Accuracy of teeth supported 3D printed versus CAD/CAM milled surgical guides used for dental implant placement (In-vitro study)

Original Article

Hesham Samy Borg [1] , Mohammed Hassan [2] , Tamer Mohamed Nasr Mostafa [3]

Assistant Professor, Prosthodontics department, Faculty of dentistry, Al-Salam University, Tanta, Egypt.[1] Lecturer, Removable Prosthodontics department, Faculty of dental medicine, King Salman International University, South Sinai, Egypt [2], Assistant Professor, Prosthodontic department, Faculty of dentistry, Tanta University,[3]

ABSTRACT

Statement of problem: The accurately placed dental implant using surgical guides in the exact pre-designed position is multifactorial goal that subjected to different factors including the method of guides manufacturing. Purpose: To evaluate the accuracy of CAD/CAM milled and 3D printed surgical guides Materials and methods. Fifteen identical mandibular Kennedy Class III modifications 1 partially edentulous stone models with missed first molar in both side were selected for the study. Preoperative CBCT of the models were done. Implants were placed virtually at the position of first molars was done. Surgical guides were designed, saved in STL format. Each model was distributed into two main groups with right side and left side according to: Group I: Surgical guides were 3D printed. Group II: Surgical guides were CAD/CAM milled. Implants were installed in the models using surgical guides. Postoperative CBCT scans of the models were done. Preoperative and postoperative scans were superimposed and compared concerning actual implant and virtually planned positions. Measuring three deviation parameters was done between each planned and actual implant positions: apical deviation (mm), Coronal deviation (mm) and angular deviation (°). The distance between the actual and planned points in the x, y, and z-axis were measured. Data were collected and analyzed. Independent t-test was used to compare between the two groups at the level of significance (p value ≤0.05). **Results.** There were no significant differences (P >0.05) between study groups although there was more angular deviation in the 3D printed guides group. **Conclusions.** Both 3D printed and CAD/CAM milled surgical guides have similar accuracy having little deviation from the pre-designed implant position with more advantages related to 3D printed guides because they are cheaper and easier in construction.

CLINICAL IMPLICATIONS Using 3D printed surgical guides is preferable over CAD/CAM milled guides because they are easier in construction and cheaper and have the same accuracy in pre-planned position of dental implants

Key Words: 3d printing, CAD/CAM, surgical guide, dental implant

Received: 2 June 2024, **Accepted:** 10 June 2024.

Corresponding Author: Tamer Mohamed , Assistant Professor, Prosthodontic department, Faculty of dentistry, Tanta University, Tanta, Egypt. **Tel.:** xxxx, **E-mail:** tamer.mostafa@dent.tanta.edu.eg

ISSN: 2090-097X, July 2024, Vol. 15, No. 3

INTRODUCTION:

Accurate positioning of dental implant is important to produce a successful restoration both in esthetic and function,[1] and an inaccurate placement will lead to peri-implantitis.[2] using surgical guides has dramatically increased because guided surgery proved to consume less time and effort and allow more accurate placement than free-hand surgery.[3] Dental procedures have been renovated as digital technology has entered the world of dentistry. Development of extra-oral and intra-oral scanners, CAD/CAM machines and 3D printers, and the introduction of its improved manufacturing shift the paradigm towards the new era of digital workflow.[4,5]

Digital workflow facilitates the transfer of virtual planning to the clinical intervention, allowing less invasive surgical intervention, accurate implant positioning, minimizing postoperative complaint and fabrication of the final prosthetic option before surgical intervention.[6]

From the beginning of preoperative data collection, data overlap, guided template production, to the surgical intervention, multiple factors may have impact on the accuracy of implantation process in the entire process of computer-assisted, template-guided implant surgery.[7]

Discrepancy between the planned and the actual position of the implant resulted from inaccuracy of implant placement using surgical guides may be due to material of fabrication, design, scanning technique, data transmission and fabrication of the surgical guide technique. [8- 12]

CAD/CAM fabricated surgical guides supposed to provide accurate implant position if the manufactured objects are true to the designs. However, a standardized manufacturing process is still a challenge. Comparison of the manufacturing techniques of surgical guides in the literature is still a topic of argument; while it was concluded that milled surgical guides are more accurate than 3D printing guides.[12- 14] Other authors revealed no difference between both types. [15]

DOI:10.21608/OMX.2024.302498.1257

So, the aim of this study is to compare static surgical guides fabricated by 3D printing versus those fabricated with milling machine. The null hypothesis is that there is no effect of manufacturing technique on the accuracy of dental implants placed using surgical guides.

MATERIALS AND METHODS

The calculated sample size was 15 for each group according to power analysis like previous study[16] using G*Power software (v3.1.9.2). The power value was 95%, and the significant α level was 0.05.

Fifteen identical mandibular Kennedy Class-III modification-1 partially edentulous stone models with missed first molar in both side were selected for the study.

Preoperative CBCT scans of the models were made. Scan settings were: 90 KV and 8 mA and voxel size (0.1) mm. (Scanora® 3Dx, Soredex).

DICOM files obtained from CBCT imaging were imported to the OnDemand3D virtual planning software (OnDemand3D, Cybermed Inc). Implants virtually were placed at first molar positions at the center of the distances between second premolars and second molars in both side. Implant positions were then evaluated in the horizontal plane, sagittal plane and the three dimensional rendering. Surgical guides outlines were designed and saved in STL format.

According to the manufactured surgical guides, models were divided into two groups: right side and left side. Group I: 3D printed surgical guides (Fig. 1). Group II: CAD/CAM milled surgical guides (Fig. 2).

Group I: Where surgical guides' STL files were 3D printed using clear Polymethylmethacrylate PMMA acrylic resin (SG100 Surgical Guide Resin E sun, china) using DLP technology in a 3D printer (Form 4, forma lab , USA)

In Group II: Where surgical guides' STL files were milled in (PMMA) acrylic resin disc (NOBILCAM, PMM discs, USA) using a 5-axis milling machine (inLab MC X5, Dentsply , sirona).

Titanium sleeves were fixed to surgical guides by cyanoacrylate resin to control direction and length of the drilling procedures. Surgical guides were checked for fit and stability on the models.

Universal surgical drills were used. Full sequential drilling procedures were performed starting from the pilot drill till the final drill using surgical implant motor (NSK®; Japan) at 900 rpm. Implants (Impla, Mani Shutz) 5.3 mm diameter and 14.5 mm length were screwed in the models using manual torque wrench at 35 Ncm (Fig. 3). Postoperative CBCT scans of the models were made. (Fig. 4)

Pre-operative (virtually planned positions) and postoperative (actual positions) implant scans were superimposed by dedicated algorithm. Three deviation parameters were measured between actual and planned implant positions using the same OnDemand3D software:

1. Coronal deviation in (mm): Vertical or horizontal distances between the mid-axial coronal point of the virtual implant and the actual implant position.
2. Apical deviation in (mm): Vertical or horizontal distances between the mid-axial apical point of the virtual implant and the actual implant position.
3. Angular deviation in degrees (°): Angular differences of the axial position of both planned and actual implant. (Fig. 5).

The distance between the actual and planned points in the x = bucco-lingual, y = mesio-distal, and z = apico-coronal deviation. The 3D deviation was calculated by computer software (Fig. 6 A,B,C)

Statistical analysis

Data were analyzed using SPSS© program (Chicago, IL, USA version 20 for windows). Normal distribution of data were resulted upon Kolmogorov Smirnov test. Independent t-test was used to compare between the two groups. The level of significance was set at (p value ≤0.05).

Figure 1: 3D printed surgical guide

Figure 2: CAD/CAM surgical guide

Figure 3: Implants placed in the proposed planned position.

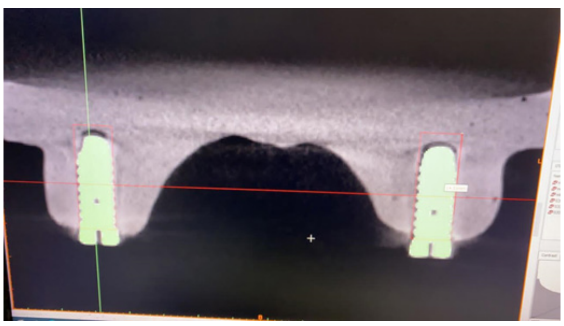

Figure 4: CBCT of model with the implants in place

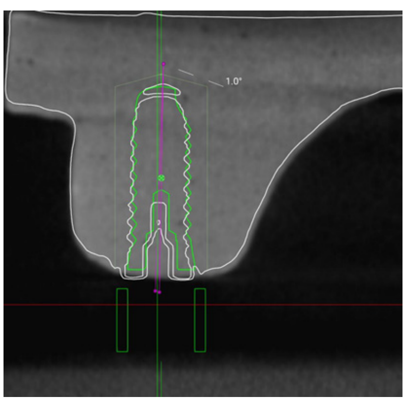

Figure 5: Angular deviation between actual and planned mplant position.

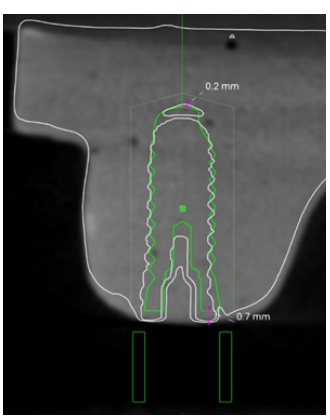

Figure 6-A: Deviation between actual and planned position X-axis.

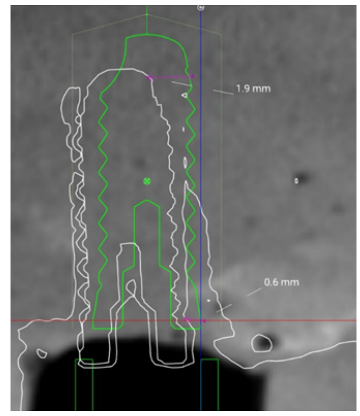

Figure 6-B: Deviation between actual and planned implant position in Y-axis.

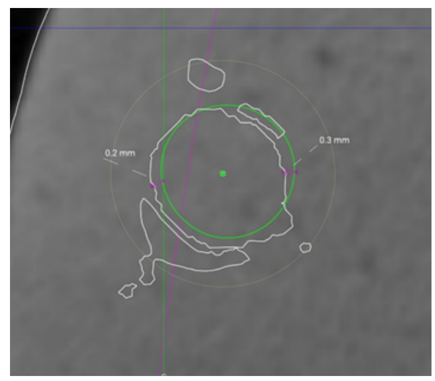

Figure 6-C: Deviation between actual and planned implant position in Z-axis.

RESULTS

The results are shown in tables (1,2) and figures (7-9). It was noted that the deviation in the coronal direction showed higher values in the Y-axis (Bucco-lingual direction) and the small values in the Z-axis (Apical-coronal direction). For the apical direction, the deviation showed high value in X-Axis (Mesial-Distal direction) and low values at Z-axis as seen in coronal direction. Independent t-test showed no significant difference between the two groups in coronal or apical direction for X,Y, and Z axes. Same non-significant results were found for angular deviation values (table 2). This indicate that this shift has no effect on the implant angulation and implies that the clinical behavior of the implant positioned by the two techniques is expected to be the same.

Table 1: Mean. SD of the coronal, apical and angular deviation in X,Y, and Z axes.

Axis		X-Axis		Y-Axis		Z-Axis		Angular Degree Deviation
Direction		Coronal	Apical	Coronal	Apical	Coronal	Apical	
		Mean ± SD						
Group	Prototyping	0.67 ± 0.16	1.92 ± 0.63	1.75 ± 0.46	0.93 ± 0.15	0.53 ± 0.09	0.4 ± 0.01	2.29 ± 0.74
	Milling	0.58 ± 0.18	2.14 ± 1.01	1.49 ± 0.51	1.07 ± 0.4	0.46 ± 0.14	0.38 ± 0.13	1.86 ± 0.58

Table 2: Results of t-Student test of both groups

Axis	Direction	t value	p value
X-Axis	Coronal	2.048	0.17
	Apical		0.7
Y-Axis	Coronal		0.15
	Apical		0.22
Z-Axis	Coronal		0.12
	Apical		0.69
Angle Deviation			0.9

level of significance (P<0.05).

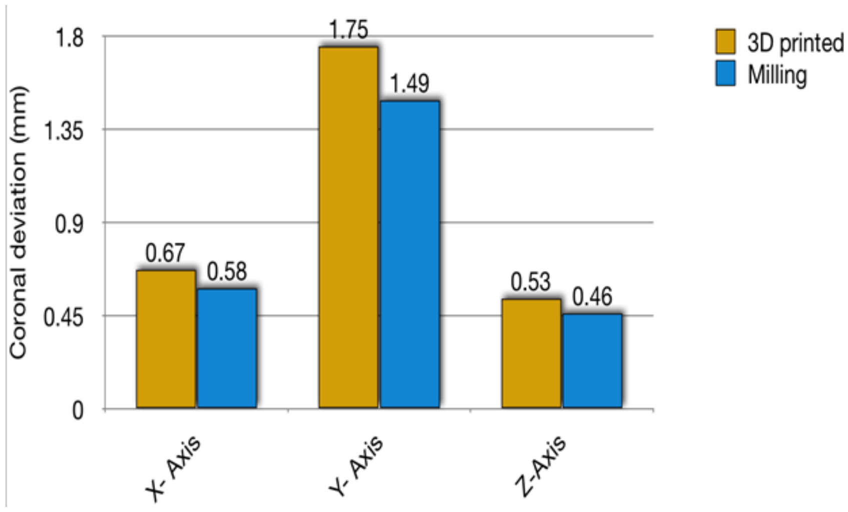

Figure 7: Deviation in coronal direction (mm).

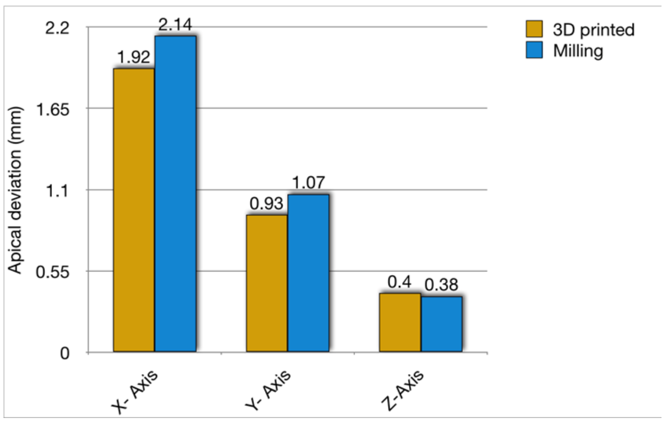

Figure 8: Deviation in apical direction (mm)

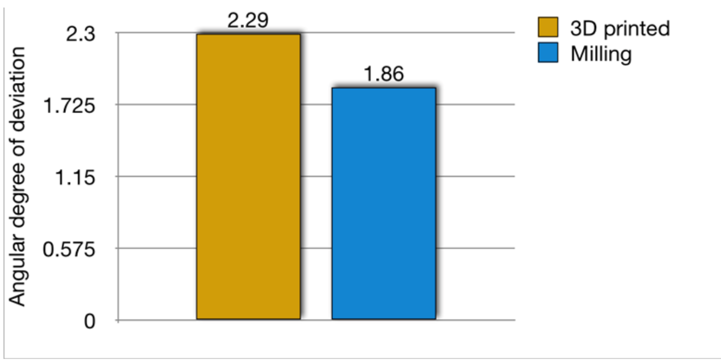

Figure 9: Angular deviation of both groups.

DISCUSSION

Nowadays; guided implant surgeries become feasible treatment option.[17] Since practicing dental implantology is no longer limited to specialists. Instead, general dental practitioners with varying levels of professional skills and expertise can do implantation easier, more efficient and successfully. Although precise fabricated surgical guide with zero deviation from its designed CAD project looks impossible, it is accepted to have a little bit inaccurate manufactured surgical guide, due to the intrinsic tolerance of specific manufacturing processes.[18]

This study purpose was to evaluate two types of surgical guides in terms of their accuracy relative to the initial planning. This evaluation was made through superimposition procedures that allows the three dimensional evaluation of any inaccuracy in implants position. No statistical difference was found between the groups regarding their accuracy. So, the null hypothesis is accepted and suggesting that both the printing and milling manufacturing methods are comparable to use with good reproducibility in guided dental implant surgeries. These results support earlier studies[19-20] but differ than what concluded by Lo Russo L et al; [21] who found that manufacturing technique can affect surgical guides accuracy but they considered the small measured differences of limited clinical significance.

The inaccuracies resulted in lateral and vertical deviations upon superimposition of the actual and planned implants at the apex and platform points was attributed to implant length, axis deviation and sleeve offset.[22]

The slight differences in deviation measurements that were noticed in the printed guides than CAD/CAM milled group can be explained due to brittleness of PMMA. [23] Sometimes, micr-cracks resulted during manufacturing affect the surgical guides accuracy. On the other hand, 3D printing manufacturing was recommended over CAD CAM milling as milling is wasting large amount of raw material, mono-blocks' unused portions will be discarded after milling and no recycling of excess raw material, also, milling drills and tools have short life-time as they are subjected to wear and abrasion. [24]

CONCLUSIONS

Within the current limitations; both 3D printed and CAD/CAM milled surgical guides have similar accuracy with little deviation from the pre-designed implant position. 3D printed guides should be considered superior than CAD/CAM milled guides as they are cheaper, easier in construction and less waste of material of construction.

CONFLICT OF INTEREST

This clinical study was self-funded by the authors, with no conflict of interest.

REFERENCES

1-Tahmaseb A, Wismeijer D, Coucke W, Derksen W. Computer technology applications in surgical implant dentistry: a systematic review. Int J Oral Maxillofac Implants. 2014;29:25–42.

2- Delibasic B, Covani U, Rakic M. Distinguishing predictive profiles for patient-based risk assessment and diagnostics of plaque induced, surgically and prosthetically triggered peri-implantitis. Clin Oral Implants Res. 2016;27:124350-.

3- Abutaleb F, Borg H, Khalifa M, Bader R, Allam M. The accuracy of implant positioning using bone supported versus mucosa supported surgical guide template for implant assisted lower complete overdenture. EDJ. 2017;63:341325-.

4- Mangano F, Mangano C, Margiani B, Admakin O. Combining intraoral and face scans for the design and fabrication of computer-assisted design/computer-assisted manufacturing (cad/cam) polyether-ether-ketone (peek) implant-supported bars for maxillary overdentures. Scanning. 2019;2019: 4274715.

5-Mostafa TM, Elgarba BM, Alam-Eldein AM. Evaluation of retention and attachment wear of cad/cam versus conventional implant-assisted overdenture frameworks. Int J Periodontics Restorative Dent. 2023;43: e43-e51.

6- Kupeyan HK, Shaffner M, Armstrong J. Definitive CAD/CAM-guided prosthesis for immediate loading of bone-grafted maxilla: A case report. Clin Implant Dent Relat Res 2006; 8: 1617-.

7-Arisan, V., Karabuda, C.Z. & Ozdemir, T. Implant surgery using bone- and mucosa-supported stereolithographic guides in totally edentulous jaws: surgical and post-operative outcomes of computer-aided vs. standard techniques. Clinical Oral Implants Research 2010, 2:980–8.

8-Skjerven, H.; Riis, U.H.; Herlofsson, B.B.; Ellingsen, J.E. In vivo accuracy of implant placement using a full digital planning modality and stereolithographic guides. Int J Oral Maxillofac Implant. 2019, 34:124–32.

9-El Kholy, K., Janner, S. F. M., Schimmel, M., Buser, D. The influence of guided sleeve height, drilling distance, and drilling key length on the accuracy of static Computer-Assisted Implant Surgery. Clinical Implant Dentistry and Related Research, 2019,21:101–7.

10- Keßler A, Dosch M, Reymus M, Folwaczny M. Influence of 3D- printing method, resin material, and sterilization on the accuracy of virtually designed surgical implant guides [published online ahead of print, 2021 Feb 8]. J Prosthet Dent. 2021;S00221-30621(20)3913-.

11- Al Yafi F, Camenisch B, Al-Sabbagh M. Is digital guided implant surgery accurate and reliable? Dent Clin North Am. 2019;63:381–97.

12- Marlière DAA, Demètrio MS, Picinini LS, Oliveira RG, Netto HDMC. Accuracy of computer-guided surgery for dental implant placement in fully edentulous patients: a systematic review. Eur J Dent. 2018;12:153–60.

13- Park JM, Yi TK, Koak JY, Kim SK, Park EJ, Heo SJ. Comparison of five-axis milling and rapid prototyping for implant surgical templates. Int J Oral Maxillofac Implants. 2014;29:374–83.

14- Farley NE, Kennedy K, McGlumphy EA, Clelland NL. Split-mouth comparison of the accuracy of computer-generated and conventional surgical guides. Int J Oral Maxillofac Implants. 2013;28:563–72.

15- Bell CK, Sahl EF, Kim YJ, Rice DD. Accuracy of implants placed with surgical guides: thermoplastic versus 3d printed. Int J Periodontics Restorative Dent. 2018;38:113–9.

16- MA, B., Park, T., Chun, I. Yun, K. The accuracy of a 3D printing surgical guide determined by CBCT and model analysis. J Adv Prosthodont. 2018,10,279285-.

17- Derksen W, Wismeijer D, Flügge T, Hassan B, Tahmaseb A. The accuracy of computer-guided implant surgery with tooth-supported, digitally designed drill guides based on CBCT and intraoral scanning. A prospective cohort study. Clin Oral Implants Res. 2019;30:100515-.

18- Yazigi C, Chaar MS, Busch R, Kern M. The Effect of Sterilization on the Accuracy and Fit of 3D-Printed Surgical Guides. Materials (Basel). 2023. 28;16:5305.

19- Mukai S, Mukai E, Santos-Junior JA, Shibli JA, Faveri M, Giro G. Assessment of the reproducibility and precision of milling and 3D printing surgical guides. BMC Oral Health. 2021, 2; 21:1.

20- Henprasert P, Dawson DV, El-Kerdani T, Song X, Couso-Queiruga E, Holloway JA. Comparison of the Accuracy of Implant Position Using Surgical Guides Fabricated by Additive and Subtractive Techniques. J Prosthodont. 2020;29:53441-.

21- Lo Russo L, Guida L, Mariani P, Ronsivalle V, Gallo C, Cicciù M, Laino L. Effect of Fabrication Technology on the Accuracy of Surgical Guides for Dental-Implant Surgery. Bioengineering (Basel). 2023, 24;10:875.

22- Lo Russo L, Ercoli C, Guida L, Merli M, Laino L. Surgical guides for dental implants: Measurement of the accuracy using a freeware metrology software program. J Prosthodont Res. 2023;67:3004-.

23- Avneet Y, Viram U and Kushaldeep. Additive Prototyping in Dentistry- 3D Printing and Selective Laser Sintering. J Dental Sci 2018, 3: 16-.

24- Abduo J, Lau D. Effect of Manufacturing Technique on the Accuracy of Surgical Guides for Static Computer-Aided Implant Surgery. Int J Oral Maxillofac Implants. 2020;35:9318-.