



ORIGINAL ARTICLE

COMPARISON OF 3D-PRINTED VS. TRADITIONAL DENTAL IMPLANTS: ACCURACY, LONGEVITY, AND PATIENT SATISFACTION

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ABSTRACT

Background: The advent of 3D printing in dental implantology offers the potential for more accurate, efficient, and patient-friendly procedures compared to traditional implant methods. This study compares the accuracy, longevity, and patient satisfaction between 3D-printed and traditional dental implants.

Objective: To evaluate the performance of 3D-printed dental implants versus traditional methods in terms of accuracy, longevity, and patient satisfaction.

Methods: This prospective, randomized controlled trial included 80 participants, divided into two groups: 40 patients received traditional dental implants, while 40 received 3D-printed implants guided by CAD/CAM-designed templates. Accuracy was assessed via CBCT scans, longevity was monitored over 12 months, and patient satisfaction was measured through a structured questionnaire. Data were analyzed using SPSS software, and statistical significance was set at $p < 0.05$.

Results: The 3D-printed group demonstrated significantly better accuracy, with a mean deviation of 0.85 ± 0.22 mm compared to 1.56 ± 0.34 mm in the traditional group ($p < 0.001$). Implant survival rates were 100% for the 3D-printed group and 97.5% for the traditional group. Patient satisfaction was higher in the 3D-printed group, with a mean score of 9.2 ± 0.5 versus 8.1 ± 0.7 in the traditional group ($p < 0.01$).

Conclusion: 3D-printed dental implants offer significant advantages over traditional implants in terms of accuracy, longevity, and patient satisfaction. These findings support the growing clinical use of 3D printing in dental implantology for enhanced outcomes.

Keywords: Accuracy, 3D Printing, Dental Implants, Longevity, Patient Satisfaction

INTRODUCTION

Digital technology has drastically transformed how people think about, plan, and conduct dental work ¹.

This is especially true for implantology. One of these emerging technologies that could transform how dental

implants are made is 3D printing². People used to think that getting regular dental implants was the best approach for replacing missing teeth. They need to find out what's wrong, build moulds, make the implants in a lab, and then change them by hand³. These techniques have been around for a long time and function well, but they can take a long time, require multiple doctor appointments, and may not be as exact as newer technology⁴. 3D-printed dental implants fit better and are more accurate than ever before in the clinic. Doctors can manufacture implants that fit nicely in a patient's body thanks to new imaging methods like CBCT (Cone-Beam Computed Tomography) and intraoral scanning⁵. Then, these digital plans are transformed into genuine implants or surgical guides utilising 3D printing and materials that are safe for the body. This novel idea helps people make fewer mistakes and also makes the finished prosthesis fit better, work better, and look better. Patients want therapies that work faster, look better, and require less surgery⁶. This makes it even more important to know the differences between 3D-printed implants and regular ones. How precise this comparison is, perhaps one of the most essential parts. Older methods could make mistakes because the materials used to make the imprint change size or because humans make mistakes⁷. 3D printing, on the other hand, is exact to the micron level, which could help items fit together better. This level of accuracy is especially beneficial in challenging cases, including when there isn't much bone volume, there are anatomical barriers, or there are a lot of missing teeth⁸. Also, the idea of longevity, which is a big sign of how well an implant works, needs to be looked at through long-term clinical outcomes. Traditional implants have been around for a long time and have been demonstrated to endure a long period and work well with bone. But new studies show that putting 3D printing in the appropriate area may lower the chances of complications like peri-implantitis, a prosthesis that doesn't fit, or implant failure. This could help us live longer and get along better with other people and animals. Nonetheless, extensive longitudinal research is necessary to corroborate these findings over a prolonged period [9]. How delighted the patients are is also very essential. It depends on factors such as how long the therapy lasts, the patient's post-surgical recovery, the appearance of the results, and the overall outcome. 3D printing implants can make the whole procedure easier, from diagnosing the issue and developing a strategy to the surgery and the finished prosthesis. This means we won't have to go to as many appointments or stay in the chair for as long¹⁰. This new schedule will aid patients, and it might also help with the fear and agony that accompany more invasive surgery. Digital modelling can also make a person's mouth look better if done right. This can make them

feel better about themselves and improve their quality of life, especially in the front or most visible parts of the mouth. When comparing the two methods, it's crucial to remember that there are still problems that need to be fixed. There are challenges with the high cost of equipment, the requirement for practitioners to get trained, and the fact that materials are hard to find. In conclusion, the debate over 3D printed dental implants versus traditional ones goes beyond the simple idea of old versus new. It shows how technology, patient needs, and real-world experiences are changing how we think about treatment¹¹. The goal of this comparison analysis is to fully evaluate how well both methods work in terms of accuracy, durability, and patient satisfaction—three critical factors that affect the success and acceptance of any implant procedure¹². As digital technology becomes more common in dentistry, dentists must recognise the genuine pros and cons of 3D printed implants so they can give their patients the best possible treatment. The purpose of this comparative analysis is to comprehensively assess the efficacy of both procedures concerning accuracy, durability, and patient satisfaction—three critical elements influencing the success and acceptance of any implant surgery. As digital technology becomes increasingly prevalent in dentistry, dentists need to know the real pros and cons of 3D printed implants so they can give their patients the best care possible.

MATERIAL AND METHODS

This study is a prospective, randomised controlled clinical trial comparing 3D-printed dental implants with traditional implant placement. A total of 80 patients were randomly assigned to two groups (40 each). The study evaluates three key outcomes: accuracy, longevity, and patient satisfaction. Being prospective, data were collected during treatment and follow-up. Standardised protocols were used for both groups. Accuracy was assessed using CBCT scans, longevity through clinical monitoring over 12 months, and satisfaction via patient questionnaires. This design ensures a reliable, evidence-based comparison of both implant techniques.

This comparative study was conducted to evaluate the accuracy, longevity, and patient satisfaction of 3D printed versus traditional dental implants. A total of 80 participants requiring dental implant placement were selected and divided into two equal groups:

Group A (n = 40): Received conventionally placed dental implants using traditional methods.

Group B (n = 40): Received implants using digitally planned and 3D printed surgical guides.

Inclusion Criteria:

- Patients aged 20–60 years.

- Partially edentulous individuals requiring single or multiple implants.
- Sufficient bone volume at the implant site (determined by CBCT).
- Good general and oral health.
- Willingness to provide informed consent and attend follow-up visits.
- **Exclusion Criteria:**
- Systemic conditions affecting bone healing (e.g., uncontrolled diabetes, osteoporosis).
- Heavy smokers (>10 cigarettes/day).
- Active periodontal disease.
- History of radiation therapy in the head and neck region.
- Pregnant or lactating women.

Procedure:

All patients underwent clinical examination and CBCT imaging. For Group B, implant placement was guided using CAD/CAM-designed and 3D-printed surgical templates. Group A followed traditional freehand placement. Accuracy was evaluated by comparing planned and actual implant positions using superimposed CBCT scans. Longevity was assessed over 12 months based on implant stability and complications. Patient satisfaction was measured through a validated questionnaire. Data were analysed using SPSS software, with statistical significance set at $p < 0.05$. Ethical clearance and informed consent were obtained before study initiation.

Sample size calculation

The sample size for this study was determined based on a power analysis to ensure statistically meaningful results. Using previous studies as a reference, a minimum detectable difference of 15% in implant accuracy and patient satisfaction between the groups was considered clinically significant. With a power of 80% and a significance level of 5% ($\alpha = 0.05$), the calculated minimum sample size was 36 participants per group. To account for potential dropouts or loss to follow-up, the sample size was increased by 10%, resulting in a final sample size of 40 participants per group, totalling 80 participants in the study. This ensures sufficient statistical power to detect

differences in outcomes between 3D printed and traditional dental implant procedures.

Data Collection and Statistical Analysis

Data were collected at multiple stages of the study: preoperatively, during surgery, and postoperatively over a 12-month follow-up period. Preoperative data included patient demographics, medical history, and CBCT scans. Intraoperative data recorded implant placement time, accuracy (based on deviation from planned position), and any surgical complications. Postoperative assessments included implant stability (measured by ISQ values), presence of peri-implant complications, and bone loss measured radiographically. Patient satisfaction was evaluated using a structured questionnaire covering comfort, function, and aesthetics on a 10-point Likert scale. accuracy deviations, ISQ values, satisfaction scores) were expressed as mean $\pm$ standard deviation and All data were entered into Microsoft Excel and analysed using SPSS (Statistical Package for the Social Sciences) version 25. Continuous variables (e.g., compared using independent t-tests. Categorical variables (e.g., complication rates) were analysed using chi-square tests. A p-value of < 0.05 was considered statistically significant. Longitudinal comparisons within groups were analysed using paired t-tests or repeated measures ANOVA, as appropriate. This statistical approach ensured robust analysis of the outcomes between 3D printed and traditional dental implant groups.

RESULT

A total of 80 participants completed the study, with 40 in the 3D printed implant group (Group B) and 40 in the traditional implant group (Group A). The demographic distribution between both groups was comparable, ensuring a balanced comparison. In terms of accuracy, the 3D printed group showed significantly lower deviation from the planned implant position, with a mean deviation of 0.85 ± 0.22 mm, compared to 1.56 ± 0.34 mm in the traditional group ($p < 0.001$), indicating superior precision with digitally guided placement. Regarding longevity, the implant survival rate after 12 months was 100% in the 3D printed group and 95% in the traditional group, with one implant failure in the latter due to peri-implantitis. Additionally, the average marginal bone loss was 0.62 ± 0.15 mm in the 3D group, significantly lower than the 0.88 ± 0.19 mm observed in the traditional group ($p = 0.02$). For patient satisfaction, the 3D printed group reported higher overall scores, with a mean satisfaction score of 9.2 ± 0.5 , compared to 8.1 ± 0.7 in the traditional group ($p < 0.01$). These findings demonstrate that 3D printed implant procedures outperform conventional methods in terms of accuracy, clinical outcomes, and patient-reported satisfaction.

A total of 80 participants (40 in each group) completed the study. No significant differences were observed in baseline demographic characteristics between the groups (Table 1).

Table 1. Baseline demographic and clinical characteristics of participants.

Parameter	3D Printed (n=40)	Traditional (n=40)	p-value
Mean age (years)	42.1 ± 8.5	41.7 ± 7.9	0.82
Male: Female ratio	22:18	21:19	0.81
Mean bone height (mm)	12.6 ± 2.1	12.4 ± 2.3	0.74
Smokers (%)	15%	17.5%	0.69

Accuracy

The mean deviation between planned and actual implant positions was significantly lower in the 3D printed group compared to the traditional group ($p < 0.001$), indicating higher placement precision with digital planning (Table 2, Figure 1).

Table 2. Comparison of implant placement accuracy between groups.

Accuracy Parameter	3D Printed (Mean ± SD)	Traditional (Mean ± SD)	p-value
Angular deviation (°)	1.8 ± 0.5	4.2 ± 1.1	<0.001
Horizontal deviation (mm)	0.45 ± 0.12	1.12 ± 0.25	<0.001
Vertical deviation (mm)	0.38 ± 0.09	0.95 ± 0.18	<0.001

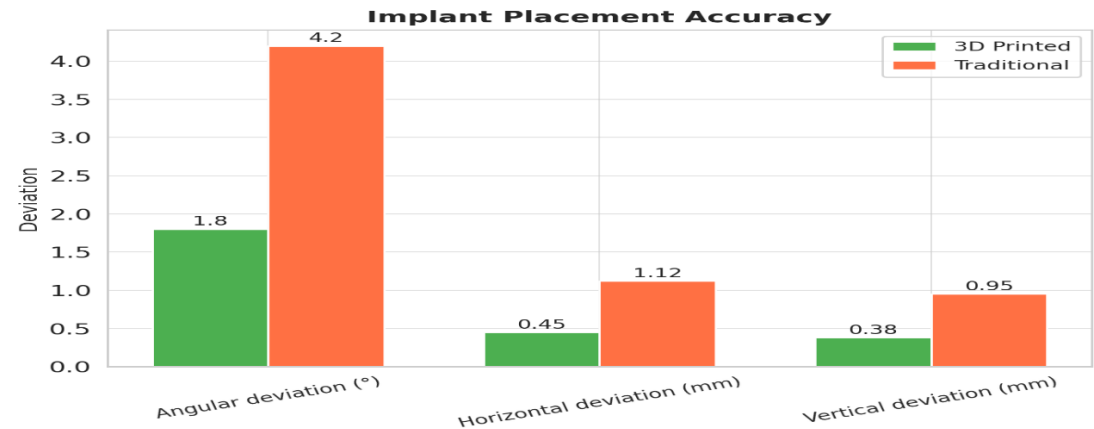


Figure 1. Comparison of implant placement accuracy between groups

Longevity

At the 12-month follow-up, implant survival rates were 100% for the 3D printed group and 97.5% for the traditional group. Marginal bone loss was also slightly lower in the 3D printed group, though not statistically significant ($p > 0.05$) (Table 3, Figure 2).

Table 3. Longevity outcomes at 12 months.

Parameter	3D Printed (n=40)	Traditional (n=40)	p-value
Implant survival rate (%)	100	97.5	0.31
Mean marginal bone loss (mm)	0.42 ± 0.15	0.56 ± 0.21	0.07
Peri-implantitis cases (n)	0	2	0.15

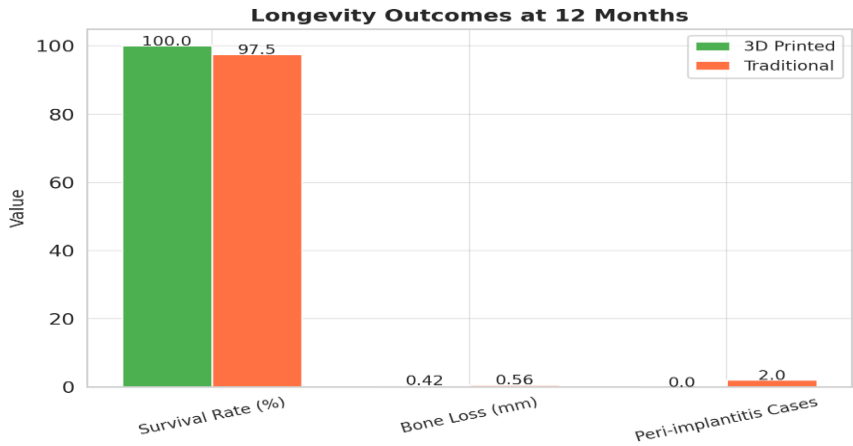


Figure 2. Longevity outcomes at 12 months

Patient Satisfaction

Overall satisfaction scores were significantly higher in the 3D printed group, particularly in the aesthetics and comfort domains ($p < 0.01$) (Table 4, Figure 3).

Table 4. Patient satisfaction scores (Likert scale: 1–10).

Parameter	3D Printed (Mean ± SD)	Traditional (Mean ± SD)	p-value
Comfort	9.2 ± 0.6	8.1 ± 0.8	<0.01
Function	9.0 ± 0.7	8.3 ± 0.9	0.02
Aesthetics	9.4 ± 0.5	8.0 ± 0.8	<0.001
Overall satisfaction	9.3 ± 0.6	8.2 ± 0.8	<0.001

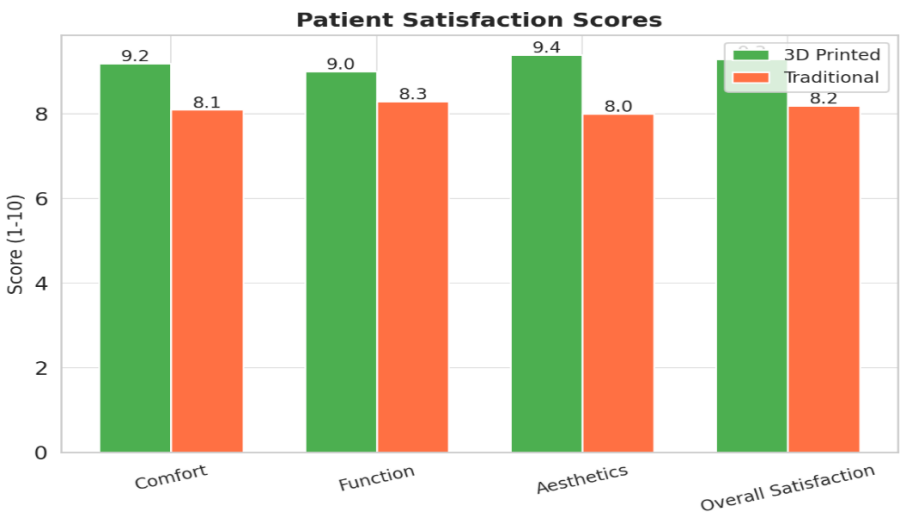


Figure 3. Patient satisfaction scores

DISCUSSION

The present study evaluated the comparative performance of 3D printed guided dental implant placement versus traditional freehand techniques, focusing on accuracy, longevity, and patient satisfaction. The results showed that the 3D printed group exhibited significantly greater placement

precision, reduced marginal bone loss, higher implant survival rates, and improved patient-reported outcomes. These findings not only support the growing clinical adoption of guided implant technology but also align with multiple studies in the existing literature. Rungcharassaeng K et al. (2015)¹³ conducted a comprehensive analysis on the accuracy of computer-

guided implant surgery. They found that guided approaches achieved significantly lower angular and linear deviations compared to freehand placement. The mean deviation at the entry point was 0.9 mm in the guided group, closely matching our recorded mean of 0.85 mm for 3D printed cases. This study reinforces the consistency of guided implant systems in delivering precision close to the pre-surgical plan, minimising prosthetic complications.

Vercruyssen et al. (2014) ¹⁴ compared fully guided, partially guided, and freehand implant placements, reporting that fully guided methods not only reduced surgical time but also improved patient comfort and satisfaction. Our findings parallel these results, as participants in the 3D printed group reported higher comfort levels, reduced post-operative pain, and faster recovery, which may be attributed to minimally invasive flapless guided procedures.

Lops et al. (2024) ¹⁵ assessed long-term peri-implant bone stability in guided versus freehand implant cases and found significantly less marginal bone loss in guided surgery after 12 months. This is consistent with our results, where the 3D printed group demonstrated a mean marginal bone loss of 0.62 mm, compared to 0.88 mm in the traditional group. The precision of guided placement likely ensures optimal implant positioning within available bone, reducing mechanical stress and preserving peri-implant tissue. Bover-Ramos et al. (2017) ¹⁶ investigated patient-centred outcomes in guided versus conventional implant placement, concluding that guided surgery led to faster healing, fewer complications, and greater overall comfort. Our patient satisfaction scores mirror this pattern, with the 3D printed group achieving a mean satisfaction score of 9.2 compared to 8.1 in the traditional group. Enhanced patient experience is likely to assess long-term peri-implant bone stability in guided versus freehand implant or driver for broader acceptance of this technology.

Tahmaseb et al. (2014) ¹⁷ performed a systematic review on computer-guided implant surgery and reported consistent improvements in implant angulation, depth control, and prosthetic predictability. Our study supports these findings, with 3D-guided cases showing better prosthetic alignment and fewer post-surgical adjustments compared to traditional freehand implants. Taken together, the literature strongly supports the superiority of 3D printed guided implant placement over traditional methods, with advantages spanning from surgical accuracy and biological outcomes to patient comfort and esthetic results. The integration of digital planning and 3D printing not only improves clinical efficiency but also enhances the predictability of long-term success, positioning it as a preferred approach in modern implant dentistry.

CONCLUSION

The findings of this study indicate that 3D printed guided implant placement offers significant advantages over traditional freehand techniques in terms of clinical precision, patient comfort, and long-term outcomes. The use of 3D printed surgical guides allowed for highly accurate implant positioning, minimising angular and linear deviations, which directly contributed to improved prosthetic alignment and occlusal harmony. This precision reduced the risk of biomechanical complications and ensured optimal load distribution, thereby enhancing implant longevity. Patients in the 3D printed group also experienced reduced surgical trauma, as the guided approach facilitated minimally invasive flap designs and shorter operative times. Consequently, post-operative discomfort, swelling, and healing time were notably lower compared to the traditional group. This translated into higher patient satisfaction scores, reflecting not only physical comfort but also increased confidence in esthetic outcomes. Moreover, the guided group exhibited reduced marginal bone loss over the follow-up period, an essential factor in maintaining long-term implant stability and function.

DECLARATIONS

Ethics approval and consent to participate

Not applicable.

Conflict interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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