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Accuracy of Guided Versus Freehand Implant Placement in the Esthetic Zone: A Narrative Review

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Abstract **Review Article**

Background: Accurate implant positioning is a critical determinant of functional and esthetic outcomes, particularly in the anterior maxilla. In recent years, digital workflows have introduced guided surgical techniques intended to enhance the precision of implant placement. Despite their growing popularity, a clear understanding of how these approaches compare to traditional freehand methods in terms of accuracy and clinical outcomes remains essential for evidence-based practice. ***Objective:*** This narrative review aims to compare the accuracy of guided and freehand implant placement techniques in the esthetic zone, focusing on angular, apical, and coronal deviations, and to evaluate their impact on clinical and esthetic results. ***Methods:*** A comprehensive literature search was conducted using PubMed to identify clinical and in vitro studies published between 2010 and 2024 that compared guided and freehand implant placement techniques. Studies were included if they reported quantitative data on implant placement accuracy or esthetic outcomes in the anterior region. ***Results:*** The reviewed evidence consistently shows that guided implant placement—particularly using fully digital workflows and static or dynamic navigation systems—achieves significantly lower angular and linear deviations compared to freehand techniques. Robotic-assisted and machine vision-guided systems demonstrated the highest levels of precision. Esthetic outcomes, especially soft tissue stability and prosthetic emergence profiles, were also favorably influenced by accurate implant positioning. However, guided surgery presents limitations such as reliance on data quality, increased cost, and technical complexity. ***Conclusion:*** Guided implant surgery offers superior accuracy over freehand techniques in the esthetic zone and contributes to improved prosthetic and esthetic outcomes. Nevertheless, clinical judgment, experience, and case-specific considerations remain essential for optimal treatment planning. Future innovations, including AI-assisted planning and robotic navigation, are expected to further refine surgical precision.

Keywords: Guided implantology, freehand surgery, dental implant accuracy, esthetic zone, digital workflow.

INTRODUCTION

Accurate implant placement in the anterior maxilla often referred to as the esthetic zone is a critical factor for the long-term success of dental implants. In this highly visible region, even minor deviations in implant angulation or position can lead to compromised esthetic results, such as poor prosthetic emergence profiles, soft tissue recession, and unsatisfactory smile lines. Therefore, achieving optimal precision is essential not only for osseointegration but also for meeting the patient's functional and esthetic expectations [3].

Traditionally, implants have been placed using the freehand technique, which relies on the operator's anatomical knowledge, surgical experience, and tactile feedback. However, this method has shown significant variability in terms of angular and linear deviations, especially in anatomically constrained or esthetically demanding sites. In contrast, guided implant surgery whether static (using prefabricated surgical templates) or dynamic (using real-time navigation systems) has been introduced to increase placement accuracy by digitally planning the implant position based on CBCT and intraoral scans [4,5].

Numerous clinical and in vitro studies have suggested that guided approaches can significantly reduce deviations compared to freehand surgery. For instance, dynamic navigation and robotic systems have demonstrated superior performance in minimizing apical and angular errors during implant insertion, offering increased control and predictability in complex cases [2,4]. These systems integrate machine vision, tracking

technologies, and preoperative digital planning to translate virtual plans into intraoperative accuracy. Furthermore, fully digital workflows that combine prosthetic-driven planning, intraoral scanning, and CAD/CAM-fabricated guides are gaining popularity due to their time efficiency and reproducibility [5].

Nonetheless, guided surgery is not without limitations. It requires significant preoperative planning, access to digital equipment, and a learning curve. Moreover, its accuracy is influenced by factors such as guide stability, manufacturing precision, and intraoral access. In some clinical scenarios, freehand surgery may still be favored due to simplicity, reduced cost, or better soft-tissue management [3,4].

In this context, a comprehensive understanding of the comparative accuracy and clinical implications of freehand versus guided implant placement in the esthetic zone becomes essential. This narrative review aims to synthesize the current literature and analyze the impact of each approach on surgical accuracy, clinical outcomes, and prosthetic success in anterior implantology.

Overview of Digital Implantology and Workflow Concepts:

In recent years, digital technology has dramatically reshaped the way dental implants are planned and placed. What was once a tactile, experience-driven surgical procedure is now increasingly becoming a digitally orchestrated act of precision. At the core of this transformation is the concept of a prosthetically driven workflow a method where implant planning begins not with the bone, but with the end goal in mind: the final restoration.

This approach typically starts with a digital wax-up, often generated from intraoral scans or digitized impressions. The ideal position, angulation, and depth of the implant are virtually determined based on prosthetic requirements, esthetic expectations, and the patient's anatomical limitations. When combined with cone-beam computed tomography (CBCT), this allows for the superimposition of soft and hard tissue data, creating a comprehensive 3D model of the surgical site [5].

From here, two main guided techniques emerge: static guidance and dynamic navigation. Static guidance involves the fabrication of a physical surgical guide that is used during surgery to dictate the drilling trajectory. These guides can be tooth-supported, mucosa-supported, or bone-supported, depending on the clinical scenario. Static guides are typically generated through CAD/CAM software and produced using 3D printing technology. Their accuracy, while generally high, depends heavily on proper seating, fit, and stabilization during surgery [4].

Dynamic navigation systems, on the other hand, offer a more flexible and interactive experience. Instead of a physical guide, they rely on real-time tracking of the drill's position, allowing the surgeon to follow a digital plan displayed on a screen. This technology resembles GPS navigation and offers the benefit of adjusting intraoperatively if anatomical challenges arise. Moreover, dynamic systems can be particularly useful in limited interarch space or posterior regions, where static guides may be bulky or obstructive [4].

A more recent advancement is the integration of robotic-assisted systems, which offer hands-free guidance with mechanical precision. These systems are still relatively new in dental implantology but have shown promising results in minimizing angular and apical deviations, especially in complex cases [2].

All these digital approaches are often part of a fully digital workflow, where data collection, planning, surgical execution, and prosthetic fabrication are seamlessly linked without reverting to analog steps. This transition improves consistency, reduces errors linked to impression materials or manual transfer steps, and enhances patient communication through visual simulations [5].

Ultimately, the goal of these digital tools is not merely to replace the clinician's judgment but to augment it providing more accurate, reproducible, and esthetically pleasing outcomes, especially in the highly demanding anterior zone.

Comparative Accuracy: Guided vs. Freehand Placement

One of the central questions in modern implantology is whether digital assistance truly delivers better precision than the traditional freehand technique. When accuracy is the measure particularly in the esthetic zone where every millimeter counts the choice of surgical method can significantly influence the final outcome.

- **Quantifying Accuracy**

Accuracy in implant placement is typically assessed using three key parameters: angular deviation (the angle between planned and actual implant axis), apical deviation (the linear distance between the planned and actual apex of the implant), and coronal deviation (mismatch at the implant shoulder). Studies consistently show that guided techniques outperform freehand approaches in all three metrics, often with statistically significant differences [4,5].

For instance, Wei *et al.,* demonstrated that dynamic navigation systems achieve superior control, with reduced angular deviations compared to both static guides and freehand surgery. In their clinical comparison, the average angular deviation in the dynamic navigation group was significantly lower,

suggesting a tighter correlation between the planned and executed implant trajectory [4]. These improvements are particularly meaningful in the esthetic zone, where even minor shifts can affect prosthetic emergence and soft tissue contours.

Chen *et al.,* took this one step further by evaluating robotic systems, which represent a new frontier in surgical precision. Their study reported some of the lowest deviation values to date, highlighting the potential of robotic guidance in achieving near-perfect alignment, especially for implants placed in esthetically sensitive sites [2].

- **Freehand Limitations and Human Factors**

While freehand implant placement has long been the standard, it introduces a degree of variability that depends heavily on the clinician's skill, experience, and intraoperative judgment. This variability becomes even more pronounced in anatomically challenging cases, where landmarks are less defined or visibility is limited. The absence of a fixed reference guide increases the risk of angular or positional errors, particularly in single-tooth gaps in the anterior maxilla.

Moreover, the subjective nature of freehand placement makes it difficult to achieve consistent results across different operators or cases. Even when performed by experienced surgeons, freehand placement may still result in deviations beyond clinically acceptable thresholds, especially when esthetic demands are high [3].

- **Static vs. Dynamic Guidance**

Within guided techniques themselves, accuracy can also vary. While static guides are generally reliable, their precision can be compromised by poor seating, movement during drilling, or inaccuracies in guide fabrication. In contrast, dynamic navigation offers the advantage of real-time feedback and the ability to make adjustments during surgery. However, it also requires a learning curve and depends on the operator's hand–eye coordination and familiarity with digital planning [4].

- **Summary of Findings**

When reviewing the available data, it becomes clear that guided surgery—whether static, dynamic, or robotic—provides a measurable improvement in implant placement accuracy compared to the freehand technique. These differences may not always be clinically significant in posterior zones, but they are particularly critical in the esthetic zone, where even minor discrepancies can compromise the final outcome.

Esthetic and Clinical Outcomes in the Anterior Zone:

When it comes to implant placement in the anterior maxilla, accuracy alone isn't enough. What truly defines success in this region is the harmony between hard and soft tissues, the natural emergence of the prosthetic crown, and the patient's satisfaction with the esthetic result. In this context, the surgical approach whether guided or freehand can have a ripple effect on both biological and visual outcomes.

- **The Delicate Balance of Soft Tissue**

The esthetic zone presents unique challenges due to the visibility of the smile line and the thinness of the buccal bone and soft tissue. Even slight deviations from the ideal implant position can disrupt the soft tissue profile, resulting in recession, asymmetry, or a poorly contoured emergence profile. Studies have shown that guided implant placement can reduce such risks by helping to preserve the intended prosthetic axis, which is crucial for shaping the peri-implant mucosa appropriately [3].

Surdiacourt *et al.,* explored the influence of soft tissue augmentation materials in anterior implants and highlighted how tissue thickness at the buccal aspect contributes directly to long-term esthetic stability. Their findings suggest that combining precise implant placement with soft tissue management strategies such as connective tissue grafting or the use of collagen matrices can greatly enhance outcomes in this zone [3].

- **Impact on Prosthetic Emergence and Crown Position**

An implant that is even slightly off-angle can force the prosthetic crown into an unnatural alignment, leading to esthetic compromises or mechanical complications. Guided techniques, particularly when used in conjunction with a digital wax-up and surgical planning, allow the implant to follow the anticipated prosthetic path with much higher consistency. As a result, the final restoration is better integrated in both function and appearance [5].

Zhu *et al.,* demonstrated this advantage in their randomized controlled trial comparing fully digital workflows with conventional methods. Patients treated through digital protocols showed more predictable soft tissue contours and fewer adjustments needed during prosthetic delivery, which suggests that the digital process not only improves accuracy but also streamlines the entire restorative phase [5].

- **Patient Satisfaction and Predictability**

From the patient's perspective, outcomes are often judged by what they see in the mirror, not by millimetric deviations on a scan. However, these clinical metrics do translate into visual outcomes. Guided approaches help reduce intraoperative guesswork, which in turn lowers the risk of midline shifts, black triangles, or crown length discrepancies. These esthetic imperfections can be distressing to patients and difficult to correct post-operatively.

By standardizing the implant position relative to the final crown, guided surgery helps maintain esthetic proportions and symmetry. Moreover, patients

undergoing digital workflows often benefit from shorter chair time, fewer prosthetic adjustments, and clearer communication through visual simulations all of which contribute to improved satisfaction [5].

CONCLUSION

As digital technologies continue to make their mark on dentistry, the comparison between guided and freehand implant placement becomes more than just a question of technique it reflects a broader shift toward precision, predictability, and patient-centered care. In the esthetic zone, where even slight inaccuracies can lead to visible and often irreversible consequences, the importance of accurate implant positioning cannot be overstated.

The evidence reviewed in this article consistently points toward the superior accuracy of guided techniques, whether through static guides, dynamic navigation, or emerging robotic systems. These approaches not only improve linear and angular placement metrics but also enhance soft tissue outcomes, reduce the likelihood of prosthetic complications, and contribute to overall esthetic harmony. Importantly, they also offer benefits for both clinicians and patients in terms of workflow efficiency, confidence in execution, and treatment acceptance.

That said, guided surgery is not a one-size-fits-all solution. Its effectiveness depends on multiple factors data quality, planning accuracy, guide stability, and the clinician's familiarity with digital systems. It also presents challenges related to cost, learning curve, and potential technical failures. Therefore, the role of the clinician remains central. Digital tools are most valuable when they enhance rather than replace surgical expertise and clinical judgment.

Looking ahead, the integration of robotics, artificial intelligence, and real-time navigation offers exciting possibilities. These innovations may not only improve accuracy further but also democratize access to high-level care by making advanced workflows more intuitive and accessible.

In the end, the decision between guided and freehand techniques should be based on a thoughtful assessment of the case at hand, the esthetic demands, and the tools available always with the patient's best outcome in mind.

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