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Precision tissue engineering in implant rehabilitation - A randomized controlled trial

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Abstract:
Implant positioning influences osseointegration, peri-implant tissue health and esthetic outcomes. Therefore, it is of interest to compare the digitally guided and conventional freehand placement in 100 implants, with 50 implants per group. Guided placement achieved lower angular, coronal and apical deviations than freehand placement ($p<0.001$). At 12 months, guided placement showed higher implant stability, lower marginal bone loss, improved peri-implant parameters, greater keratinized mucosa and higher Pink Esthetic Scores ($p\leq0.027$). Thus, guided implants also showed higher survival (98% vs. 92%), supporting precision-guided placement for predictable peri-implant tissue and esthetic outcomes.

Keywords: Guided implant surgery, osseointegration, implant accuracy, peri-implant health, Pink Esthetic Score

Background:
Dental implants provide predictable rehabilitation of edentulous patients, but long-term success depends on accurate three-dimensional positioning and peri-implant tissue stability **[1, 2]**. Computer assisted implant surgery improves positional accuracy compared with freehand placement, supporting prosthetically guided implant positioning **[3]**. Dynamic navigation also provides clinically acceptable accuracy and facilitates precision guided implant placement **[4]**. Peri-implant health is influenced by plaque control and the surrounding soft tissue phenotype, including the width of keratinized mucosa **[5]**. Evidence indicates that ≥2 mm of keratinized tissue is associated with more favorable peri-implant health parameters and reduced tissue complications **[6]**. Implant stability can be objectively monitored using resonance frequency analysis, while esthetic outcomes can be assessed using standardized indices such as the Pink Esthetic Score **[7]**. Therefore, it is of interest to evaluate the guided implant placement improves positional accuracy and translates into better implant stability, peri-implant tissue health and esthetic outcomes compared with conventional freehand placement.

Methodology:
This prospective, parallel-arm, randomized controlled trial was conducted after obtaining Institutional Ethics Committee approval and all participants provided written informed consent after receiving verbal and written study information. One hundred implants were placed in systemically healthy, partially edentulous adults requiring single or multiple implant rehabilitation. Inclusion criteria were adequate residual bone height and width for a prosthetically driven implant, sound physical and mental health and acceptance of the recall schedule. Exclusion criteria were uncontrolled systemic disease, active periodontal disease, para-functional habits and the need for concurrent extensive bone augmentation. Participants were allocated by simple randomization into two groups of 50 implants each. In the guided group, implants were placed using static, fully guided computer-assisted surgery: pre-operative cone-beam computed tomography (CBCT) was merged with an intraoral surface scan, the implant was planned prosthetically in dedicated planning software and a tooth-supported surgical guide was fabricated to control the entire osteotomy and fixture insertion. In the freehand (control) group, implants were placed conventionally using the manufacturer's drilling sequence guided by clinical judgment and the same pre-operative CBCT for planning reference, without a surgical guide. The primary outcome was placement accuracy, assessed by superimposing the postoperative CBCT on the virtual plan and measuring angular deviation (degrees) together with coronal (platform) and apical linear deviation (mm). Secondary outcomes were recorded to capture the biological and esthetic consequences of placement. Implant stability was measured by resonance frequency analysis (ISQ) at placement and at 3, 6 and 12 months. Radiographic marginal bone loss (MBL) was measured at 6 and 12 months. Peri-implant probing depth (PPD), bleeding on probing (BOP, percentage of sites) and the modified Plaque Index (mPI) were recorded and keratinized mucosa width (KMW) and the Pink Esthetic Score (PES, 0–14) were assessed at

12 months. Implant survival was determined at 12 months. Data were analyzed using SPSS. The distribution of each variable was examined with the Shapiro–Wilk test. Normally distributed continuous variables were compared between groups using the independent t-test and non-normally distributed variables using the Mann–Whitney U test; within-group change in stability was assessed with the paired t-test. Categorical variables (gender, smoking, survival) were compared using the chi-square or Fisher exact test. The level of significance was set at $p < 0.05$.

Results:

The two groups were comparable at baseline **(Table 1).** Mean age was 52.34 years in the guided group and 51.38 years in the freehand group ($p = 0.687$), with no significant differences in gender distribution ($p = 0.162$) or smoking status ($p = 1.000$) and a similar spread of maxillary/mandibular and anterior/posterior sites. This balance indicates that subsequent differences are attributable to the surgical technique rather than to baseline case mix. Placement accuracy strongly favored guided surgery **(Table 2).** The guided group showed substantially smaller angular deviation (2.57°C versus 7.12°C), coronal deviation (0.86 mm versus 1.46 mm) and apical deviation (1.04 mm versus 1.95 mm); all three differences were highly significant ($p < 0.001$). Guided placement thus reduced angular error by roughly two-thirds relative to freehand placement. Implant stability was consistently higher in the guided group **(Table 3).** Although primary stability at placement was similar (67.92 versus 66.08, $p = 0.059$), the guided group recorded higher ISQ values at 3 months ($p = 0.033$) and 12 months ($p = 0.027$). Both groups gained stability from placement to 12 months (paired increase of 6.03 ISQ units in the guided group and 5.39 in the freehand group, $p < 0.001$), confirming progressive secondary stabilization in each arm. Hard-tissue and peri-implant probing outcomes favored guided placement **(Table 4).** Marginal bone loss was lower in the guided group at both 6 months (0.43 mm versus 0.67 mm) and 12 months (0.62 mm versus 0.94 mm) and probing depth was shallower at both time points (all $p < 0.001$). Soft-tissue inflammation followed the same pattern **(Table 5),** bleeding on probing and the modified Plaque Index at 12 months were significantly lower in the guided group ($p < 0.001$), indicating a cleaner, less inflamed peri-implant environment. Soft-tissue quality and esthetics were also superior after guided placement **(Table 6).** Keratinized mucosa width was greater in the guided group (2.87 mm versus 2.38 mm, $p = 0.008$) and the Pink Esthetic Score was markedly higher (11.78 versus 9.84, $p < 0.001$). Implant survival at 12 months was 98% in the guided group and 92% in the freehand group **(Table 7);** the numerical difference (one versus four failures) did not reach statistical significance in this sample ($p = 0.362$).

Table 1: Baseline demographic and site characteristics of the two groups

Variable	Guided (n = 50)	Freehand (n = 50)	p-value
Age (years), mean ± SD	52.34 ± 10.90	51.38 ± 12.81	0.687
Male, n (%)	21 (42%)	29 (58%)	0.162
Female, n (%)	29 (58%)	21 (42%)	–
Smokers, n (%)	16 (32%)	15 (30%)	1
Maxilla / Mandible, n	31 / 19	24 / 26	–
Anterior / Posterior, n	17 / 33	18 / 32	–

Independent t-test (age) and chi-square test (categorical variables); groups comparable at baseline.

Table 2: Implant placement accuracy (deviation between planned and placed position)

	Guided (mean ± SD)	Freehand (mean ± SD)	Difference	p-value
Angular deviation (°C)	2.57 ± 0.93	7.12 ± 2.36	-4.55	<0.001*
Coronal deviation (mm)	0.86 ± 0.27	1.46 ± 0.44	-0.6	<0.001*
Apical deviation (mm)	1.04 ± 0.29	1.95 ± 0.61	-0.91	<0.001*

*Independent t-test; * indicates a significant difference at $p \leq 0.05$. Lower values indicate greater accuracy.*

Table 3: Implant stability quotient (ISQ) by resonance frequency analysis over time

Time point	Guided (mean ± SD)	Freehand (mean ± SD)	p-value
At placement	67.92 ± 4.82	66.08 ± 4.83	0.059
3 months	70.36 ± 5.84	67.74 ± 6.31	0.033*
6 months	72.74 ± 5.78	70.45 ± 5.82	0.052
12 months	73.95 ± 5.67	71.47 ± 5.37	0.027*

*Independent t-test; * indicates a significant difference at $p \leq 0.05$. Higher ISQ indicates greater stability.*

Table 4: Marginal bone loss and peri-implant probing depth

Parameter	Guided (mean ± SD)	Freehand (mean ± SD)	p-value
Marginal bone loss – 6 months (mm)	0.43 ± 0.15	0.67 ± 0.25	<0.001*
Marginal bone loss – 12 months (mm)	0.62 ± 0.18	0.94 ± 0.29	<0.001*
Probing depth – 6 months (mm)	2.73 ± 0.47	3.36 ± 0.48	<0.001*
Probing depth – 12 months (mm)	2.54 ± 0.48	3.17 ± 0.55	<0.001*

*Independent t-test; * indicates a significant difference at $p \leq 0.05$. Lower values are more favorable.*

Table 5: Peri-implant soft-tissue inflammation

Parameter	Guided (mean ± SD)	Freehand (mean ± SD)	p-value
Bleeding on probing – 6 months (%)	15.56 ± 6.92	24.84 ± 11.03	<0.001*
Bleeding on probing – 12 months (%)	14.45 ± 7.98	23.47 ± 9.96	<0.001*
Modified Plaque Index – 12 months	0.63 ± 0.39	1.10 ± 0.55	<0.001*

*Independent t-test; * indicates a significant difference at $p \leq 0.05$.*

Table 6: Keratinized mucosa width and Pink Esthetic Score at 12 months

Parameter	Guided (mean ± SD)	Freehand (mean ± SD)	p-value
Keratinized mucosa width (mm)	2.87 ± 0.74	2.38 ± 1.01	0.008*
Pink Esthetic Score (0–14)	11.78 ± 1.40	9.84 ± 1.87	<0.001*

*Independent t-test (KMW) and Mann–Whitney U test (PES); * indicates a significant difference at $p \leq 0.05$. Higher values are more favorable.*

Table 7: Implant survival at 12 months

Outcome	Guided (n = 50)	Freehand (n = 50)	p-value
Survived, n (%)	49 (98%)	46 (92%)	0.362
Failed, n (%)	1 (2%)	4 (8%)	–

Fisher exact test; the difference did not reach statistical significance in this sample.

Discussion:

Static guided surgery substantially improved implant positioning, with lower angular, coronal and apical deviations than freehand placement, consistent with evidence showing

greater accuracy with computer assisted implant surgery **[8].** The reduced positional error supports the value of prosthetically driven guides for achieving reproducible implant placement **[9].** Guided implants also demonstrated higher ISQ values during follow-up, suggesting improved secondary stability. Resonance frequency analysis provides a reliable non-invasive method for monitoring changes in implant stability during osseointegration **[10].** The guided group showed lower marginal bone loss, probing depth, bleeding on probing and plaque scores, indicating more favorable peri-implant tissue conditions. These parameters are clinically relevant for monitoring peri-implant health and inflammatory disease progression **[11]**. Greater keratinized mucosa in the guided group may have contributed to improved soft-tissue stability and plaque control. Recent evidence supports an association between adequate keratinized tissue and more favorable peri-implant clinical parameters **[12]**. The higher Pink Esthetic Score further indicates improved peri-implant soft tissue esthetics following guided placement. Implant position, emergence profile, papillary architecture and peri-implant mucosal characteristics are important determinants of esthetic outcomes **[13, 14]**. Although implant survival was numerically higher with guided placement (98% vs. 92%), the difference was not statistically significant. This may reflect the limited sample size and short follow-up, as survival is a relatively insensitive endpoint compared with continuous measures such as positional deviation, bone loss and esthetic scores **[15, 16]**. The findings should be interpreted considering the single center design, 12 month follow-up, limited power for survival analysis and inability to blind operators to surgical technique. Larger multi-center trials with longer follow-up and patient reported outcomes are required to determine whether the early biological and esthetic advantages of guided placement translate into superior long term implant and prosthetic outcomes **[17, 18].**

Conclusion:

Static guided implant surgery provided greater placement accuracy and was associated with improved implant stability, peri-implant tissue health and esthetic outcomes at 12 months. Implant survival was numerically higher with guided placement but did not differ significantly between groups. Thus, data support precision guided, prosthetically driven implant placement for more predictable biological and esthetic rehabilitation.

References:

[1] James JR *et al. Cureus*. 2025 **17**:e90380. [PMID: 40970042]
[2] Zhang Z *et al. BMC Oral Health*. 2025 **25**:345. [PMID: 40050830]
[3] Werny JG *et al. Int J Implant Dent.* 2025 **11**:35. [PMID: 40314873]
[4] Younis H *et al. Head Face Med*. 2024 **20**:30. [PMID: 38745297]
[5] Nayyar A *et al. Oral Sphere J. Dent. Health Sci.* 2026 **2**:47. [DOI: 10.63150/osjdhs.2026.08]
[6] Jankowski T *et al. J Clin Med.* 2024 **13**:3501. [PMID: 38930030]
[7] Sanchez-Perez A *et al. Sci Rep*. 2021 **11**:20024. [PMID: 34625591]
[8] Banerjee S *et al. J Indian Prosthodont Soc*. 2025 **25**:22. [PMID: 40654119]
[9] Chackartchi T *et al. Periodontol 2000*. 2022 **88**:64. [PMID: 35103317]
[10] Mangalekar SB *et al. Bioinformation*. 2025 **21**:2807. [PMID: 41393422]
[11] de Tapia B *et al. Clin Implant Dent Relat Res*. 2026 **28**:e70138. [PMID: 41873754]
[12] ElNahass H *et al. Int J Implant Dent.* 2026 **12**:39. [PMID: 42533208]
[13] Lops D *et al. J Clin Med*. 2022 **11**:6243. [PMID: 36362471]
[14] Patel R *et al. Dent J (Basel).* 2023 **11**:218. [PMID: 37754338]
[15] Das B *et al. Ann Surg Oncol*. 2026 **33**:1007. [PMID: 41131389]
[16] Meretsky CR *et al. Cureus.* 2024 **16**:e68872. [PMID: 39376883]
[17] Kotsilkov K *et al. Dent J (Basel).* 2025 **13**:483. [PMID: 41149130]
[18] Alexander R & Liu X. *Biomaterials.* 2026 **324**:123491. [PMID: 40505390]

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