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. An electronic and hand search of the literature revealed 3 categories, namely, nonlimiting, partially limiting, and completely limiting design. Most clinicians still adopt the partially limiting design due to its cost-effectiveness and credibility. Moreover, clinicians use cross-sectional imaging during the preimplant assessment of surgical sites.

**Key Words:** implant guidance, implant placement, surgical guide, surgical template, implant dentistry

**INTRODUCTION**

Recent studies on the clinical success of dental implants have indicated a high implant survival rate. Nevertheless, the inadvertent association of most surgical and prosthetic complications with improper diagnosis and implant placement has also been documented. These factors play a crucial role in the long-term predictability and success of implant prosthetics. Surgical guide templates not only assist in diagnosis and treatment planning but also facilitate proper positioning and angulation of the implants in the bone. 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.

**DISCUSSION**

Surgical guide template fabrication involves a diagnostic tooth arrangement through one of the following ways: (1) a diagnostic waxing, (2) a trial denture teeth arrangement, or (3) the duplication of a preexisting dentition/restoration. The fabrication of the surgical guide templates is then based on one of the following design concepts:

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

These design concepts are classified based on the amount of surgical restriction offered by the surgical guide templates.

**Nonlimiting Design**

Nonlimiting designs only provide an indication to the surgeon as to where the proposed prosthesis is in relation to the selected implant site. 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 and Engelman et al described a technique in which a guide pin hole was drilled through a clear vacuum-formed matrix (Figure 1). This hole indicated the optimal position of the dental implant. However, the angulation was determined by the use of adjacent and opposing teeth. Almog et al 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.

It has been observed that the use of these guides may result in unacceptable placement of the access hole and/or unacceptable implant angulation. Hence, these templates can serve as imaging indicators during the surgical phase of implant placement.
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. Techniques based on this design concept involve fabrication of a radiographic template, which is then converted into a surgical guide template following radiographic evaluation. Various authors have proposed different techniques involving modifications in the following stages of fabrication, namely, material used for the fabrication of the surgical template, radiographic marker used, type of imaging system used, and the conversion process involved in converting the radiographic template into a surgical template. These various techniques are discussed in the Table. Nonetheless, all of the aforementioned techniques failed to completely restrict the angulation of the surgical drills.

COMPLETELY LIMITING DESIGN

Completely limiting design restricts all of the instruments used for the osteotomy in a buccolingual and mesiodistal plane. 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.

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. 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 using wires that are used to create a framework around the teeth. Vinyl polysiloxane occlusal registration material is used to form the superstructure (Figures 13 and 14).

FIGURES 1–6. Figure 1. Vacuum-formed template. Figure 2. Brass tube incorporated into the surgical guide. Reprinted from J Prosthet Dent 2000;83:248–251, with permission from the corresponding author. Figure 3. Bilaminar dual-purpose surgical guide. Reprinted from J Prosthet Dent 2000;84:55–58, with permission from Elsevier. Figure 4. Gutta-percha guide. Reprinted from J Prosthet Dent 2001;85:504–508, with permission from Elsevier. Figure 5. Metal sleeve guide. Reprinted from J Prosthet Dent 2001;85:504–508, with permission from Elsevier. Figure 6. Surgical guide attached to the head of the contra-angle hand piece. Reprinted from J Prosthet Dent 2002;88:548–552, with permission from the corresponding author.
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</tr>
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<td>Sicilia et al(^{16})</td>
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<td>Surgical osteotomy but more error in the buccolingual placement</td>
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<td>Almog et al 9</td>
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<td>Akça et al 22</td>
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<td>Tsuchida et al 26</td>
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<td>Silicone markers: clear radiopaque markers that do not create artifacts in CT scanning</td>
</tr>
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<td>Windhorn27 (Figure 9)</td>
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<td>Wooden stick simulate implant location and angulation 2-piece implant placement guide</td>
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<td>Arfai and Kiatt-Amnuy29 (Figure 11)</td>
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<td>Convenient, economical, less traumatic, stable for edentulous arch opposing a partially edentulous arch, compatible with all implant systems</td>
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<td>Oh and Saglik31</td>
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<td></td>
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<tr>
<td>Annibali et al32</td>
<td>Auto polymerizing acrylic resin</td>
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<td>Panoramic and periapical radiography, lateral cephalography, CT</td>
<td>Cylindrical marker guides the pilot drill</td>
<td>Uses silicone matrix that depicts the emergence profile and the ideal loading center of the proposed restoration</td>
</tr>
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CT indicates computerized tomography; FPD, fixed partial denture; DRPD, duplicate interim removable partial denture.
CAD/CAM technology uses data from computerized tomography scan (CT) to plan implant rehabilitation. The CT images are converted into data that are recognized by a CT imaging and planning software. This software then transfers this presurgical plan to the surgery site using stereolithographic drill guides. CAD/CAM-based surgical guides offer many advantages. For example, the virtual 3-dimensional (3D) views of the bony morphology allow the surgeon to visualize the surgical bone site prior to implant placement; risks such as inadequate osseous support or compromise of important anatomic structures are avoided; incorporation of prosthetic planning using a scanographic template allows the treatment to be optimized from a prosthodontics and biomechanical point of view, and the technique promotes flapless surgeries, allows presurgical construction of the master cast and provisional restorations, and facilitates immediate loading. Accuracy of CAD/CAM technology in dental implant planning and predictable transfer of the presurgical plan to the surgical site has been documented. However, the effectiveness has not yet become an established fact and still needs ongoing research. This technique has certain drawbacks. Special training for familiarity with the entire system and special equipment is necessary.
Also, a considerable number of technique-related complications were observed. The various complications recorded were related to inaccurate planning, radiographic stent error, intrinsic errors during scanning, software planning, the rapid prototyping of the guide stent, and the transfer of information for the prosthetics. However, if the clinician recognizes these sources of inaccuracy, efforts can be made to minimize the error and optimize patient treatment.

The procedure for fabrication of CAD/CAM-based surgical guides can be divided into the following steps:

1. Fabrication of the radiographic template,
2. The computerized tomography scan,
3. Implant planning using interactive implant surgical planning software, and
4. Fabrication of the stereolithographic drill guide.

The radiographic template must be an exact replica of the desired prosthetic end result, as it allows the clinician to visualize the location of planned implants from an esthetic and biomechanical standpoint. This is followed by fabrication of an interocclusal index, to allow reproducible placement of the scan template intraorally.

A double scanning procedure is then followed. The patient is scanned wearing the radiographic scan template and radiographic index (interocclusal index) during the first scan, whereas the second scan is performed without the index. The first scan is used to visualize the bony architecture and anatomy of the site of interest, and a second scan is performed to visualize the nonradiopaque radiographic guide. The 2 resulting sets of 2D CT data (Digital Imaging and Communication in Medicine [DICOM files]) are then superimposed over each other according to the radiographic markers and are further converted into a file format compatible with the 3D planning program. Resulting from this fusion is an exact representation of the patient’s bone structure and scanning denture in 3D space. At this point, the virtual surgical procedure can be performed. A 3D implant planning software allows for simultaneous observation of both the arches and the radiographic scan template in 3 spatial planes and helps to virtually plan the location, angle, depth, and diameter of the virtual implants. It produces an axial image, a panoramic image, and a series of cross-sectional images on the screen at the same time. Various implant planning software products are available commercially, namely, SimPlant, SurgiCase (Materialise Dental Inc, Leuven, Belgium), Procera (Nobel Biocare, Göteborg, Sweden), ImplantMaster (I-Dent Imaging Ltd, Hod Hasharon, Israel), coDiagnostiX (IVS Solutions AG, Chemnitz, Germany), and Easy Guide (Keystone Dental, Burlington, MA).

Once the computer planning is accomplished, this plan is saved as a “.sim” file and sent to the processing center for fabrication of the surgical guide, using stereolithography. Stereolithography is a computer-guided, laser-dependent, rapid prototyping polymerization process that can duplicate the exact shape of the patient’s skeletal anatomic landmarks in a sequential layer of a special polymer to produce a special 3D transparent resin model, which fits intimately with the hard and/or soft tissue surface. Once hardened, the polymeric prototype contains spaces for stainless steel or titanium drill-guiding tubes. These tubes precisely guide the osteotomy drills, precluding the need for the pilot drills.

CONCLUSION

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.

ABBREVIATIONS

CAD/CAM: computer-aided design and manufacturing
CT: computerized tomography
FPD: fixed partial denture
DRPD: duplicate interim removable partial denture

REFERENCES

47. Block MS, Chandler C. Computed tomography-guided...

