International Journal of Research in Health and Allied Sciences

Journal home page: www.ijrhas.com

Official Publication of "Society for Scientific Research and Studies" [Regd.]

ISSN: 2455-7803

Review Article

Surgical Templates in Implantology

Dr Renu Gupta[1], Dr Priya Ravichandran[2], Dr Divya Vashisht[3], Dr Varsha Khichi[4], Dr Venus Chandel[5]

[1]Professor and Head, [2,4,5]PG student, [3]Professor, Department of Prosthodontics, HP Government Dental College & Hospital, Shimla, HP, India

ABSTRACT:
Dental implants have been utilized in various forms for an extensive period. Since the mid-20th century, there has been a notable surge in interest regarding the implant procedure for the restoration of absent teeth. Branemark emerged as one of the early innovators who employed scientifically grounded research methodologies to create an endosseous implant that establishes a stable bond with the surrounding bone. The requirement for a dental implant to effectively address numerous physical and biological considerations imposes significant limitations on both the surgical and handling protocols. While metallic dental implants have been effectively employed for many years, they exhibit considerable deficiencies concerning their integration with bone and the disparity between their mechanical properties and those of natural bone. Consequently, it is prudent to ensure a coherent relationship between the intended restoration and the surgical stages, necessitating the use of a transfer device that enhances the predictability of successful outcomes. The surgical guide template is crafted by a dental technician following the presurgical restorative consultations, which primarily focus on determining the occlusal scheme and the angulations of the implants.

Received: 2 June, 2024 Accepted: 19 June, 2024

Corresponding Author: Dr. Priya Ravichandran, PG student, Department of Prosthodontics, HP Government Dental College & Hospital, Shimla, HP, India

This article may be cited as: Gupta R, Ravichandran P, Vashisht D, Khichi V, Chandel V. Surgical Templates in Implantology. Int J Res Health Allied Sci 2024; 10(4): 17- 23

Introduction

The introduction of dental implants has significantly advanced oral rehabilitation for patients with missing teeth, becoming a popular option for those who are edentulous or partially edentulous. Techniques like sinus augmentation, distraction osteogenesis, bone grafting, and tissue regeneration have enabled implant treatments even in cases of severe bone atrophy.[1] The success of dental implants is closely linked to thorough patient evaluation and meticulous treatment planning.[2]

Osseo integrated implants promise a bright future for dental prostheses, but achieving predictable outcomes in prosthodontic rehabilitation requires precise planning and surgical positioning.[3] Historically, implant placement focused on bone availability, often resulting in complications like improper positioning and nerve damage.[4] In the early 1990s, issues with maxillary implant placement were noted, leading to prostheses that were difficult to maintain and lacked accuracy.[5]

The need for predictable outcomes led to prosthetically guided implantology, which establishes correct implant positions based on the planned restoration.[6] Successful implant restoration involves three key parameters: adequate bone volume, sufficient soft tissue, and a three-dimensional site for an appropriate gingival margin.[5] Close collaboration between restorative dentists and surgeons is essential, aided by surgical guides that ensure optimal implant placement.[7]

Surgical templates greatly aid in diagnosis and treatment planning, ensuring proper positioning and angulation of implants in the bone. They enhance aesthetic and restorative outcomes while minimizing surgical and prosthetic complications. The rising demand for dental implants has driven the development of advanced techniques for creating these templates. With the advent of CAD-CAM technology in implantology, surgical guides can now be designed and constructed virtually, allowing for implant placement without the need to reflect a soft tissue flap.[8]

This literature review explores the surgical templates in implantology, highlighting their significant impact on implant placement and recent advancements in the field.

Historical Background

Stumpel was one of the pioneers in using surgical stents for dental implants. He identified three design concepts based on the level of surgical restriction: nonlimiting, partially limiting, and completely limiting designs.[9] Nonlimiting designs provide a basic indication of the implant site but do not ensure correct angulation, which can lead to imprecise implant positioning.[3]

Engelman et al. developed a technique using a clear vacuum-formed matrix for the guide pin hole, determined by adjacent and opposing teeth.[10] This method was later enhanced by adding radiographic checks to confirm implant positioning and parallelism with adjacent teeth.[3]

Adrian et al. used auto-polymerizing acrylic resin with lead foil to create a combined radiographic and surgical template, verified with a lateral cephalogram.[11] Tarlow employed an acrylic resin duplicate denture with a vacuum-formed thermoplastic matrix for accurate implant location and angulation.[12] Espinosa Marino et al introduced the use of heat-polymerizing acrylic resin with dual-curing composite resin mixed with coloured chalk for CT visibility.[13]

Stellino et al used gutta-percha as a radiopaque marker in acrylic resin provisional fixed restorations.[14] Pesun and Gardner used a vacuum-formed thermoplastic matrix over a diagnostic model.[15] Takeshita et al introduced mixing acrylic resin with barium sulfate powder for radiopacity.[16] Sicilia et al used orthodontic wires and auto-polymerizing acrylic resin for template fabrication while Minoretti et al. used vacuum-formed thermoplastic matrix or auto-polymerizing acrylic resin to fabricate template.[17,18]

Ku and Shen used a vacuum-formed matrix with clear acrylic resin and gutta-percha markers for single implants.[19] Becker and Kaiser, and Cehreli et al used vacuum-formed thermoplastic matrix and orthodontic resin for precise surgical guides, especially in posterior maxillary regions.[20]

Almog et al used auto-polymerizing resin with a vacuum-formed matrix and lead strips on the palatal wall of the buccal access groove.[21]

Adrian et al also introduced a technique using mounted diagnostic models for surgical guides fabrication and space verification for fixed prostheses.[11] Cehreli proposed a bilaminar dual- purpose stent for CT evaluation and implant placement.[22] Solow highlighted the use of radiographic surgical templates for consultation and precise surgical placement.[24] Akça described a modified stent for proper mesio-distal paralleling of implants.[23]

Definition and Parts of a Surgical Template

Glossary of prosthodontic terms (GPT)10, define surgical template as a guide used to assist in proper surgical placement and angulation of dental implants.[25]

The primary objective of a surgical template is to guide the implant drilling system for precise implant placement according to the surgical treatment plan. It directs the surgeon to position the implant for optimal support against occlusal forces, aesthetics, and hygiene requirements

A surgical guide is the union of two components: - The guiding cylinders and the contact surface. The contact surface fits either on an element of a patient's gums or on the patient's jaw (i.e., the bone, the teeth). Cylinders within the drill guides helps in transferring the plan by guiding the drill in the exact location and orientation[4] (Fig 1).

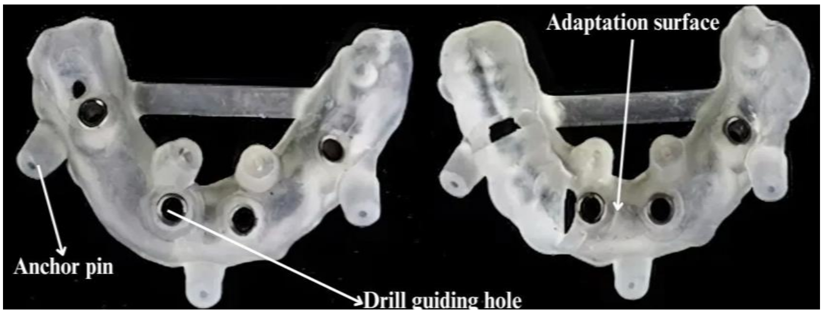

Fig 1: Parts of a surgical guide

Ideal Requisites of Surgical Template: -

- Stable and rigid when in the correct position.
- If the arch treated has remaining teeth, the template should fit over and/or around enough teeth to stabilize it in position. If the arch has no remaining teeth, the template should extend onto un-reflected soft tissue regions.
- It should not be bulky and difficult to insert or obscure surrounding surgical landmarks.

- It must not contaminate a surgical field during bone grafts or implant placement.
- It should be transparent so that the bony ridge and drills can be observed more easily when the template is in place.
- The surgical template should be related to the ideal facial contour. Many edentulous ridges have lost facial bone, and the template can determine the amount of augmentation required for implant placement or support of the lips and face.
- It should permit re-sterilization.
- The surgical template may be used in conjunction with a bone graft, and later the same template may be used for insertion of implants and again for implant recovery.
- Simple and cost-effective to fabricate.[3]

Classification of Surgical templates

Implant guides/templates are broadly of 3 types: -

- Diagnostic/Radiographic
- Surgical and
- Combination

Surgical guides can be classified based on the following criteria: -

1. Area of operation

- Guides for partially edentulous sites: Tooth-supported surgical guides can be used in short-span partially edentulous arches. They require at least three stable teeth to support the guide during the surgery. In the case of long span partially edentulous arches, tooth and bone-supported implant surgical guides are indicated. This requires at least 3 cm of supporting bone.

- Guides for completely edentulous site: Mucosa or bone supported surgical guides are indicated. Bone guides are specially indicated when edentulous sites possess a thin bone.[8]

2. Support

- Tooth Supported guides (Fig 2): Minimum three stable teeth should be present to support the guide during surgery. In cases of long span edentulous arches, they ae used along with bone supported surgical guides.

- Mucosa supported guides (Fig 2): - It is used in fully edentulous sites.

- Bone supported guides (Fig 2): They are used in partially edentulous sites and completely edentulous sites. When used in partially edentulous sites, it should possess at least 3 cm of supporting bone or 3 teeth would need replacement. Bone guides are especially used when edentulous sites possess thin bone. Raised flap should provide a good view to implant sites and insertion of guides.

- Special-supported guides (Fig 3): uses mini-implants or pins for supporting the surgical guide placement during implant surgery.[26]

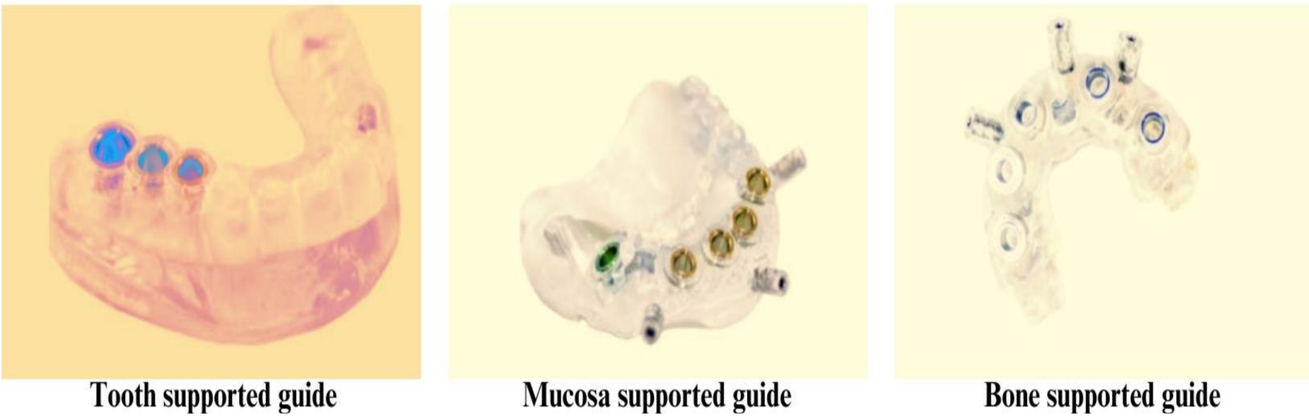

Fig 2: Surgical guides based on support

Fig 3: Mini pin supported guide

3. **Utility**
- Pilot guides: These surgical guides only control the implant angulation by allowing only the pilot drill. Depth control is to be attained manually using the markings on drills. The osteotomy site is expanded using conventional drilling without the guide.

- Complete drill guides: They are provided with different drill keys or sleeves. As the osteotomy site is widened with each sequential drill, the sleeves are changed concomitantly. Both the angulation as well as the size of the osteotomy is controlled by the guide but the depth is controlled manually.

- Safe/easy guides: They are provided with additional implant drill stoppers that control the depth of drilling in addition to the sleeves of different diameters. They enable osteotomy site preparation and also implant placement.[8]

4. **Accessibility**
- Open sleeve
- Closed sleeve[26]

5. **Material**
- Self/light cure acrylic resin
- Metal reinforced acrylic templates
- Vacuum formed polymers
- CAD-CAM prosthesis
- Stereo lithographic models[26]

6. **Design Concept**
- Non-Limiting Design: This design provides the ideal location of the implants without any emphasis on the angulation, therefore allowing too much flexibility in the final implant position. 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.

- Completely Limiting Design: This design tends to restrict all the instruments used for the osteotomy in a buccolingual and mesiodistal plane. The depth of the preparation is limited by drill stops. As the surgical guides is more restrictive, subsequent surgical execution is carried out intra-operatively with minimal decision making.
  Completely limiting design includes 2 popular designs: -
  Cast-based guided surgical guide
  Computer-assisted design and manufacturing (CAD/CAM) based surgical guide.[26]

Fabrication

Three primary techniques for fabricating implant guides are the conventional freehand method, analog milling with a dental surveyor, and CAD/CAM technology.

Advances in implant imaging and 3D planning have made digital-aided implant surgeries increasingly popular. Studies show that computer-guided implant placement is more accurate and predictable than the conventional freehand method, reducing positioning errors.

Digital guides can be created using either additive or subtractive manufacturing techniques.[27,28]

Broadly, the procedure of CAD/CAM-based surgical guide fabrication can be divided into the following steps:
- Fabrication of the radiographic template
- Computerized tomography scan or data acquisition
- Virtual implant planning
- Fabrication of the stereolithographic (SLA) drill guide

Radiographic templates often use the radio-opaque marker barium sulphate. Alternatively, a duplicate denture with radio-opaque markers in the occlusal surfaces can align with the screw access holes of the implant-supported prosthesis.

A CT scan is performed with this radiographic template in place.

Using software like Columbia Scientific Incorporated, Nobel Guide, and coDiagnostiX, the surgeon and prosthodontist can simulate implant placement on a 3D model of the patient's jaw. Specific implants are selected and replicated in 3D on the computer model.

The SLA (stereolithography) machine creates a model by polymerizing a liquid resin in 1-mm increments. Approximately 80% of the polymerization is done in the SLA vat, with the remainder completed under ultraviolet light. Surgical templates are formed by attaching small triangles of resin to the surface of the SLA model. The surgical flap design determines the extent of the buccal and lingual flanges. The SLA machine identifies the diameter and angulation of the implants and polymerizes resin around them to create cylindrical guides. Surgical-grade stainless steel tubes replace the resin triangles, resulting in surgical templates with metal sleeves that correspond to each implant location and seat directly on the bone.[29]

Static and Dynamic Navigation

Static navigation and dynamic navigation are the two most popular among the various digital guide systems. While studies state no superior accuracy of dynamic navigation over static navigation,[28] there are few other studies that prove dynamic navigation superior to static systems in terms of accuracy and precision for implant placement.[30]

Static Navigation

The static or template-based system uses rapid prototyped guides to communicate predetermined implant sites in the operating field. "Static" means that the implant positioning is fixed and cannot be monitored in real-time during the procedure. Adjusting the implant position intraoperatively requires removing the guide. These guides are highly recommended, especially for edentulous patients, and are often used when a flapless technique, bone reduction, or full-mouth fixed prosthetic treatment is planned. Static guides are less intrusive, causing less patient morbidity and making flapless approaches possible. However, they limit access to bone, which can hinder irrigation and increase heat output during drilling. Additionally, using static guides is challenging for patients with insufficient mouth opening, particularly in the molar region.[30]

Dynamic Navigation

The dynamic system utilizes visual imaging devices and a virtual treatment plan to guide the operative area. It employs a tracking array to detect and monitor the position of optical reference markers.[28] Optical technology involves either active or passive tracking arrays to trace the patient and the handpiece while displaying images. Active arrays emit light tracked by stereo cameras, whereas passive arrays reflect light back to the cameras (Fig 4).

During cone-beam CT (CBCT) scanning, a passive optical dynamic navigation system uses fiducial markers attached to the patient’s maxillary or mandibular arch. An additional array registers the arch to the cameras, mounted extra orally with the fiducial markers. The implant handpiece also has an array that, when paired with the markers, allows for triangulation and precise navigation. For accurate tracking, both the drill and patient-mounted arrays must be within the stereo cameras' line of sight.

Dynamic navigation is recommended for cases with limited mouth opening, hard-to-reach areas, same-day implant insertion, and tight interdental spaces where static guides are ineffective. It offers high precision, speed, cost-effectiveness, and flexibility to adjust implant size, system, and placement during surgery. However, it requires a collaborative team approach and is limited by its sensitivity to reflections, interference with sensor-camera line of sight, higher cost, strict intraoperative referencing, and a steep learning curve.[30]

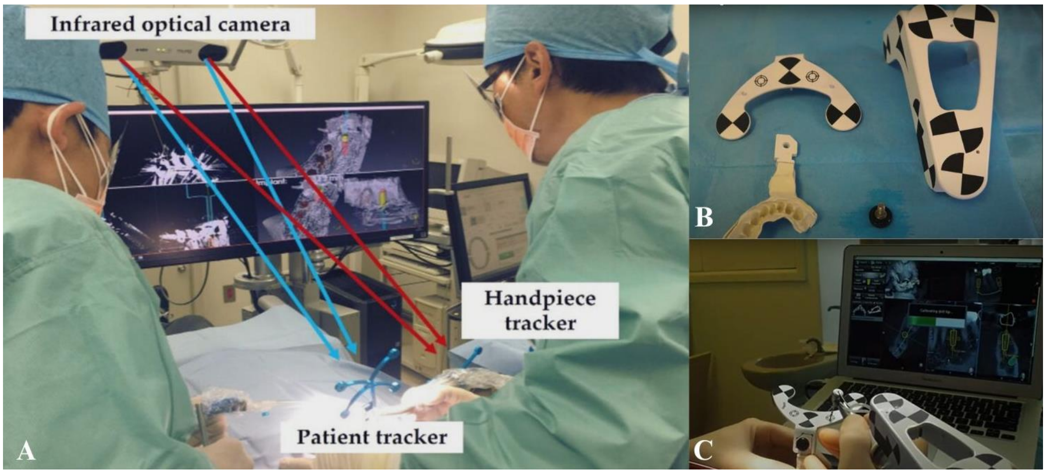

Fig 4: Dynamic Navigation system (A, Parts of Dynamic navigation system, B. Jaw and Drill tags, C. Calibrating drill axis)

Recent Advancements

Zygomatic Implant Guides

Although zygomatic implants are often placed without surgical guides, some methods use initial drilling guides with manual implant insertion afterward. Challenges such as limited access, poor visibility, flexible twist drills, and uneven bony surfaces at the base of the zygoma can hinder precise apical placement. Therefore, meticulous preoperative planning and accurate transfer to the surgical field are essential. Most zygomatic implant guides control the implant's entry and emergence at the alveolus but not its trajectory or apical exit within the zygoma. Recently, metal drill guides have been developed to enable control over the implant's apical exit placement.[31]

Guides for sinus augmentation and implant placement

Mandelaris and Rosenfeld pioneered a roadmap for complex sinus augmentation procedures. Initially, the fabrication process and various types of surgical guides, especially for lateral window opening, had significant shortcomings. Today, CAD/CAM surgical guides are available for simultaneous sinus augmentation and implant placement, often secured with titanium screws for stability. Despite achieving immobility, these screws can obstruct the implant path, require additional bone removal, and depend on good bone quality. Removing the guide for sinus floor elevation is also inconvenient. Conversely, tooth-borne surgical guides offer better stability and convenience.[32]

Chairside fabrication of guides

Implant drilling guides can be precisely fabricated in a dental office using low-cost desktop 3D printers, reducing costs and eliminating laboratory and shipping fees. This increases the accessibility of guided surgery. Knowledge of additive manufacturing and calibration of implant planning and 3D printing software is essential to avoid errors. This technology holds great potential in dentistry and is expected to improve over time.

Several authors have documented the manufacturing technique for a chairside CAD-CAM radiological and surgical guide for dental implants. This approach integrates analog methods and CAD-CAM techniques, particularly useful when digital system incompatibilities exist. It can be implemented in dental offices with a CEREC Omnicam AC intraoral scanner, an MCXL milling unit, and any CBCT scanner. A stone cast or printed model is required to secure the milling guide for the initial 2-mm osteotomy site.[33]

Robotic Technology

Robotic technology in dental implant surgery provides real-time physical and visual guidance, allowing surgeons to adjust plans dynamically. It employs haptic robotic systems to guide drill location, orientation, and depth, using actuators for tactile feedback. These actuators include advanced technologies like electroactive polymers and piezoelectric materials, enhancing precision with rapid response times. Surgeons maintain control throughout, ensuring accuracy and consistency without the need for specialized guides or the risks of freehand methods.[34]

Conclusion

Implant guides remain crucial for precise implant placement and angulation. Clinicians select fabrication techniques and materials based on personal preferences and experience. While robotic implant placement shows promise, further clinical trials are necessary to fully understand its potential in implant dentistry.

References

1. Widmann G, Bale RJ. Accuracy in Computer-Aided Implant Surgery- A Review. The International Journal of Oral & Maxillofacial Implants.2006;21(2):855-63.
2. Ramasamy M, Giri, Raja R, Subramonian, Karthik, Narendrakumar R. Implant surgical guides: From the past to the present. J Pharm Bioallied Sci. 2013 Jun;5(Suppl 1): S98- S102.
3. Kola MZ, Shah AH, Khalil HS, Rabah AM, Harby NM, Sabra SA, Raghav D. Surgical templates for dental implant positioning; current knowledge and clinical perspectives. Niger J Surg. 2015 Jan-Jun;21(1):1-5.
4. Nasti S, Anjum S, Sufiyan M, Ashok A. Surgical guides: Precision redefined in implant placement. International Journal of Periodontology and Implantology. 2023; 8(4):177- 180.
5. Salem D, Mansour MH. Surgical Guides for Dental Implants; a Suggested New Classification. J Dent Oral Health 2019; 6:1-8.
6. Talwar N, Singh BP, Chand P, Pal US. Use of diagnostic and surgical stent: a simplified approach for implant placement. J Indian Prosthodont Soc. 2010 Dec;10(4):234-9.
7. Monson ML. Diagnostic and surgical guides for placement of dental implants. J Oral Maxillofac Surg. 1994 Jun;52(6):642-5.
8. Akhila et al. Surgical guides in Implantology: A realistic approach towards precision. International Journal of Maxillofacial Imaging. 2022;8(3):101-105.
9. Stumpel LJ 3rd. Cast-based guided implant placement: a novel technique. J Prosthet Dent. 2008 Jul;100(1):61-9.
10. Engelman MJ, Sorensen JA, Moy P. Optimum placement of osseointegrated implants. J Prosthet Dent. 1988 Apr;59(4):467-73.
11. Adrian ED, Ivanhoe JR, Krantz WA. Trajectory surgical guide stent for implant placement. J Prosthet Dent. 1992 May;67(5):687-91.
12. Tarlow JL. Fabrication of an implant surgical stent for the edentulous mandible. J Prosthet Dent 1992; 67:217-8.
13. Espinosa Marino J, Alvarez Arenal A, Pardo Ceballos A, Fernandez Vazquez JP, Ibaseta Diaz G. Fabrication of an implant radiologic-surgical stent for the partially edentulous patient. Quintessence Int. 1995 Feb;26(2):111-4.
14. Stellino G, Morgano SM, Imbelloni A. A dual-purpose, implant stent made from a provisional fixed partial denture. J Prosthet Dent. 1995 Aug;74(2):212-4.
15. Pesun IJ, Gardner FM. Fabrication of a guide for radiographic evaluation and surgical placement of implants. J Prosthet Dent. 1995 Jun;73(6):548-52.
16. Takeshita F, Tokoshima T, Suetsugu T. A stent for presurgical evaluation of implant placement. J Prosthet Dent. 1997 Jan;77(1):36-8.
17. Sicilia A, Noguerol B, Cobo J, Zabalegui I. Profile surgical template: a systematic approach to precise implant placement. A technical note. Int J Oral Maxillofac Implants. 1998 Jan-Feb;13(1):109-14.
18. Minoretti R, Merz BR, Triaca A. Predetermined implant positioning by means of a novel guide template technique. Clin Oral Implants Res. 2000 Jun;11(3):266-72.
19. Ku YC, Shen YF. Fabrication of a radiographic and surgical stent for implants with a vacuum former. J Prosthet Dent. 2000 Feb;83(2):252-3.
20. Becker CM, Kaiser DA. Surgical guide for dental implant placement. J Prosthet Dent. 2000 Feb;83(2):248-51.
21. Almog DM, Torrado E, Meitner SW. Fabrication of imaging and surgical guides for dental implants. J Prosthet Dent. 2001 May;85(5):504-8.
22. Cehreli MC, Aslan Y, Sahin S. Bilaminar dual-purpose stent for placement of dental implants. J Prosthet Dent. 2000 Jul;84(1):55-8.
23. Akça K, Iplikçioğlu H, Cehreli MC. A surgical guide for accurate mesiodistal paralleling of implants in the posterior edentulous mandible. J Prosthet Dent. 2002 Feb;87(2):233- 5.
24. Solow RA. Simplified radiographic-surgical template for placement of multiple, parallel implants. J Prosthet Dent. 2001 Jan;85(1):26-9.
25. Layton DM, Morgano SM, Kelly JA, Nguyen CT, Scherrer SS et al. Glossary of Prosthodontic Terms 2023, 10th edition. J Prosthet Dent 2023; 130(4S1): e1-e126.

26. Khanna S, Munde BS, Baisane PM, Shujaulla S. Surgical guides in Implants: A Review. Saudi J Oral Dent Res, 2020;5(9):425-430.
27. Sajjan MS, Yekula PS, Kovvuri SS, AllurI RR. A simple technique for fabrication of a surgical guide for predictable placement of dental implants. J Dent Implants 2017; 7:11-4.8.
28. Mediavilla Guzmán A, Riad Deglow E, Zubizarreta-Macho Á, Agustín-Panadero R, Hernández Montero S. Accuracy of computer-aided dynamic navigation compared to computer-aided static navigation for dental implant placement: An in vitro study. J Clin Med 2019; 8:2123.9.
29. Ramasamy M, Raja R, Narendrakumar R. Implant surgical guides: From the past to the present. J Pharm Bioallied Sci 2013;5: S98-102.
30. Block MS, Emery RW. Static or dynamic navigation for implant placement-choosing the method of guidance. J Oral Maxillofac Surg 2016; 74:269-77.
31. Wang CI, Cho SH, Cho D, Ducote C, Reddy LV, Sinada N. A 3D-printed guide to assist in sinus slot preparation for the optimization of zygomatic implant axis trajectory. J Prosthodont 2020; 29:179-84.
32. Osman AH, Mansour H, Atef M, Hakam M. Computer guided sinus floor elevation through lateral window approach with simultaneous implant placement. Clin Implant Dent Relat Res 2018; 20:137-43.
33. Whitley D 3rd, Eidson RS, Rudek I, Bencharit S. In-office fabrication of dental implant surgical guides using desktop stereolithographic printing and implant treatment planning software: A clinical report. J Prosthet Dent 2017; 118:256-63.
34. Kapoor S, Arora P, Kapoor V, Jayachandran M, Tiwari M. Haptics– Touchfeedback technology widening the horizon of medicine. J Clin Diagn Res2014; 8:294-9.