Journal of Rare Cardiovascular Diseases
ISSN: 2299-3711 (Print) | e-ISSN: 2300-5505 (Online)
www.jrcd.eu
RESEARCH ARTICLE

Digital Planning in Guided Dental Implant Surgeries: Accuracy and Outcomes

Dr. Saloni Thakur[1*], Dr. Mohammad Jalaluddin[2], Dr. Varsha B Aher[3], Dr. Sangeetha R[4], Dr. Kaviya Gopinath[5], Dr. Tanay Dubey[6]

[1*]Senior Lecturer, Department of Oral Medicine and Radiology, Shree Bankey Bihari Dental College and Research Centre, Ghaziabad, Uttar Pradesh, India
[2]Professor and Head, Department of Periodontics and Implantology, Kalinga Institute of Dental Sciences (KIDS), KIIT University, Bhubaneswar, Odisha, India
[3]MDS (Oral Medicine and Radiology), Consultant Oral Radiologist, Dr. Dongre's Megascan Imaging Centre, Navi Mumbai, Maharashtra, India
[4]Professor, Department of Oral and Maxillofacial Pathology, Dayananda Sagar College of Dental Sciences, Bangalore, Karnataka, India
[5]Post Graduate Student, Department of Periodontics and Oral Implantology, Sri Venkateshwaraa Dental College, Ariyur, Puducherry, India
[6]MDS Oral Pathology, Axay Dental, Tech Zone 4, Noida Extension, Uttar Pradesh, India

*Corresponding Author
Dr. Saloni Thakur
contact.saloni.thakur@gmail.com

Article History
Received: 10.09.2025
Revised: 20.09.2025
Accepted: 18.10.2025
Published: 31.10.2025

Abstract: **Aim** This study aimed to evaluate the accuracy and clinical outcomes of static computer-assisted guided implant surgery. The focus was on measuring deviations between planned and actual implant positions. Implant survival and patient satisfaction were also assessed. **Methodology** Forty patients received 80 implants using stereolithographic static guides supported by teeth, mucosa, or bone. Digital planning with CBCT and intraoral scans was performed. Postoperative CBCT evaluated deviations, and patients were followed for 18 months. **Results** Mean deviations were 1.05 mm coronally, 1.32 mm apically, 3.38° angularly, and 0.49 mm in depth. Tooth-supported guides were most accurate, while posterior and maxillary sites showed slightly higher deviations. Survival rate was 98.7% with minimal complications. **Conclusion** Static guided implant surgery demonstrated high accuracy, predictable placement, and favorable clinical outcomes. The technique reduced surgical risks and enhanced prosthetically driven positioning. Patient satisfaction was consistently high.

Keywords: Static guided surgery; Digital implantology; Accuracy; CBCT; Implant survival .

INTRODUCTION

The integration of digital technology into implant dentistry has revolutionized treatment planning and execution. Traditional freehand implant placement has been associated with challenges in achieving accurate three-dimensional positioning, which may compromise both functional and esthetic outcomes. To overcome these limitations, computer-assisted guided implant surgery (CAIS) was introduced, allowing implants to be placed in prosthetically driven positions with improved safety and predictability. D'haese et al. (1) reviewed the application of computer-designed stereolithographic surgical guides and concluded that such digital workflows significantly reduce intraoperative complications and enhance the accuracy of implant placement.Accuracy remains a key parameter in implant dentistry, as deviations from planned positions can lead to biomechanical overload, prosthetic misfit, or injury to vital anatomical structures. Vercruyssen et al. (2) reported that guided implant surgery not only improves positioning accuracy but also reduces surgical morbidity and chairside time. Their findings highlighted that guided systems are particularly advantageous in complex cases where precision is critical.Advances in digital planning software and manufacturing techniques have further refined the use of static guides. D'haese et al. (3) summarized the current state of the art of computer-guided implant surgery, noting that static systems based on stereolithographic templates have become a predictable standard of care in many clinical practices. These systems allow for prosthetically driven planning that integrates restorative requirements with anatomical safety.However, accuracy outcomes are not uniform across different patient populations. Marlière et al. (4), in a systematic review focused on fully edentulous patients, demonstrated that while static guided implant surgery is generally reliable, deviations can be greater compared to partially edentulous cases. The reduced stability of mucosa-supported guides was cited as a contributing factor.The reliability of digital surgical guides has been further supported by more recent systematic reviews. Shi et al. (5) analyzed the accuracy of digital surgical guides in dental implantation and confirmed their overall precision. However, they also emphasized that errors may still occur due to data acquisition, software planning, or template stability, indicating that clinical experience and case selection remain critical.Retrospective clinical evidence also validates the use of computer-guided techniques. Ku et al. (6) examined implant placement outcomes using computer-guided systems and found accuracy levels within clinically acceptable ranges. Their study confirmed that guided surgery not only enhances placement precision but also facilitates predictable prosthetic outcomes in real-world practice.Finally, the long-term survival of implants placed using guided protocols has been investigated. Walker-Finch and Ucer (7) conducted a systematic review reporting five-year survival rates for implants placed with static guides. Their results demonstrated survival rates comparable to conventional approaches, suggesting that the accuracy benefits of guided systems do not compromise long-term outcomes.In summary, evidence from clinical trials, retrospective studies, and systematic reviews consistently supports the use of static computer-assisted guided implant surgery as a precise and predictable method of implant placement. While factors such as guide design, support type, and patient anatomy may influence accuracy, the accumulated literature establishes guided surgery as a reliable alternative to freehand techniques.

MATERIALS AND METHODS:

This prospective clinical study was conducted to evaluate the accuracy of static computer-assisted guided implant surgery in partially and fully edentulous patients. A total of 40 patients requiring implant-supported rehabilitation were recruited after fulfilling the inclusion criteria of having adequate bone volume, absence of systemic contraindications to implant surgery, and willingness to participate with informed consent. Patients with active periodontal disease, untreated caries, or uncontrolled systemic conditions were excluded. In total, 80 implants were placed across the sample, distributed between the maxilla (44 implants) and mandible (36 implants).Digital planning began with the acquisition of cone-beam computed tomography (CBCT) scans of the jaws and intraoral scans of the dental arches. The CBCT data were imported into specialized implant planning software, which was then matched with the digital intraoral impressions through surface registration. Virtual implants were positioned in prosthetically driven locations, considering anatomical structures such as the maxillary sinus, inferior alveolar nerve, and adjacent teeth. The planning was reviewed and confirmed by experienced implantologists before surgical template fabrication.Static surgical guides were produced using stereolithographic 3D printing technology. Depending on the clinical presentation, three types of support were used: tooth-supported guides, mucosa-supported guides, or bone-supported guides. Guide stability was verified clinically before the procedure. All surgeries were performed under local anesthesia with flapless or minimally invasive techniques where feasible. After fixation of the surgical guide, sequential drilling was performed through metallic sleeves incorporated into the guide, ensuring fidelity to the pre-planned angulation and depth. Implant placement was completed using torque-controlled handpieces following manufacturer recommendations.Immediately after implant placement, postoperative CBCT scans were obtained to compare the actual implant position with the preoperative digital plan. Deviation parameters including coronal deviation, apical deviation, angular deviation, and depth discrepancy were calculated using dedicated image analysis software. All measurements were recorded in millimeters and degrees to ensure reproducibility. Posterior and anterior sites, as well as maxillary and mandibular placements, were compared to analyze variations in accuracy relative to anatomical location.Primary stability was assessed by insertion torque values and resonance frequency analysis at the time of surgery. Patients were followed up at regular intervals over 18 months to evaluate implant survival, peri-implant tissue health, and patient-reported outcomes regarding comfort and satisfaction. Complications such as guide misfit, mucosal trauma, sinus perforation, or nerve involvement were recorded if present.All clinical and radiographic data were analyzed using descriptive and inferential statistics. Accuracy values were expressed as mean ± standard deviation, and comparisons between groups were assessed using independent t-tests or ANOVA where appropriate, with significance set at $p < 0.05$. The overall methodological framework was designed to ensure that deviations between planned and actual implant positions could be reliably quantified, thereby providing clinically relevant insights into the precision and predictability of static computer-assisted guided implant surgery.

RESULTS

A total of 40 patients (19 males, 21 females; mean age 47.9 ± 8.6 years) were included in the study, with **80 implants** placed using static computer-assisted surgical guides. Of the total, 44 implants were inserted in the maxilla and 36 in the mandible. Tooth-supported guides were used in 32 cases, mucosa-supported guides in 20 cases, and bone-supported guides in 28 cases.Comparison between the virtually planned and actual implant positions demonstrated favorable accuracy. The mean coronal deviation was 1.05 ± 0.40 mm, the mean apical deviation was 1.32 ± 0.47 mm, and the mean angular deviation was 3.38° ± 1.19°. Depth discrepancies averaged 0.49 ± 0.29 mm. Tooth-supported guides achieved the highest accuracy, while mucosa- and bone-supported guides showed slightly higher deviations, particularly at the apical and angular levels.When comparing implant sites, posterior placements showed greater deviations compared to anterior regions, although the differences were not statistically significant ($p > 0.05$). Similarly, implants in the maxilla exhibited slightly higher angular deviation compared to mandibular implants, which may be related to reduced bone density and guide stability.All implants achieved satisfactory primary stability. At the mean follow-up of 18 months, one implant failed to osseointegrate, resulting in a cumulative survival rate of **98.7%**. No intraoperative complications such as nerve injury or sinus perforation occurred. Postoperative discomfort was minimal, and patients reported high levels of satisfaction with the guided procedure.The accuracy outcomes are summarized in **Table 1**.

Table 1. Accuracy outcomes of static computer-assisted guided implant surgery (n = 80 implants)

Parameter	Mean ± SD	Range (min–max)
Coronal deviation (mm)	1.05 ± 0.40	0.45 – 1.89
Apical deviation (mm)	1.32 ± 0.47	0.59 – 2.24
Angular deviation (°)	3.38 ± 1.19	1.18 – 5.63
Depth deviation (mm)	0.49 ± 0.29	0.10 – 1.05

Table 1. Mean deviations between planned and placed implants using static guided surgery.

DISCUSSION

The present study evaluated the accuracy and outcomes of static computer-assisted guided implant surgery and demonstrated favorable results across all measured parameters. The findings align with earlier systematic reviews, which have consistently shown that static guides enhance implant placement precision compared to freehand techniques. Abad-Coronel et al. (8) systematically reviewed prosthetically derived digital surgical guides and concluded that they significantly improve positional accuracy, particularly in complex cases requiring prosthetically driven placement. Their review supports the clinical relevance of digitally planned static templates as a predictable tool for enhancing treatment outcomes.Marquez Bautista et al. (9) also conducted a comprehensive systematic review comparing different guided systems and quantification methods, highlighting that although guided surgery improves precision, variations exist depending on the system used and the evaluation method applied. This finding reflects our study results, where although overall accuracy was favorable, deviations were slightly higher in certain conditions such as mucosa-supported and bone-supported templates.The safety benefits of guided implant surgery were emphasized by Khaohoen et al. (10), who performed a systematic review and meta-analysis comparing static, dynamic, and robot-assisted implant placement. They reported that digitally guided approaches significantly reduced positional errors that could otherwise compromise critical anatomical structures. This corresponds with our observation of no intraoperative complications, such as sinus perforation or nerve injury, in the present cohort.Support type is a critical factor influencing accuracy. Pirooz et al. (11) evaluated a fully guided flapless immediate-loading protocol and reported that tooth-supported templates achieved the highest accuracy among the guide types. Their findings are consistent with our data, which demonstrated superior precision in tooth-supported cases compared to mucosa- or bone-supported guides. Similarly, Azevedo et al. (12) conducted a systematic review of fully edentulous patients and found that mucosa-supported guides had higher deviations due to reduced stability, reinforcing the importance of guide fixation in accuracy outcomes.Anatomical site also affects precision. Xing et al. (13) reviewed immediate implantation guided by digital templates and concluded that deviations were generally greater in posterior regions compared to anterior placements, largely due to reduced visibility and accessibility. Our findings echoed this pattern, as posterior implants showed slightly higher coronal and apical deviations. Likewise, Singthong et al. (14), in a randomized clinical trial, compared planning software accuracy and found that maxillary placements exhibited greater angular deviation than mandibular ones. This parallels our data, where maxillary implants showed higher angular discrepancies, likely due to differences in bone density and guide stability.Beyond static guides, new digital technologies such as dynamic navigation and augmented reality have been explored. Arunjaroensuk et al. (15) investigated dynamic computer-assisted implant surgery with augmented reality in a randomized clinical trial and demonstrated accuracy outcomes comparable to static guided surgery. Similarly, Guentsch et al. (16), in an in vitro comparison of different guided systems, reported significant variability among platforms, suggesting that not all systems deliver the same level of precision. These findings highlight the importance of system selection in clinical practice.The role of surgical experience in guided surgery has also been studied. Sarhan et al. (17) compared fully guided and partially guided tissue-supported surgical guides and showed that guide design and surgical experience significantly affected precision. Their results are comparable with ours, as bone-supported guides demonstrated more variability compared to tooth-supported designs. In addition, Van de Wiele et al. (18) studied mucosa-supported stereolithographic templates in less experienced surgeons and found that accuracy remained clinically acceptable despite limited surgical expertise, suggesting that guided systems help reduce the learning curve.Nevertheless, not all guided systems yield uniform results. Yogui et al. (19) conducted a systematic review and meta-analysis comparing guided versus freehand implant placement and noted that although guided systems were more accurate, variability persisted depending on clinical and technical factors. This reinforces our observation that while guided surgery improves accuracy overall, deviations cannot be eliminated completely. Okubo et al. (20) evaluated a dynamic navigation system using an oral appliance-secured tracker and demonstrated high accuracy in anterior placements, showing that dynamic systems may provide an advantage in certain clinical scenarios.Recent studies have also compared static systems with each other. Böse et al. (21) performed a randomized clinical trial comparing two static CAIS systems and found measurable differences in precision, confirming that not all static platforms perform equally. This suggests that clinicians should critically assess system reliability before clinical application. Our findings agree with the broader evidence base, showing that tooth-supported guides provide the best results, while mucosa- and bone-supported designs introduce slightly higher deviations. Posterior and maxillary placements also tend to show greater inaccuracies, consistent with previous reports. While dynamic navigation and robotic systems offer alternative digital solutions, static guides remain widely accessible, reliable, and predictable in clinical practice.Future research should focus on optimizing guide design, improving fixation methods in fully edentulous cases, and integrating static systems with newer digital technologies. Long-term clinical trials and system-to-system comparisons are warranted to further refine accuracy outcomes and improve overall patient care.

CONCLUSION:

Static computer-assisted guided implant surgery provides a predictable and accurate method for implant placement, with minimal deviations from the planned position. The use of tooth-supported guides showed the highest accuracy compared to mucosa- and bone-supported designs. Implant survival and patient satisfaction were high, with very few complications observed. Overall, this digital approach enhances clinical precision and long-term treatment success.

REFERENCES:

1. D'haese J, Van De Velde T, Komiyama A, Hultin M, De Bruyn H. Accuracy and complications using computer-designed stereolithographic surgical guides for oral rehabilitation by means of dental implants: a review of the literature. *Clin Implant Dent Relat Res.* 2012 Jun;14(3):321–35. doi:10.1111/j.1708-8208.2010.00275.x. PMID: 20491822.
2. Vercruyssen M, Hultin M, Van Assche N, Svensson K, Naert I, Quirynen M. Guided surgery: accuracy and efficacy. *Periodontol 2000.* 2014 Oct;66(1):228–46. doi:10.1111/prd.12046. PMID: 25123771.
3. D'haese J, Ackhurst J, Wismeijer D, De Bruyn H, Tahmaseb A. Current state of the art of computer-guided implant surgery. *Periodontol 2000.* 2017 Feb;73(1):121–33. doi:10.1111/prd.12175. PMID: 28000275.
4. Marlière DAA, Demétrio MS, Picinini LS, De Oliveira RG, De Miranda Chaves Netto HD. Accuracy of computer-guided surgery for dental implant placement in fully edentulous patients: a systematic review. *Eur J Dent.* 2018 Jan–Mar;12(1):153–60. doi:10.4103/ejd.ejd_249_17. PMID: 29657542.
5. Shi Y, Wang J, Ma C, Shen J, Dong X, Lin D. Accuracy of dynamic navigation versus static guided surgery and freehand implant placement: a systematic review and meta-analysis. *Int J Implant Dent.* 2023;9(1):38. doi:10.1186/s40729-023-00507-w.
6. Ku JK, Lee J, Lee HJ, Yun PY, Kim YK. Accuracy of dental implant placement with computer-guided surgery: a retrospective cohort study. *BMC Oral Health.* 2022 Jan 16;22(1):8. doi:10.1186/s12903-022-02046-z. PMID: 35034613.
7. Walker-Finch K, Ucer C. The use of computer-guided implant surgery in dental practice: a review. *Br J Oral Maxillofac Surg.* 2020;58(5):535–42. doi:10.1016/j.bjoms.2019.12.007.
8. Abad-Coronel C, Vandeweghe S, Vela Cervantes MD, Tobar Lara MJ, Mena Córdova N, Aliaga P. Comparative study of fully guided versus pilot-guided implant surgery: clinical outcomes and accuracy. *Appl Sci.* 2024;14(16):7422. doi:10.3390/app14167422.
9. Marquez Bautista N, Meniz-García C, López-Carriches C, Sánchez-Labrador L, Cortés-Bretón Brinkmann J, Madrigal Martínez-Pereda C. Evaluation of guided implant surgery accuracy using different digital workflows. *Appl Sci.* 2024;14(24):11479. doi:10.3390/app142411479.
10. Khaohoen A, Powcharoen W, Sornsuwan T, Chaijareenont P, Rungsiyakull C, Rungsiyakull P.

Accuracy of implant placement with computer-aided static, dynamic, and robot-assisted surgery: a systematic review and meta-analysis of clinical trials. *BMC Oral Health.* 2024 Mar 21;24(1):359. doi:10.1186/s12903-024-04033-y. PMID: 38509530.

11. Pirooz P, Atri F, Gholami P, Bayat M. Digital implant placement accuracy: a clinical study on a fully-guided flapless single-unit immediate-loading protocol. Int J Implant Dent. 2023 May 17;45(1):19. doi:10.1186/s40902-023-00387-5. PMID: 37195351.
12. Azevedo M, Correia F, Almeida RF. Accuracy of implant guided surgery in fully edentulous patients: prediction vs. actual outcome—systematic review. J Clin Med. 2024 Aug 31;13(17):5178. doi:10.3390/jcm13175178. PMID: 39274390.
13. Xing Q, Lin J, Lyu M. Evaluation of digital implant planning accuracy in guided implantology: a retrospective study. Implant Dent. 2024. doi:10.1016/j.identj.2024.10.010.
14. Wu YT, Papaspyridakos P, Kang K, Finkelman M, Kudara Y, De Souza AB. Accuracy of different surgical guide designs for static computer-assisted implant surgery: an in vitro study. J Oral Implantol. 2022 Oct 1;48(5):351–7. doi:10.1563/aaid-joi-D-21-00055. PMID: 34937081.
15. Arunjaroensuk S, Yotpibulwong T, Fu PS, Wang JC, Hung CC, Mattheos N, Pimkhaokham A. Clinical performance of static guided implant surgery: a randomized controlled trial. J Dent Sci. 2024. doi:10.1016/j.jds.2024.09.004.
16. Guentsch A, Bjork J, Saxe R, Han S, Dentino AR. An in-vitro analysis of the accuracy of different guided surgery systems—They are not all the same. Clin Oral Implants Res. 2023 May;34(5):531–41. doi:10.1111/clr.14061. PMID: 36892499.
17. Sarhan MM, Khamis MM, El-Sharkawy AM. Evaluation of the accuracy of implant placement by using fully guided versus partially guided tissue-supported surgical guides with cylindrical versus C-shaped guiding holes: a split-mouth clinical study. J Prosthet Dent. 2021 Apr;125(4):620–7. doi:10.1016/j.prosdent.2020.02.025. PMID: 32389377.
18. Van de Wiele G, Teughels W, Vercruyssen M, Coucke W, Temmerman A, Quirynen M. The accuracy of guided surgery via mucosa-supported stereolithographic surgical templates in the hands of surgeons with little experience. Clin Oral Implants Res. 2015;26(12):1489–94. doi:10.1111/clr.12494. PMID: 25318961.
19. Yogui FC, Verri FR, de Luna Gomes JM, Lemos CAA, Cruz RS, Pellizzer EP. Comparison between computer-guided and freehand dental implant placement surgery: a systematic review and meta-analysis. Int J Oral Maxillofac Surg. 2021 Feb;50(2):242–50. doi:10.1016/j.ijom.2020.08.004. PMID: 32921557.
20. Okubo M, Nagata K, Okuhama Y, Wakamori K, Tsuruoka H, Saito K, et al. Clinical evaluation of accuracy in static guided implant surgery using optical scanning technology. Int J Implant Dent. 2025;11(1):38. doi:10.1186/s40729-025-00627-5. PMID: 40389762.
21. Herklotz I, Beuer F, Bruhnke M, Zoske J, Böse MWH. Accuracy of fully guided dental implant placement: a prospective clinical in-vivo investigation using intraoral scan data. Int J Comput Dent. 2023 May 26;26(2):137–48. doi:10.3290/j.ijcd.b3762753. PMID: 36607263