Scholars Journal of Dental Sciences
OPEN ACCESS
Abbreviated Key Title: Sch J Dent Sci
ISSN 2394-4951 (Print) | ISSN 2394-496X (Online)
Journal homepage: https://saspublishers.com

Digital Implant Planning and Guided Surgery: Current Trends and Clinical Outcomes

Dr. Thondati Poornachandra Rao[1], Dr. Salina Manandhar[2*], Dr. Mounica Pinnamaneni[3], Dr. Sruthi Kalakota[4], Dr. Ridhi Bhola[5], Dr. Sandeep Singh[5]

[1]Government Dental College, RIMS, Dr NTR University of Health Sciences, Kadapadst, Andhra Pradesh
[2]Rangpur Dental College, Medical East Gate, Rangpur, Bangladesh
[3]Gitam Dental College & hospital, Rushikonda, Visakhapatnam, Andhra Pradesh
[4]Drs. Sudha & Nageswara Rao Siddartha Institute of Dental Sciences, Chinoutpalli, Gannavaram Mandal, Andhra Pradesh
[5]Post Graduate Institute of Dental Sciences, Rohtak, Haryana

DOI: https://doi.org/10.36347/sjds.2025.v12i04.001 | **Received:** 15.04.2025 | **Accepted:** 19.05.2025 | **Published:** 23.05.2025

***Corresponding author**: Dr. Salina Manandhar
Rangpur Dental College, Medical East Gate, Rangpur, Bangladesh

Abstract **Review Article**

The amalgamation of digital technologies in implant dentistry has revolutionized treatment planning and execution, improving both precision and predictability. Advancements in cone-beam computed tomography (CBCT), intraoral scanning, and computer-aided design/computer-aided manufacturing (CAD/CAM) systems have facilitated the transition from conventional analog methods to fully digital workflows. This review explores the current trends in digital implant planning and guided surgery, emphasizing their clinical implications. The review also evaluates current literature on the clinical outcomes of digitally guided implant placement, including implant survival rates, marginal bone loss, and prosthetic success. Despite the promising results, certain limitations, such as guide stability, learning curve, and cost-effectiveness, are addressed.

Keywords: Computer-aided surgery, Dental implants, Digital workflow, Implant dentistry, Surgical guide, Surgical template.

1. INTRODUCTION

Advancements in digital technologies have revolutionized the field of dentistry, bringing about a paradigm shift in diagnostic accuracy, treatment planning, and clinical execution. In the early stages of osseointegration-based implant therapy, diagnosis and treatment planning primarily relied on clinical examination, study casts, and conventional two-dimensional radiographs such as periapical and panoramic imaging. However, these modalities presented inherent limitations in terms of spatial accuracy and depth perception, often leading to imprecise assessments of the available bone [1].

The advent of digital computed tomography, and more notably the broad implementation of cone beam computed tomography (CBCT), has made it possible to obtain precise and detailed three-dimensional assessments of bone structures. This has allowed clinicians to better assess the bone topography, proximity to vital anatomical structures, and overall feasibility of implant placement, leading to more predictable outcomes [2].

Guided implant surgery represents a significant advancement in implantology, made possible through the integration of digital technology. It involves a comprehensive digital workflow that includes three-dimensional implant planning, the design and fabrication of custom surgical guides, and the precise placement of implants using system-specific guided surgical kits. This approach not only enhances the accuracy and safety of the surgical procedure but also aligns implant positioning with the desired prosthetic outcome (Figure 1) [2,3].

Given the high expectations of patients—owing to the significant cost and invasiveness of implant procedures—precision, predictability, and minimal invasiveness have become essential goals.4 While a 2016 survey in the UK indicated that many dentists had not yet fully embraced computer-based technologies, there was a broad consensus on their growing importance in the future of dental care. Today, the digital transformation in dentistry is not only well underway but is also considered irreversible [5]. This review aims to provide a comprehensive overview of digital implant planning and guided surgery, with a particular focus on current trends, workflow protocols, and clinical outcomes.

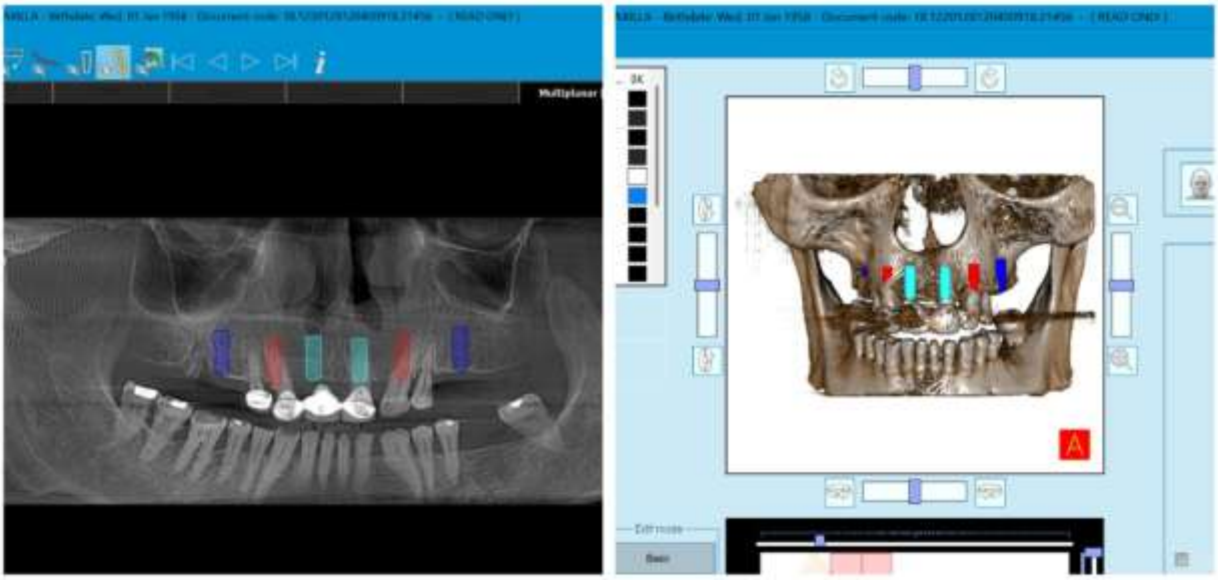

Figure 1: Digital Implant Planning

2. Benefits of Guided Implant Surgery

Guided implant surgery offers numerous advantages that contribute to improved precision, safety, and predictability in implant dentistry. One of the primary benefits is prosthetic-driven planning and placement, which enables the clinician to virtually plan the final prosthetic outcome and accordingly position the implants to support optimal functional and esthetic results. This backward planning approach allows for the selection of implants that are best suited to the anatomical and prosthetic requirements of the case [6].

The use of three-dimensional imaging and digital planning software facilitates comprehensive visualization of anatomical structures, including nerves, maxillary sinuses, and bony irregularities. This enables a more accurate assessment of available bone volume and quality, early identification of potential complications, and informed decision-making. As a result, guided surgery significantly reduces intraoperative guesswork and the need for spontaneous deviations from the surgical plan [2,6].

Moreover, guided surgery ensures precise implant placement in the most favorable bone, even in cases with minimal bone availability. This is particularly beneficial in the rehabilitation of completely edentulous jaws, where guided protocols allow for strategic angulation and positioning of longer implants to maximize cortical bone anchorage and enhance antero-posterior (AP) spread, thereby improving biomechanical stability. Additionally, it facilitates restoration up to the first molar, expanding the scope of functional rehabilitation in challenging cases. Overall, guided implant surgery leads to enhanced clinical predictability, increased patient satisfaction, and streamlined prosthetic outcomes [7].

3. Steps in guided implant placement

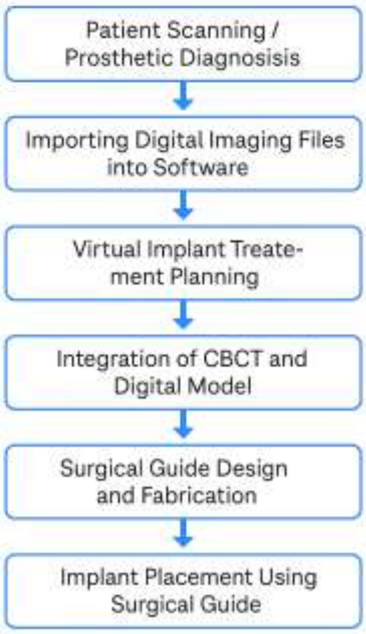

Figure 2- Steps in Guided Implant placement

Fabricating the surgical template

After completing the design phase, the data can be exported in STL file format and then transformed into a physical surgical guide using additive or subtractive computer-aided manufacturing (CAM) techniques. Commonly employed methods for this process include 3D printing and rapid prototyping technologies such as stereolithography (SLA), digital light processing (DLP), and selective laser sintering (SLS). Stereolithographic technique is most commonly used. SLA involves the layer-by-layer polymerization of a photosensitive liquid resin using a laser beam. This technique offers exceptional precision, with print resolutions as fine as 10 μm, and results in an extremely smooth surface finish. Once the surgical guide is polished, titanium cylindrical sleeves are inserted through simple friction fitting. The guide can then be sterilized using various methods, including autoclaving, gamma radiation, or immersion in a chlorhexidine solution for cold sterilization (Figure 3).

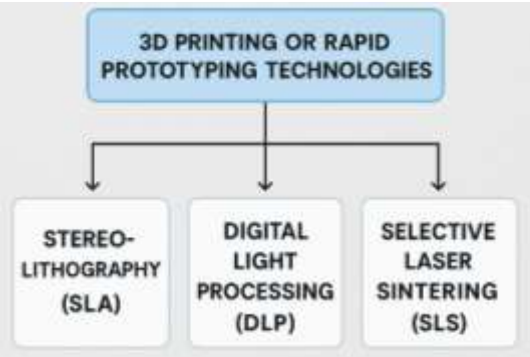

Figure 3: Methods to fabricate surgical guide

4. Types of Implant guides

Guided implant surgery is generally classified into two main approaches: static and dynamic. Dynamic guided surgery utilizes computer-assisted navigation systems that provide real-time feedback during implant placement, allowing the surgeon to make intraoperative adjustments to the planned implant position. The main advantage of this approach lies in its flexibility during surgery. Despite the growing interest in dynamic navigation, static guides remain the most widely used method [8].

There are different types of surgical guides available, based on the surgical technique employed. These include pilot-drill-only guides, which assist with initial drilling, and fully guided templates that direct the entire sequence of implant placement. The internal diameter of the guide cylinders can vary based on the design, as titanium sleeves are often inserted to guide the drills accurately [9].

Surgical guides can also be classified according to the type of anatomical support they utilize:

1. Mucosa-supported guides
2. Bone-supported guides
3. Tooth-supported guides

5.1 Mucosa-supported guide (Figure 4)

For full edentulous cases, guide is recommended. Its main advantage lies in the mini-invasive Flapless surgical technique that circumvents the need to use a periosteum flap. However, it does require a certain degree of experience to handle. This guide should be used with an occlusion key, after which a retaining or stabilisation screw (also known as a trans-osseous pin) should be put in place, to keep it firmly in situ with maximum stability.

The bearing surface that the guide sits on is the mucosa, which is a compressible surface up to 3 to 4mm thick. Uneven pressure can cause it to tip and create a deviation in the initial impact point, and therefore in the planned implant angulation [9,10].

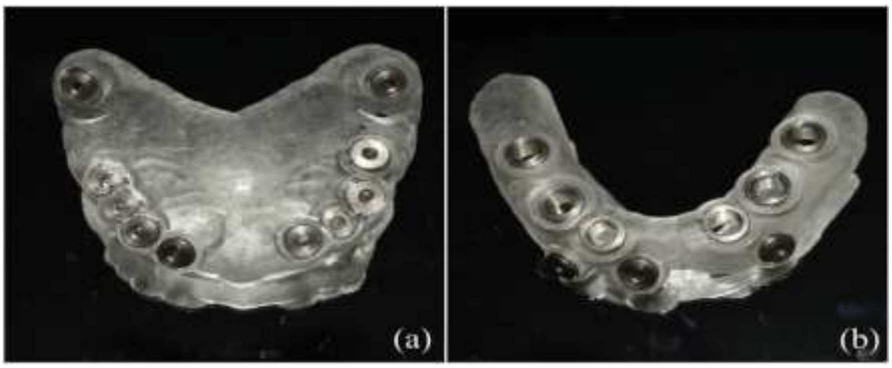

Figure 4: Maxillary all-on 6 surgical guide, (b) Mandibular all-on 6 surgical guide

5.2 Bone-Supported Surgical Guide

This type of guide is stabilized directly on the bone and typically requires extensive elevation of the mucoperiosteal flap for proper placement and adaptation [9].

5.3 Tooth-supported guide

It is suitable for anterior or posterior partially tooth-bound edentulism, as well as free-end edentulous cases less than 30mm from the edentulous area. It can also be used for surgeries with or without flaps. Tooth-supported guide is the most accurate of all surgical guides, particularly in the cases of tooth-bound edentulism [11].

Figure 5: Tooth Supported surgical guide, Bone supported surgical guide

5. Placement of guided Implants

Prior to surgery, it is essential to ensure that the surgical guide fits properly within the mouth. In flapless procedures, a tissue punch technique can be performed through the guide to expose the underlying bone. The punched-out tissue can be stored in saline. To enhance the precision of the procedure, the guide can be secured to the bone using mini-screws. To maintain correct positioning during screw placement, the use of a bite index for guide stabilization is recommended.

During the drilling phase, drill keys can be placed into the guide sleeves to direct a series of drills with varying diameters, ensuring accurate positioning and angulation. Depending on the system, these drill keys may be attached directly to the drills or shaped like spoons. The drills may include physical or visual stops for depth control. In some systems, separate guides are used for each drill size. The method of implant guidance during placement varies based on the specific system being used. After the placement of implants, punched-out tissue can be secured back using cyanoacrylate adhesive (Figure 6).

Figure 6: Post op OPG after guided all-on 4 implant placement, Post-op clinical image

6. DISCUSSION

In a 2012 meta-analysis, Van Assche and colleagues reported average deviations of 1.09 mm at the implant entry point, 1.28 mm at the apex, and an angular deviation of 3.9° [12]. A later systematic review by Tahmaseb *et al*. in 2014 showed similar findings, with mean deviations of 0.93 mm at the entry and 1.29 mm at the apex, and an angular deviation of 3.53° [13]. In contrast, implant placement performed freehand tends to show significantly higher deviations at both the entry and apex points [14,15]. Moreover, studies have shown that templates produced through CAD/CAM technology provide greater placement accuracy compared to traditional surgical guides, which is likely due to the comprehensive nature of three-dimensional digital planning involved in their fabrication [16].

The existing literature presents mixed findings regarding the significance of a learning curve in guided implant surgery. While one clinical trial conducted by Vasak *et al*. identified the presence of a learning curve [17], other studies, specifically those by Valente *et al*. (2009), Cassetta *et al*. (2013), and Vercruyssen *et al*. did not observe such a trend [18,19]. Intraoperative complications have also been documented; for instance, Tahmaseb *et al*. reported issues such as surgical guide fracture (3.6%), alterations in the surgical plan (2.0%), and insufficient primary implant stability (1.3%). 13 Additionally, certain limitations can hinder the use of guided implant surgery, including restricted mouth opening and specific pre-existing conditions that make comprehensive three-dimensional diagnostic imaging unfeasible [20].

Radiation exposure from cone-beam computed tomography (CBCT) can range from 10 µSv to 1000 µSv, depending on factors such as the specific device used, its operational settings, and the field of view (FOV) [21]. As a result, the decision to use 3D imaging should be carefully weighed on a case-by-case basis, ensuring that the clinical benefits for the patient justify the potential radiation risks. It is important to note that three-dimensional imaging, digital implant planning, or guided implant surgery are not mandatory in every case. While they offer extensive diagnostic detail, the associated radiation dose remains a limiting factor.

Another challenge is the high cost associated with digital workflows, which includes not only the imaging and planning but also the production of surgical templates. Furthermore, the process requires significant technical resources and specialized knowledge, including dedicated software and hardware. Despite these drawbacks, the time invested in preoperative preparation is often compensated by enhanced surgical precision, procedural efficiency, and a more predictable overall treatment outcome [22].

7. CONCLUSION

Digital implant planning and guided implant surgery offer significant advantages by enabling precise surgical and prosthetic preparation, ultimately contributing to more predictable and successful treatment outcomes. Studies have consistently shown that, in terms of accuracy, guided implant placement surpasses conventional freehand techniques. However, these benefits come with certain limitations. The approach involves higher financial costs, the requirement for advanced technology, and the necessity of specialized training. Moreover, the success of guided implant surgery heavily depends on the expertise of both the clinician and the dental technician. A thorough understanding of the indications, limitations, and proper execution of the digital workflow is essential to avoid complications. When used judiciously, guided surgery empowers dental professionals to deliver safer, more efficient, and outcome-driven care, truly enhancing patient satisfaction and long-term clinical success.

Conflict of Interest: None

Source of Funding: None

REFERENCES

1. Pandey C, Rokaya D, Bhattarai BP. Contemporary Concepts in Osseointegration of Dental Implants: A Review. Biomed Res Int. 2022;14:6170452.
2. Singh S *et al*. Prosthodontic Rehabilitation for Edentulous Ridges-Clinical Cases at Glance. BP International. 2024
3. Sarkar A, Hoda MM, Malick R, Kumar A. Surgical Stent Guided Versus Conventional Method of Implant Placement. J Maxillofac Oral Surg. 2022;21(2):580-589.
4. Schubert O, Schweiger J, Stimmelmayr M, Nold E, Güth JF. Digital implant planning and guided implant surgery - workflow and reliability. British dental journal.2019;226(2):101-108.
5. Tran D, Nesbit M, Petridis H. Survey of UK dentists regarding the use of CAD/CAM technology. Br Dent J. 2016;221:639-644.
6. Nickenig H J, Eitner S. Reliability of implant placement after virtual planning of implant positions using cone beam CT data and surgical (guide) templates. J Cranio maxillofac Surg. 2007;35207-211.
7. Sarment D P, Sukovic P, Clinthorne N. Accuracy of implant placement with a stereolithographic surgical guide. Int J Oral Maxillofac Implants. 2003;18:571-577.
8. Jung RE, Schneider D, Ganeles J, *et al*. Computer technology applications in surgical implant dentistry: a systematic review. Int J Oral Maxillofac Implants. 2009; 24:92-109.
9. Tahmaseb A, Wismeijer D, Coucke W, *et al*. Computer technology applications in surgical implant dentistry: a systematic review. Int J Oral Maxillofac Implants . 2014;29(Suppl):25–42.
10. Al Yafi, F., Camenisch, B., & Al-Sabbagh, M. Is Digital Guided Implant Surgery Accurate and Reliable?. Dental clinics of North America.2019; 63(3):381-397.
11. D'Souza, KM, Aras, MA. Types of implant surgical guides in dentistry: a review. The Journal of oral implantology. 2012;38(5):643-652.
12. Van Assche N, Vercruyssen M, Coucke W, Teughels W, Jacobs R, Quirynen M. Accuracy of computer-aided implant placement. Clin Oral Implants Res. 2012;23 Suppl 6:112-123.
13. Tahmaseb A, Wismeijer D, Coucke W, Derksen W. Computer technology applications in surgical implant dentistry: a systematic review. Int J Oral Maxillofac Implants. 2014; 29 Suppl:25-42.
14. Arisan V, Karabuda C Z, Mumcu E, Ozdemir T. Implant positioning errors in freehand and computer-aided placement methods: a single-blind clinical comparative study. Int J Oral Maxillofac Implants. 2013;28:190-204.
15. Vermeulen J. The Accuracy of Implant Placement by Experienced Surgeons: Guided vs Freehand Approach in a Simulated Plastic Model. Int J Oral Maxillofac Implants. 2017; 32:617-624.
16. Nokar S, Moslehifard E, Bahman T, Bayanzadeh M, Nasirpouri F, Nokar A. Accuracy of implant placement using a CAD/CAM surgical guide: an in vitro study. Int J Oral Maxillofac Implants. 2011;26:520-526.

17. Vasak, C., Watzak, G., Gahleitner, A., Strbac, G., Schemper, M. & Zechner, W. Computed tomography-based evaluation of template (Nobel Guide)-guided implant positions: a prospective radiological study. Clinical Oral Implants Research. 2011;22: 1157-1163.
18. Valente, F., Schiroli, G. & Sbrenna, A. Accu racy of computer-aided oral implant surgery: a clinical and radiographic study. International Jour nal of Oral Maxillofacial Implants. 2009;24:234-242.
19. Cassetta M, Giansanti M, Di Mambro A, Calasso S, Barbato E. Accuracy of two stere olithographic surgical templates: a retrospective study. Clinical Implant Dentistry and Related Research. 2013;15:448-459.
20. S2-kLeitlinie. Indications for implantological 3D X-ray diagnostics and navigational implantology [Indikationen zur implantologischen 3D-Rontgendiagnostik und navigationsgestutzten implantologie]. AWMF-Register nummer: 083–011 aktueller Stand: 12/2011.
21. Jacobs R, Quirynen M. Dental cone beam computed tomography: justification for use in planning oral implant placement. Periodontol. 2014;66:203-213.
22. Benavides E, Rios H F, Ganz S D *et al*. Use of cone beam computed tomography in implant dentistry: the International Congress of Oral Implantologists consensus report. Implant Dent. 2012;21:78-86.