical stage of implant placement, these templates can be used as imaging indicators. Examples include vacuum formed template (Figure 1) and circumference lead strip guide.

Partially limiting design

In such designs, the surgeon directs the first drill used for the osteotomy using the surgical guide before finishing the rest of the osteotomy and implant placement by hand. Techniques based on this design concept entail creating a radiographic template that is later transformed into a surgical guide template after radiographic evaluation. Numerous authors have put forth various techniques involving changes to the following fabrication stages: the material used to make the surgical template, the radiographic marker used, the kind of imaging system used, and the conversion procedure used to turn the radiographic template into a surgical template. All the methods, however, fell short of completely limiting the angulation of the surgical drills. Examples include Gutta Percha Guide and Surgical guide with brass tube.^[29]

Completely limiting design

All of the osteotomy tools are constrained in a buccolingual and mesiodistal plane by completely limiting design. Additionally, the addition of drill stops restricts the depth of preparation and, consequently, the placement of the prosthetic table of the implant. The amount of intraoperative decision-making and subsequent surgical execution decreases as the surgical guides become more restrictive. This consists of two well-known models: the cast-based surgical guide and the CAD/CAM surgical guide.^[29]

Cast-based surgical guide

In a typical flapless guided implant surgery, the surgical guide combines an analog technique with bone sounding and the use



Figure 1: Vacuum formed guide

of periapical radiographs.^[6] Digital software is used to modify the periapical radiograph to help transpose the root structure onto the cast.

A cast osteotomy is then performed by sectioning the cast at the proposed implant site and transferring bone-sounding measurements to aid in drill bit orientation. A laboratory analog is inserted into the area, and a guide sleeve modified with wires to form a framework around the teeth is made to match the width of the implant. The Occlusal superstructure is made with Vinyl polysiloxane occlusal registration material (Figure 2).^[30]

CAD/CAM based surgical guide

The traditional approach to planning implant treatment is significantly changing as a result of modern digital technologies. Radiological templates and surgical guides based on cone-beam computed tomography (CBCT) and computer-aided design/computer-aided manufacturing (CAD/CAM) enable the implant placement easier.^[31] Implant rehabilitation is planned using CAD/CAM technology using information from a computerized tomography (CT) scan. The CT images are transformed into data that CT imaging and planning software can recognize. The presurgical plan is then transferred through this software using stereolithographic drill guides to the surgical site.^[32,33]

Surgical guides built using CAD/CAM have many advantages. For instance, the incorporation of prosthetic planning using a scanographic template allows the treatment to be optimized from a prosthodontics and biomechanical point of view;^[34] the technique promotes flapless surgeries, reduces risks like inadequate osseous support or compromise of important anatomic structures; and it allows for the visualization of the surgical bone site before implant placement.^[35] The following steps can be used to separate the fabrication of CAD/CAM-based surgical guides: Fabrication of the radiographic template, CT scan, interactive implant surgical planning software, fabrication of the stereolithographic drill guide, and implant planning. Since the radiographic template enables the clinician to visualize the location of planned implants from an esthetic

and biomechanical perspective, it must be an exact replica of the desired prosthetic end result.^[35] An interocclusal index is then created to enable repeatable intraoral placement of the scan template.^[36]

Then comes a double-scanning process. The radiographic scan template and radiographic index (interocclusal index) are worn by the patient during the first scan, while the index is not worn during the second scan. A second scan is carried out to visualize the nonradiopaque radiographic guide after the first scan has been used to visualize the bony architecture and anatomy of the site of interest. The 2 sets of 2D CT data that are produced (called DICOM files for Digital Imaging and Communication in Medicine) are then superimposed over one another in accordance with radiographic markers before being further converted into a file format appropriate for use with a 3D planning program.^[36]

This fusion produces an accurate 3D representation of the patient's bone structure and scanning denture. The virtual surgical procedure can now be carried out. An aid to virtually planning the location, angle, depth, and diameter of the virtual implants is a 3D implant planning software that enables simultaneous observation of the arches and the radiographic scan template in three spatial planes. On the screen, it simultaneously displays an axial image, a panoramic image, and several cross-sectional images. After completion of the computer planning, the plan is saved as a ".Sim" file and sent to the processing facility to be used to create the surgical guide using stereolithography.^[36,37]

A special 3D transparent resin model is created using stereolithography, a computer-guided, laser-dependent rapid prototyping polymerization process, which can precisely replicate the patient's skeletal anatomic landmarks. This model fits closely to the surface of the patient's hard and/or soft tissues. The polymeric prototype has places for drill-guiding tubes made of titanium or stainless steel once it has hardened. The osteotomy drills are precisely guided by these tubes, eliminating the requirement for pilot drills.^[33]

CONCLUSION

With the incorporation of CAD/CAM technology and computer-guided surgery, surgical models and guidance have taken on a new dimension. With increased precision, less uncertainty, and shorter surgical times, complex rehabilitation can be handled with more assurance. Furthermore, predictable positioning simplifies abutment selection and prevents complicated laboratory fabrication when misalignment needs to be fixed, improving prosthetic outcomes. In addition, cutting-edge methods are developing that might make it possible to prepare the final prosthesis before implant placement. For such a complex reconstruction, precise guidance is essential to ensure that the least amount of adaptation is required after surgery. Future technological advancements will probably enable dentists to use these technologies while limiting restorative procedures, minimizing surgical time, and controlling costs.

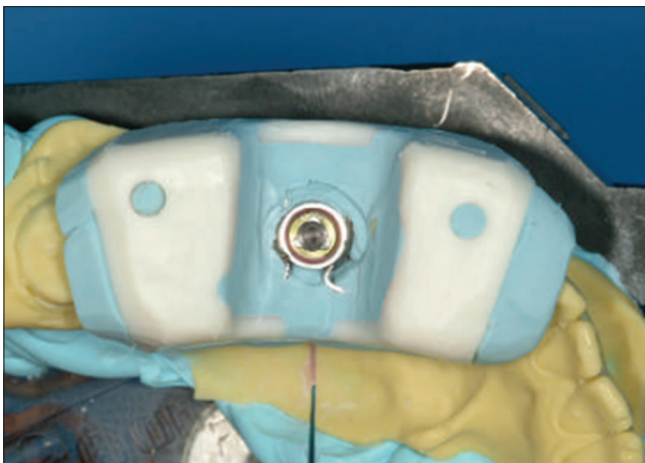


Figure 2: Cast-based surgical guide

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