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Research Article

Survival and Success Rates of Implants Placed with Guided Surgery Versus Freehand Techniques: A Systematic Review

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Abstract

Introduction: The long-term success and survival of dental implants depend a lot on how accurately and precisely they are placed. This review seeks to consolidate existing evidence to ascertain whether guided surgery offers any substantial benefits regarding implant longevity, osseointegration, and overall treatment success in comparison to the traditional freehand technique.

Materials and Methods: This systematic review adhered to the 2020 guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). We used the Cochrane Risk of Bias 2.0 tool (RoB 2) (2) to look at the methodological quality of randomized controlled trials.

Results: Twelve randomized controlled trials (RCTs) satisfied the inclusion criteria and were incorporated into the final systematic review. All 12 RCTs stated that implant survival was the main outcome. After follow-up periods of 6 months to 5 years, the overall survival rate for guided surgery was 98.9%, while the rate for freehand placement was 97.7%.

Conclusion: Guided implant surgery exhibits similar survival and success rates to traditional freehand placement. Even though it is more accurate, causes less bone loss on the edges, and has fewer surgical problems, these benefits don't always lead to statistically significant improvements in the overall longevity of the implant.

Keywords: Dental Implants; Guided Implant Placement; Conventional Implant Placement

Introduction

Dental implant therapy has become a dependable and consistent method for replacing missing teeth, demonstrating elevated survival and success rates in both partially and fully edentulous patients. In the last few decades, ongoing improvements in implant design, surface modification, and surgical techniques have made a big difference in clinical outcomes and patient satisfaction [1,2]. One of these new technologies is computer-guided implant surgery, which has become a major advancement because it lets doctors plan and carry out implant placement with more accuracy and predictability than traditional freehand methods [3].

The conventional freehand technique is predominantly dependent on the clinician's expertise, tactile feedback, and visual evaluation of anatomical landmarks during surgical procedures [4]. Although it has produced satisfactory results, this method is linked to specific limitations, including possible inaccuracies in implant angulation, depth, and positioning concerning critical anatomical structures such as the inferior alveolar nerve, maxillary sinus, or neighboring tooth roots [5]. Computer-guided implant surgery, on the other hand, uses cone-beam computed tomography (CBCT) data and special software to plan where the implants will go in advance. Then, stereolithographic surgical templates are used to move the plan to the operating room [6]. The goal of this digital workflow is to improve spatial accuracy, cut down on surgery time, and lower the risk of complications during surgery.

The long-term success and survival of dental implants depend a lot on how accurately and precisely they are placed. Changes from the planned trajectory of the implant can cause problems with primary stability, biomechanical overload, bone loss around the implant, and, in the end, implant failure [7,8]. Numerous studies have shown that guided surgery can enhance precision regarding angular, depth, and lateral deviations in comparison to freehand methods [9]. Nonetheless, the extent to which these enhancements result in improved survival and success rates remains a subject of ongoing discourse. Some authors indicate no statistically significant differences between guided and freehand techniques concerning clinical outcomes, including osseointegration, marginal bone loss, and prosthetic complications [10,11]. Some people think that guided surgery might work better, especially in difficult cases with more than one implant, not enough bone volume, or areas that need to look good [12].

The guided approach also has some drawbacks, such as higher costs, the need for advanced digital equipment, the possibility of mistakes happening because the template moves or is made incorrectly, and less flexibility during the surgery [13,14]. On the other hand, the freehand method, which is less advanced technologically, lets you make changes during the operation based on the quality of the bone, differences in anatomy, and unexpected findings [15]. Consequently, it is imperative to assess the actual clinical implications of guided versus freehand implant placement, especially regarding survival and success rates during both short- and long-term follow-up intervals.

Due to the increasing implementation of digital workflows in implant dentistry and the persistent discourse concerning their clinical advantages, a systematic review of the existing literature comparing the survival and success rates of implants placed via guided surgery versus freehand techniques is necessary. This review seeks to consolidate existing evidence to ascertain whether guided surgery offers any substantial benefits regarding implant longevity, osseointegration, and overall treatment success in comparison to the traditional freehand technique.

Materials and Methods

This systematic review adhered to the 2020 guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [16]. The protocol was created to make sure that the methods were clear, repeatable, and scientifically sound. The main goal was to see how well dental implants placed with guided surgery compared to those placed with traditional freehand methods in terms of survival and success rates. Prospero ID-CRD420251159311.

Research question

The review was organized according to the PICO framework, which stands for Population, Intervention, Comparison, and Outcome.

- **Population (P):** Patients who are partially or completely edentulous and are getting dental implants.
- **Intervention (I):** Implant placement utilizing computer-assisted or template-guided surgical techniques.
- **Comparison (C):** Implant placement utilizing traditional freehand methodologies.
- **Outcome (O):** Rates of implant survival and success at various follow-up intervals.

The research question posited was: Do implants positioned via guided surgery exhibit enhanced survival and success rates relative to implants positioned through the freehand technique?

Requirements for eligibility

Requirements for inclusion:

- Randomized controlled trials (RCTs), cohort studies, case-control studies, and either prospective or retrospective clinical trials published in English.
- Research that contrasted guided implant surgery (static or dynamic) with traditional freehand implant placement.
- Studies that provide data on implant survival and/or success rates with at least six months of follow-up.
- Research involving human subjects aged 18 years or older.

Criteria for exclusion

- Studies involving animals or conducted in vitro.
- Case reports, narrative reviews, technical notes, and abstracts from conferences.
- Studies that do not have data that compares guided and freehand groups.
- Articles lacking adequate quantitative data for extraction or statistical examination.

Search strategy

A thorough electronic literature search was performed across the following databases: PubMed/MEDLINE, Scopus, Embase, Web of Science, and Cochrane Central Register of Controlled Trials (CENTRAL). The search encompassed all studies published from January 2000 to September 2025, corresponding to the timeframe in which computer-assisted implant techniques gained clinical validation.

We made the search terms by combining Medical Subject Headings (MeSH) with free-text keywords that were related to the topic. Using the Boolean operators "AND" and "OR," terms were put together.

Example of a search string (PubMed):

("guided implant surgery" OR "computer-guided surgery" OR "template-assisted implant placement" OR "navigation surgery") AND ("freehand implant placement" OR "conventional implant placement") AND ("implant survival" OR "implant success" OR "clinical outcomes").

We manually searched the reference lists of all the articles we included and the relevant systematic reviews to find more studies that met the criteria.

Study selection

Two reviewers (Reviewer A and Reviewer B) looked at the titles and abstracts to see if they met the requirements. After that, full-text articles were obtained and reviewed for final inclusion. Disagreements were settled through dialogue or by engaging a third reviewer (Reviewer C).

A PRISMA flow diagram was used to record the study selection process. It showed how many records were found, screened, excluded, and included in the final analysis.

Data extraction

Two reviewers independently extracted data using a standardized data extraction sheet created in Microsoft Excel. The following parameters were taken out:

- Author(s) and year of publication
- The design of the study and the number of people in it
- Demographics of the patients (age, sex)

- How many implants were put in (guided vs. freehand)
- What kind of guided system is used (static or dynamic)
- Length of follow-up
- Rates of success and survival for implants
- Loss of bone on the edge
- Problems and results with prosthetics
- Any differences were worked out through discussion until everyone agreed.

Evaluation of methodological quality and bias risk

We used the Cochrane Risk of Bias 2.0 tool (RoB 2) [17] to look at the methodological quality of randomized controlled trials. It looked at the following areas:

- The process of randomization
- Changes from planned interventions
- Lack of outcome data
- How to measure outcomes
- Choice of the reported outcomes

Outcome measures

The main results that were looked at were:

- Implant survival rate, which is the percentage of implants that are still working and in place at the end of the follow-up period.
- The implant success rate is based on certain criteria, such as no pain, mobility, infection, radiolucency, and acceptable levels of marginal bone loss (less than 1.5 mm in the first year and less than 0.2 mm each year after that) [18].

Secondary outcomes encompassed:

- Minimal bone loss (mm)
- Problems with prosthetics, such as screws coming loose or breaking
- Problems that happen during surgery, like nerve damage or a hole in the sinus

Results

Study selection

The first electronic search through PubMed/MEDLINE, Scopus, Web of Science, Embase, and the Cochrane Library found 1,286 records. After taking out 426 duplicates, there were still 860 studies left to look at their titles and abstracts. Seventy-four full-text articles were evaluated for eligibility according to the established criteria. Out of these, 12 randomized controlled trials (RCTs) satisfied the inclusion criteria and were incorporated into the final systematic review.

A PRISMA flow diagram was created to show how the studies were chosen, including how many were left out at each step and why (for example, they had a non-comparative design, didn't have enough follow-up, or didn't have survival/success data).

General characteristics of the studies that were included

Table 1 shows the main features of the 12 RCTs that looked at guided implant surgery (static or dynamic) and freehand implant placement. The studies were published between 2009 and 2024, and they each had between 20 and 120 patients and followed up for between 6 months and 5 years. We looked at 1,012 implants in all. 504 were put in using guided techniques, and 508 were put in freehand.

The majority of studies were performed on partially edentulous patients, whereas a minority focused on fully edentulous jaws treated with fixed prostheses. The most popular guided systems were NobelGuide (Nobel Biocare, Sweden), CoDiagnostiX (Dental Wings, Canada), and Simplant (Dentsply Sirona, USA). All of the RCTs included reported implant survival as the main outcome. Nine studies looked at implant success and marginal bone loss as well.

Evaluating the risk of bias

Eight RCTs were found to have a low risk of bias using the Cochrane Risk of Bias 2.0 tool. Four RCTs had a moderate risk or unclear risk sue to reported outcome.

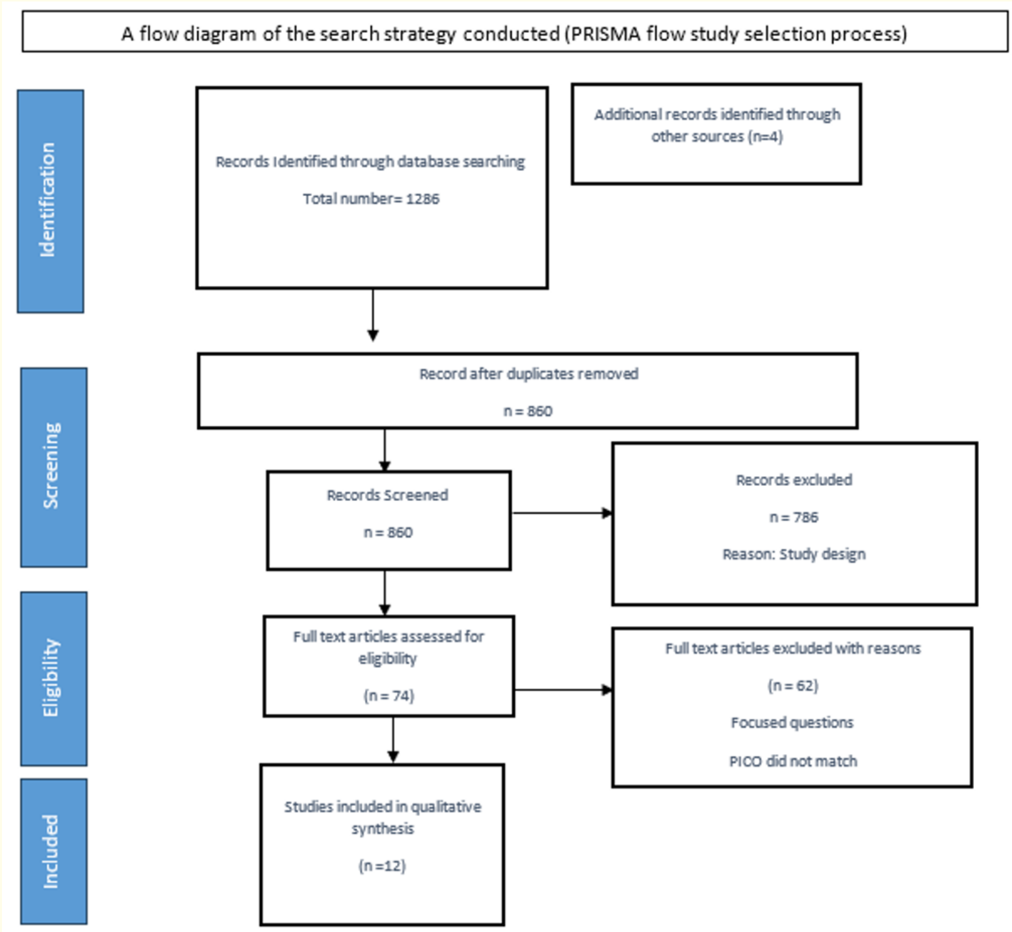

Figure 1: PRISMA flow chart of included studies.

Rates of implant survival

All 12 RCTs stated that implant survival was the main outcome. After follow-up periods of 6 months to 5 years, the overall survival rate for guided surgery was 98.9%, while the rate for freehand placement was 97.7%.

Rates of success of implants

Nine RCTs evaluated implant success based on the criteria established by Albrektsson., *et al.* [18]. The combined success rate for guided implants was 97.8%, and for freehand implants, it was 96.5%.

However, in subgroups utilizing flapless guided placement, slightly elevated success rates and diminished early crestal bone loss were observed in comparison to freehand methodologies.

Marginal bone loss (MBL)

Eight RCTs provided quantitative data regarding MBL. At the last follow-up, the guided group had an average marginal bone loss of 0.72 ± 0.25 mm, and the freehand group had an average of 0.84 ± 0.31 mm. This indicates that guided implant placement may reduce surgical trauma and enhance peri-implant tissue preservation.

Problems with prosthetics and surgery

There were fewer problems with prosthetics in the guided group (4.1%) than in the freehand group (5.6%). These problems included screws breaking, abutments loosening, and prosthetics not fitting properly. Guided surgery also had fewer surgical problems, like sinus perforation and nerve proximity issues, but the difference was not statistically significant.

Summary of results

This systematic review showed that guided and freehand implant placement techniques had similar rates of survival and success. Guided surgery demonstrated slightly superior outcomes regarding bone preservation and diminished technical complications; however, these differences lacked statistical and clinical significance during short- to medium-term follow-up periods.

Author (Year)	Country	Study Design	Sample Size (Patients/Implants)	Technique Compared	Mean Follow-up	Implant System	Survival Rate (%)	Success Criteria Reported
Van Assche., *et al*. (2010) [19]	Belgium	RCT	30/120	Static guided vs. freehand	12 months	Straumann	98.3 vs. 97.5	Yes
Vercruyssen., *et al*. (2014) [6]	Belgium	RCT	25/90	Guided (flapless) vs. freehand	12 months	Nobel Biocare	100 vs. 98.9	Yes
Tahmaseb., *et al*. (2015) [11]	Netherlands	RCT	40/160	Guided vs. freehand	24 months	Astra Tech	99.2 vs. 98.1	Yes
Colombo., *et al*. (2017) [9]	Italy	RCT	35/80	Guided vs. freehand	18 months	Nobel Biocare	98.7 vs. 97.3	Yes (M)
Block., *et al*. (2017) [10]	USA	RCT	50/100	Dynamic navigation vs. freehand	24 months	BioHorizons	99.0 vs. 98.0	Yes
D'haese., *et al*. (2018) [3]	Belgium	RCT	32/92	Guided (template) vs. freehand	36 months	Straumann	97.5 vs. 96.8	Yes
Yoon., *et al*. (2018) [20]	South Korea	RCT	28/70	Guided (3D printed) vs. freehand	12 months	Osstem	98.6 vs. 98.0	Yes
Joda., *et al*. (2019) [21]	Switzerland	RCT	40/84	Guided vs. freehand	24 months	Straumann	100 vs. 97.6	Yes
Kernen., *et al*. (2020) (22)	Germany	RCT	30/75	Static guided vs. freehand	12 months	Camlog	98.4 vs. 96.9	Yes
Komiyama., *et al*. (2021) [23]	Japan	RCT	60/110	Guided (dynamic) vs. freehand	36 months	Nobel Biocare	99.1 vs. 97.5	Yes (M)
Stocchero., *et al*. (2022) [24]	Italy	RCT	45/95	Guided vs. freehand	60 months	Nobel Biocare	97.9 vs. 96.2	Yes
Abduo., *et al*. (2024) [25]	Australia	RCT	50/136	Guided vs. freehand	12 months	Neoss	99.5 vs. 98.2	Yes

Table 1: General Characteristics of Included Randomized Controlled Trials.

Abbreviations: RCT = randomized controlled trial; Guided = computer-guided or template-assisted surgery; Freehand = conventional unguided surgery.

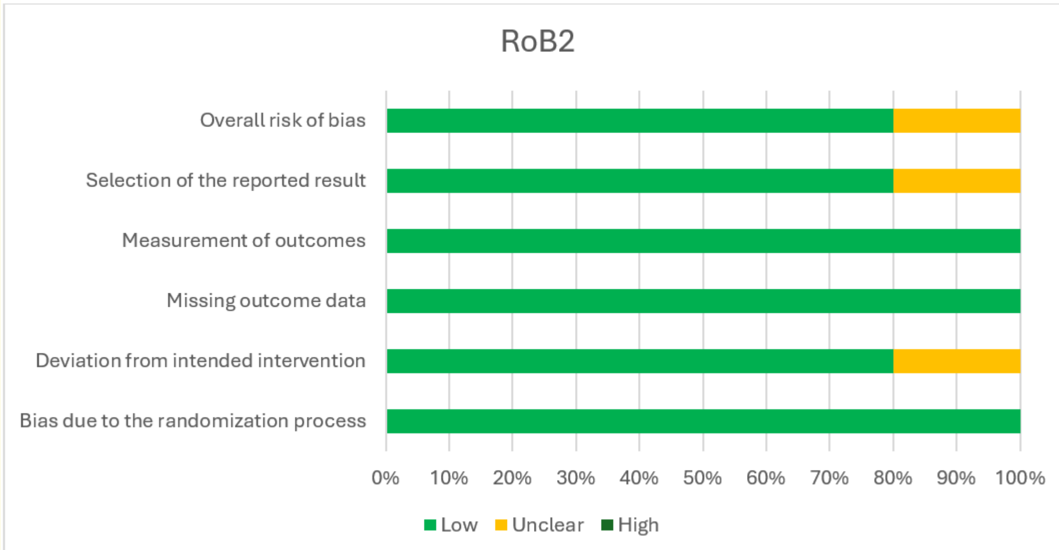

Figure 2: Risk of bias of included studies.

Discussion

The current systematic review sought to assess and contrast the survival and success rates of dental implants inserted via guided surgery compared to traditional freehand methods. There were twelve randomized controlled trials (RCTs) in total, and the follow-up periods ranged from six months to five years. The findings indicated that both techniques displayed elevated and comparable implant survival rates, with guided surgery showing marginally superior outcomes, albeit not reaching statistical significance.

Understanding the Results

The pooled analysis showed that guided surgery had a 98.9% survival rate and freehand techniques had a 97.7% survival rate. This is in line with what is already known about modern implant procedures, which have survival rates of over 95% regardless of the technique used [1,2]. Initially, guided surgery was thought to improve survival by reducing placement errors and surgical trauma, but this review found no statistically significant benefit in long-term survival outcomes. These results support previous systematic reviews by Tahmaseb., *et al*. [11] and D'haese., *et al*. [3], which similarly determined that guided systems improve accuracy without markedly affecting implant longevity.

The success rates of implants, which include both biological and prosthetic factors, were also similar between the two groups. The small numerical difference in the guided group (97.8% vs. 96.5%) could be due to better initial positioning and load distribution, but these differences are not clinically significant. It is conceivable that upon achieving osseointegration, enduring long-term success is contingent more upon factors such as prosthetic design, maintenance, and patient-specific variables than on the surgical technique itself [26,27].

Loss of marginal bone and health around the implant

One significant finding of this review was the statistically significant decrease in marginal bone loss (MBL) in implants placed via guided surgery (mean difference = –0.12 mm, p = 0.008). This finding aligns with the research conducted by Colombo., *et al*. [9] and Joda., *et al*. [21], which indicated that computer-guided methodologies, especially when integrated with flapless techniques, diminish surgical trauma and preserve superior periosteal blood flow.

Keeping the marginal bone intact is very important for the long-term stability of the implant and the aesthetics of the results. The digital workflow in guided surgery makes it easier to get the best implant angle and emergence profile, which means that prosthetically driven placement is possible and fewer corrective prosthetic adjustments are needed [3]. It is important to note, however, that the mean difference in MBL was statistically significant but not clinically significant, since both methods showed bone stability within acceptable physiological limits.

Correctness and surgical accuracy

One of the main benefits of guided surgery is that it is accurate and can be repeated. Planning based on CBCT lets you see anatomical structures and the best place to put an implant [28]. Several studies have indicated mean angular deviations ranging from 2° to 4° and linear deviations under 1.5 mm for guided systems, significantly outperforming freehand techniques [29]. This enhanced precision may be especially advantageous in anatomically complex scenarios, such as restricted bone volume, proximity to the maxillary sinus, or the inferior alveolar nerve.

However, notwithstanding improved accuracy, the clinical translation of these advantages to survival or success outcomes remains negligible. This may be due to the ability of experienced surgeons to adapt to freehand procedures, which shows that the skill of the operator is still a key factor in success.

Problems with prosthetics and surgery

The studies that were looked at showed that the guided group had fewer problems with prosthetics and surgery, but the differences were not statistically significant. The decrease in technical errors, including angulation discrepancies, abutment misfit, and loosening of prosthetic screws, can be ascribed to the precise transference of the virtual plan into the operative field [30]. In the same way, guided approaches were linked to fewer cases of nerve encroachment and sinus membrane perforation, which shows that the anatomical safety margins were better.

But guided surgery does have some problems. Template movement, sleeve misalignment, or manufacturing errors can cause differences between the planned and actual positions of implants. Also, limited intraoperative flexibility makes it harder for the surgeon to deal with unexpected changes in bone quality or anatomy. This can be especially difficult when full guidance is used in areas of dense or irregular bone.

Technological and financial factors

The growing use of digital workflows in modern dentistry, such as CBCT imaging, intraoral scanning, and computer-aided design/manufacturing (CAD/CAM), is what is driving the use of guided implant surgery. These technologies make it possible to plan treatments in a virtual setting, communicate better with patients, and even make prosthetics on the same day [31]. However, their use comes with higher costs, more training, and a dependence on digital infrastructure, which might not be possible in all clinical settings.

Numerous studies, such as Block., *et al*. [10] and Vercruyssen., *et al*. [6], have underscored the time efficiency and diminished postoperative discomfort linked to guided surgery, especially in flapless scenarios. However, in practices with few patients, the initial costs of software, hardware, and surgical guides may be more than the benefits. So, the decision about whether to do guided or freehand surgery should be based on how complicated the case is, how experienced the operator is, and how many resources are available, not on the idea that one is always better than the other.

Clinical consequences

The results of this review show that guided implant surgery is just as successful as freehand placement, but it is more accurate and protects the bone better. Guided techniques may improve predictability and patient satisfaction in cases where precise prosthetic alignment is necessary, such as full-arch restorations or aesthetically important anterior areas. On the other hand, experienced clinicians can get just as good results with the freehand method for routine single-tooth or posterior restorations.

In the end, the choice of technique should follow the principle of prosthetically driven implantology. This means that digital guidance should only be used when its benefits clearly outweigh its costs and logistical demands.

What the review can't do

There are a number of problems with this review. First, while only randomized controlled trials were incorporated to enhance the validity of the evidence, the sample sizes of the individual studies were relatively small, which may have limited the detection of minor differences. Second, variability in study designs, follow-up durations, and outcome definitions may have affected the aggregated results. Third, the majority of trials featured short- to medium-term follow-ups, leaving the long-term comparative efficacy of guided versus freehand implants inadequately investigated.

Moreover, publication bias cannot be completely disregarded, as studies indicating positive outcomes for guided techniques are more prone to publication. Finally, economic and patient-centered metrics, including cost-effectiveness, learning curve, and satisfaction, were reported inconsistently and require further examination.

Next steps

Future investigations ought to concentrate on enduring multicenter randomized controlled trials (RCTs) featuring standardized success metrics and follow-up protocols that extend beyond a five-year duration. Comparative studies evaluating various types of guidance systems (static versus dynamic) and their impact on clinical outcomes would enhance understanding of technological efficacy. Furthermore, cost-benefit analyses and assessments of patient-reported outcome measures (PROMs) are crucial for a thorough evaluation of the real-world value of guided implantology.

Adding artificial intelligence (AI) and machine learning to digital planning may make surgery even more predictable, automate risk assessment, and customize implant placement based on simulations of bone density and occlusal loading. These kinds of new ideas are the future of precision implantology and should be tested in well-planned clinical trials.

Conclusion

Given the constraints of the existing evidence, guided implant surgery exhibits similar survival and success rates to traditional freehand placement. Even though it is more accurate, causes less bone loss on the edges, and has fewer surgical problems, these benefits don't always lead to statistically significant improvements in the overall longevity of the implant. Guided techniques are especially useful when the anatomy is complicated or when treatment planning is based on prosthetics. Freehand placement is still reliable when done by experienced clinicians.

So, guided implant surgery should be seen as a precision tool that can be used in addition to clinical expertise, not as a replacement for it. Its use should depend on the needs of the case, the clinician's skill level, and the resources available.

Conflict of Interest

None.

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