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ACCURACY OF IMPLANT POSITION USING SURGICAL GUIDES FABRICATED BY THREE DIFFERENT ADDITIVE TECHNIQUES: A COMPARATIVE IN VITRO STUDY

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ABSTRACT

Background: Several factors determine the degree of variation in dental implant location following computed tomography-guided surgery. Three-dimensional (3D) printing technologies are commercially available in the market. The influence of different technologies on the accuracy of printed surgical guides is unclear. The fabrication of surgical guides with desktop 3D printers is one such element, although their accuracy has yet to be completely verified. The major goal of this research was to assess the accuracy of implant placement in class I partly edentulous mandibular models utilizing three distinct additive approaches.

Materials and Methods: For the current investigation, 18 mandibular class 1 dentulous casts were established and scanned using CBCT to ensure accurate planning of the eventual implant site. The placements of the implants in the premolar-molar area were digitally planned, and the future surgical guide was developed, and 3D printed utilising three distinct additive techniques: stereolithography (SLA), fused deposition modelling (FDM), and digital light processing. The research participants were separated into three groups. Each set includes six class I partly edentulous mandibular models.

Results: There was a statistically significant difference in implant deviation across the research groups when comparing the intended and final implant positions. The lowest degree of variance was observed for the SLA group, followed by DLP, and lastly, the FDM group, which recorded the highest degree of deviation.

Conclusions: Based on the outcomes of this investigation, we may conclude that stereolithography surgical guides are more accurate than fused deposition modeling and digital light processing.

KEYWORDS: Surgical guide, Stereolithography, Fused Deposition Modeling, Digital Light Processing.

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INTRODUCTION

Osseointegration of dental implants has proved to be predictable, providing competent surgical and prosthetic management.[1] Comprehensive presurgical planning is required for a satisfactory treatment outcoms.[2] This comprises both anatomical and prosthetic considerations to ensure that the implants are accurately positioned. In difficult or challenged instances, conventional periapical and panoramic imaging modalities, along with ocular examination and clinical palpation, may be insufficient to provide optimal presurgical planning.[3] 3D imaging methods have the potential to enhance commonly accessible preoperative radiographs. This can be especially valuable since they give more precise information concerning bone volume, bone quality, or anatomical constraints.[4]

Diagnostic imaging technologies have recently seen significant technical advancements and are now more widely available. The development of computed tomography imaging, notably cone-beam computed tomography (CBCT), enhanced the success of implant-based therapies by allowing for good pre-operative diagnostics with reduced radiation exposure for patients. Using CBCT in conjunction with CAD/CAM allows for virtual and 3D surgical planning, providing practitioners with a realistic view of the patient's bony anatomy. This allows for precise and ideal prosthetic surgery execution[5]. This also provides less invasive operations, appropriate implant placement, decrease in postoperative pain, and manufacture of prosthetic components prior to surgical treatments [6].

A consensus on clinical criteria and indications for CAD/CAM procedures in implant dentistry was created by Hämmerle et al. According to this consensus, guided surgery is the process of using a static guide that replicates the implant's virtual position so that drills may be tracked in real time along a predetermined route [7].

According to recent studies, CAD/CAM is growing in popularity. A number of techniques include guided surgery, comparing the precision of dental implant placement to virtual planning, and evaluating patient outcomes [8]. The surgical advantages of implant-based treatment had been the exclusive use of computer-guided surgery. It is still necessary to deliver prosthetic treatment according to traditional standards. However, the link to provide the patient with prosthetic information is crucial, and accurate reference points are required to place the implants for a precise fit with prefabricated prostheses [9]. Nevertheless, there were always variances between the actual outcomes at the dental implant site and the virtual planning [10].

The digital revolution has now reached the sector of dentistry, which is undergoing significant development. These devices aid in the construction of several prosthetic structures, including crowns, bridges, models, and surgical guides. The patient can be "virtualised" with the help of these devices, which facilitate the shift from the physical world to the virtual one. One of the most important applications of digital dentistry is surgical guiding. Using surgical guidelines for implant placement can boost confidence and provide predictability [11].

It may aid the practitioner minimise anatomic structural damage while also minimising alveolar ridge fenestration and dehiscence at possible implant locations. Reduced surgical exposure while improving prosthesis fit. So it is superior than free hand implant implantation.

A thorough assessment of the surgical site and the intended prosthetic restoration is required for restoration-driven implant design and placement. Many kinds of surgical guides have been developed and used in implant dentistry to accomplish suprastructure-oriented implant positioning. Using surgical templates created from CBCT, surgeons may install implants in the best possible spot before performing surgery and prosthetic procedures [12].

The establishment of a radiographic template, cone-beam computed tomography (CBCT) acquisition while the template is in place, computer-assisted implant planning, and the development and application of a surgical guide with sleeves that closely match the diameter of the drills and/or implants are among the preoperative steps necessary for template-guided implant surgery. Given the intricacy of the treatment planning procedure and the many potential sources of error, the possibility of discrepancies between the preoperative plan and the postoperative implant position is a serious concern. Recent years have seen a number of papers on the precision of computer-assisted template-guided implant surgery approaches [(13)].

Stereolithographic technology (CADCAM) and laboratory-based procedures are the two different approaches that have been developed for the fabrication of static templates.

There are several methods for creating surgical guides, including both conventional and 3D techniques. Conventional (moulding or casting) surgical guide made by hand on a cast using clear acrylic resin (stent) that finds the implant's entrance point regardless of the implant's accuracy and connection to the bone.

Several controlled machining and material removal processes that begin with solid blocks, bars, or rods of plastic, metal, or other materials and are created by removing material by cutting, boring, drilling, and grinding are referred to as subtractive (milling) techniques.

Vapours are a typical feature of human anatomical systems and may be created by additive (3D printing) technology. Layer by layer, material is added in this approach to create things, with each layer adhering to the one before it until the portion is finished, creating models for use.

There are a range of additive technologies on the market, including: Stereolithography (SLA) is an additive manufacturing method that builds up the needed structure layer by layer, starting at the bottom of the model and progressing upward. A liquid photopolymer solidifies using a computer-controlled laser. Second, digital light processing (DLP) utilises UV laser beam technology to polymerise a liquid resin into a hard item. Finally, fused Deposition Modelling (FDM) is a manufacturing technology that produces three-dimensional things by depositing ejected molten polymers onto a building platform. Which is contrary to SLA.

Few studies have investigated the effect of static surgical guides made with different 3D printing techniques on implant location accuracy.

To evaluate the variations in the final position of dental implants following the use of surgical guides created by three different desktop 3D printers utilising a digital workflow: Stereolithography (SLA), Fused Deposition Modelling (FDM), and Digital Light Processing (DLP).

The null was that there is no significant difference in the implant position when consediring using different additive techniques in the fabrication of surgical guides.

MATERIALS AND METHODS:

This in vitro study was conducted in the digital lab of the Department of Prosthodontics, Faculty of Dentistry, Alexandria University. The sample consisted of 54 epoxy models representing Kennedy Class I, which were allocated to 3 study subgroups (n=18). The 3 study groups were formulated based on the different printing technologies. Postulating an 80% power and 95% level of confidence, this study was planned to detect an effect size of f=0.75. A software program (G*Power v3.1.9.2; Heinrich Heine University Düsseldorf)26 was used to calculate the sample size in reference to previous studies.2,15 Based on a comparison of means using the F test, the minimum required sample size was calculated to be 5 specimens, increased to 6 to account for laboratory processing errors

1- Model preparation:

In the current investigation, 18 class I partially edentulous mandibular models were created using a clear epoxy resin, following the manufacturer's instructions. The models were placed into three groups. Each group had four models (Fig. 1).

2. Planning Procedure and Surgical Guide Fabrication:

Four sets of models were produced, and conventional impressions were made with additional silicone material. The cast was made with dental stone and scanned to an STL file using a Sirona scanner. The models were scanned using CBCT using a Sordex Scanora 3Dx machine to generate Dicom series for each model with a field of view of 8x10cm. The implant was planned to use BlueSky Bio Software (Fig. 2, 3). The implant was digitally put in the appropriate position in virtual cast based on the scanned impression. STL files were prepared for each surgical guide and printed on three separate printers (Fig. 4).

Regarding the type of each printer, each surgical guide had its own 3D printing machine we used formlab printer for SLA surgical guides, Asiga printer for DLP group and Creality ender V2 for FDM group. All printers were calibrated before resuming also we use one STL file for all the surgical guides to ensure standardization throughout the study. Each printer has its own resin type and was as follow formlab photopolymer resin for SLA surgical guides, Norton premium resin for DLP surgical guides and finally 3D printer filament PLA+ for FDM surgical guides.

3. Implant Placement Procedure:

For the implant insertion technique, 24 dummy implants sized 4.5mm in diameter and 10mm in length were employed, with 8 implants in each group. Two implants for each model, using guided tools (Guided Surgical Kit) (Fig. 5). After surgical guide seating drilling started with the pilot drill and ended with the final drill as mentioned. These done though the surgical guides and then implant placement was done though the guide using torque wrench and its mount till the mount touches the guide.

4. Implant Position Accuracy Measurement:

After implant placement, each model was scanned again using CBCT, and an STL of the final implant position was created and placed on the intended models. BlueSky Bio Software was used to perform the measurements. 3D measures consist of shoulder depth deviation, shoulder radial deviation, angular deviation, apex depth deviation, and apex radial deviation.

Fig. (1) Epoxy resin Models of class I mandibular edentulous arch.

Measurements were taken at two points: the entrance point and the apical point. They were examined in three planes: bucco-lingual (ΔX), mesio-distal (ΔY), and apico-coronal (ΔZ).

The deviations were measured in micrometres (µm) and shown as point of entrance deviation (µm) and apical deviation (µm) at X, Y, and Z coordinates respectively. In addition, the angular deviation (degrees) was assessed by placing reference dots at the cross-sections of bucco-lingual and mesio-distal areas of intended and implant placements (Fig. 6 - 8).

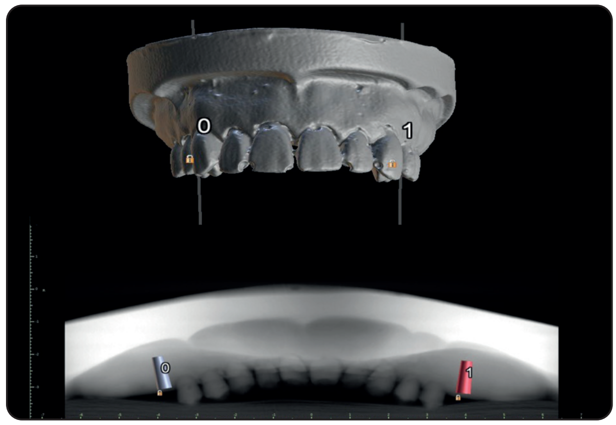

Fig. (2) Implant Position Planning Procedure and Surgical Guide Fabrication

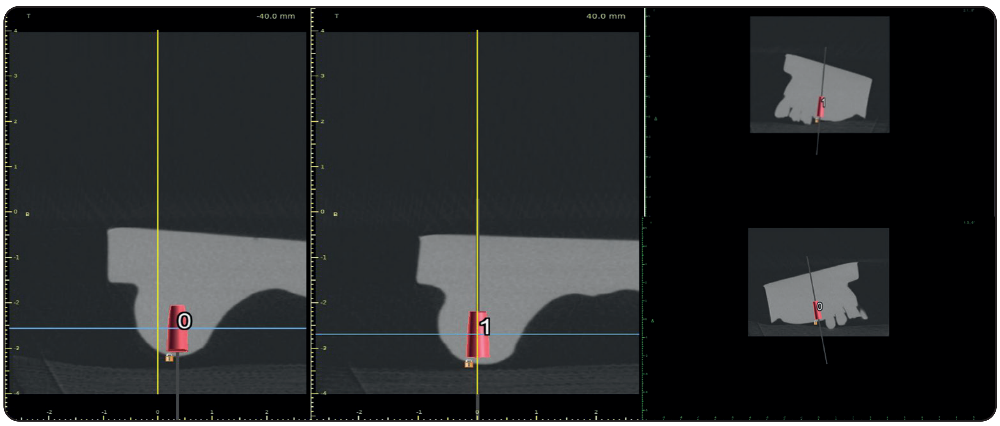

Fig. (3) Implant Position Planning Procedure and Surgical Guide Fabrication

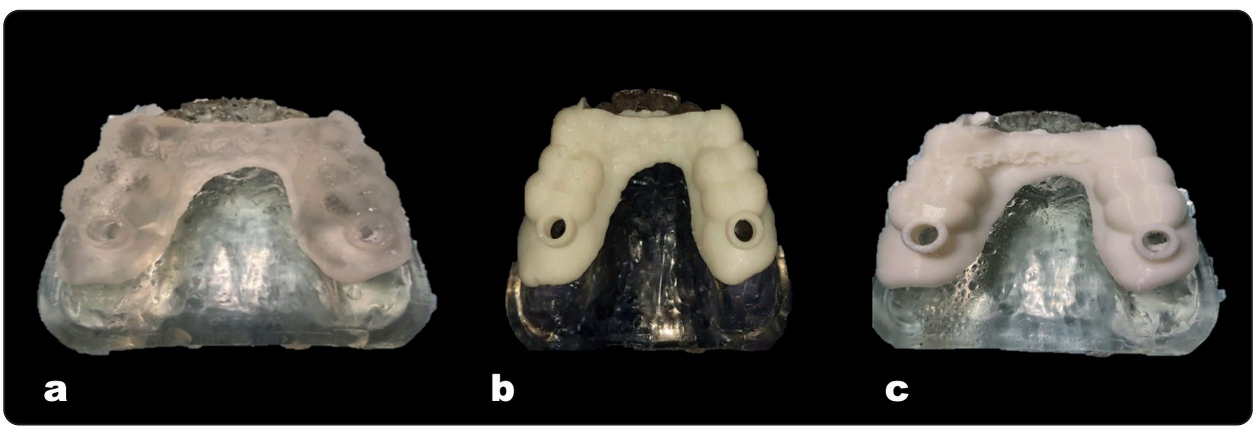

Fig. (4) STL of each surgical guide was obtained and printed using 3 different printers: a. DLP, b. SLA, c. FDM.

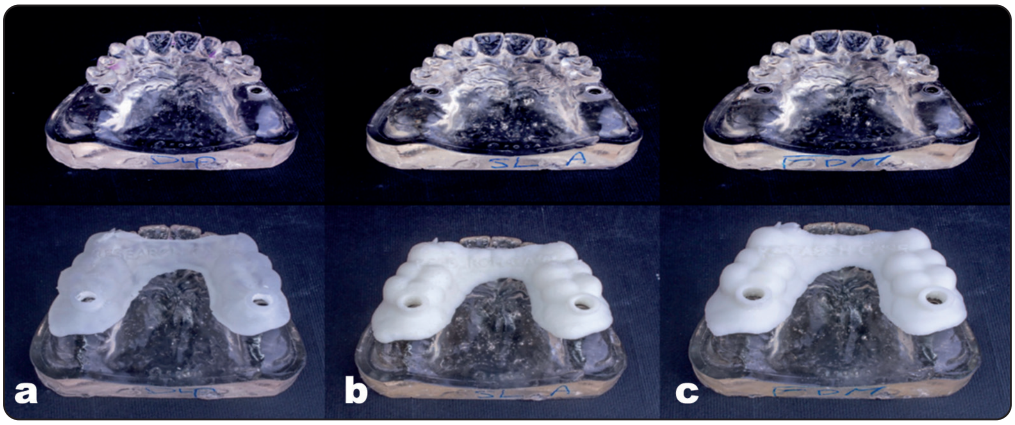

Fig. (5) Casts with surgical guide after implant placement: a. DLP, b. SLA, c. FDM

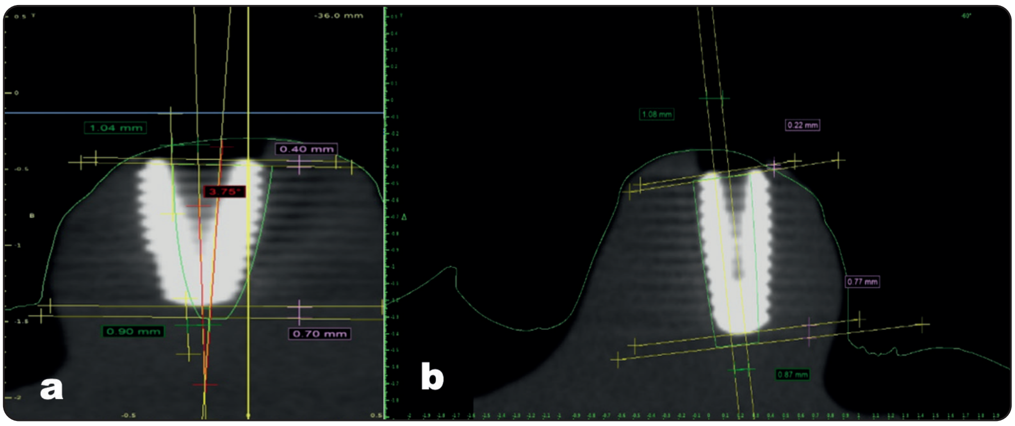

Fig. (6) CBCT scan of SLA type: a. buccolingually, b. CBCT scan of SLA type mesiodistally

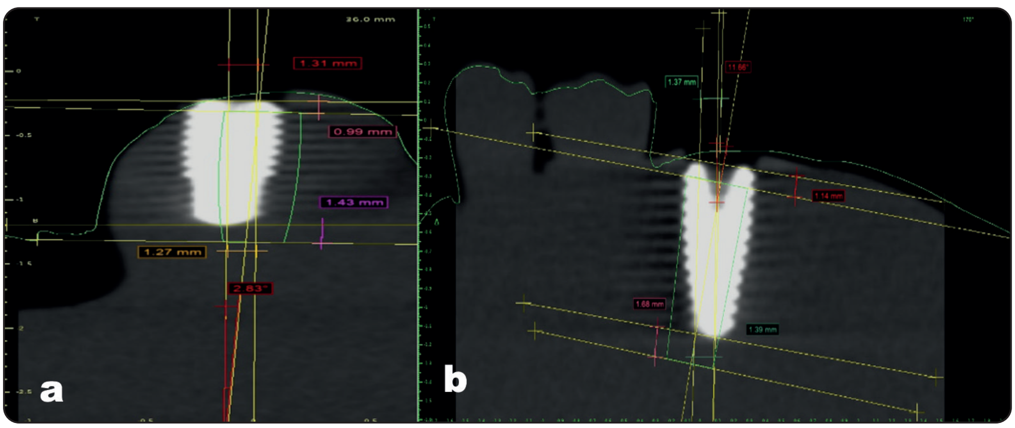

Fig. (7) CBCT scan of DLP type: a. buccolingually, b. CBCT scan of DLP type mesiodistally

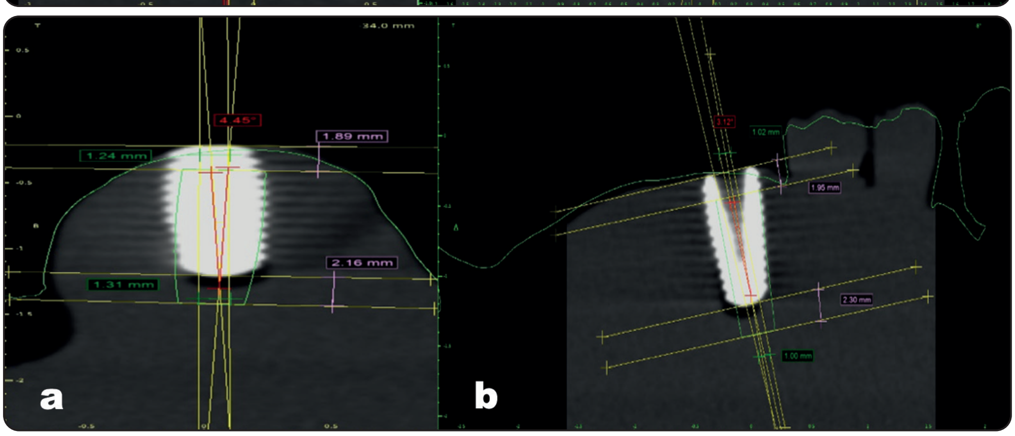

Fig. (8): CBCT scan of FDM type: a. buccolingually, b. CBCT scan of FDM type mesiodistally

RESULTS

Statistical analysis of the data

Version 20.0 of the IBM SPSS software program was used to analyse the data that was entered into the computer. (IBM Corporation, 2011; Armonk, NY). Using percentages and numbers, the qualitative data was described. The normality of the distribution was confirmed using the **Shapiro-Wilk test**. The mean, standard deviation, and range (minimum and maximum) were used to characterise quantitative data. The results' significance was assessed at the 5% level.

The used tests were

1 - One way ANOVA test

Comparing more than two groups for quantitative variables with a normally distributed distribution, and **Post Hoc test (Tukey)** for pairwise comparisons

TABLE (1) Comparison between the three studied groups according to Buccolingual

Buccolingual	SLA (n = 18)	DLP (n = 18)	FDM (n = 18)	F	p
Angular deviation					
Min. – Max.	2.50 – 5.26	2.83 – 6.26	3.48 – 7.41	37.814*	<0.001*
Mean ± SD.	3.49 ± 0.69	5.26^{a} ± 0.97	6.13^{ab} ± 1.08		
Sig. bet. grps.		p_1<0.001*,p_2<0.001*,p_3=0.019*			
Shoulder depth deviation					
Min. – Max.	0.0 – 0.40	0.38 – 0.99	0.72 – 1.89	65.778*	<0.001*
Mean ± SD.	0.13 ± 0.14	0.62^{a} ± 0.20	1.06^{ab} ± 0.34		
Sig. bet. grps.		p_1<0.001*,p_2<0.001*,p_3<0.001*			
Shoulder radial deviation					
Min. – Max.	1.04 – 1.15	1.31 – 1.57	1.40 – 1.81	161.145*	<0.001*
Mean ± SD.	1.09 ± 0.04	1.43^{a} ± 0.09	1.62^{ab} ± 0.12		
Sig. bet. grps.		p_1<0.001*,p_2<0.001*,p_3<0.001*			
Apex depth deviation					
Min. – Max.	0.56 – 0.70	0.55 – 1.43	1.31 – 2.16	126.145*	<0.001*
Mean ± SD.	0.63 ± 0.05	1.04^{a} ± 0.31	1.91^{ab} ± 0.30		
Sig. bet. grps.		p_1<0.001*,p_2<0.001*,p_3<0.001*			
Apex radial deviation					
Min. – Max.	0.04 – 1.18	1.27 – 1.47	1.31 – 1.86	47.202*	<0.001*
Mean ± SD.	0.92 ± 0.31	1.35^{a} ± 0.06	1.58^{ab} ± 0.18		
Sig. bet. grps.		p_1<0.001*,p_2<0.001*,p_3=0.005*			

SD: **Standard deviation**
F*:* F for One way ANOVA test*, Pairwise comparison bet. each 2 groups was done using* Post Hoc Test (Tukey)
p: p value for comparing between the three studied groups
***p_1: p value for comparing between* SLA *and* DLP**
***p_2: p value for comparing between* SLA *and* FDM**
***p_3: p value for comparing between* DLP *and* FDM**
****: Statistically significant at p ≤ 0.05***
***a: Significant with* SLA**
***b: Significant with* DLP**

Regarding buccolingual direction deviations, there was statistically significant difference between SLA, DLP and FDM regarding deviations in entry point, apex point, and angular deviation and this significant difference was in favor to SLA surgical guide. Also, there was significant difference between DLP and FDM and this significant was in favor to DLP.

TABLE (2) Comparison between the three studied groups according to Mesiodistal

Mesiodistal	SLA (n = 18)	DLP (n = 18)	FDM (n = 18)	F	p
Angular deviation					
Min. – Max.	0.79 – 6.80	4.62 – 8.31	4.49 – 11.66	24.567^*	$<0.001^*$
Mean ± SD.	3.14 ± 1.93	4.95^a ± 0.84	7.32^{ab} ± 2.28		
Sig. bet. grps.		$p_1=0.011^*, p_2<0.001^*, p_3=0.001^*$			
Shoulder depth deviation					
Min. – Max.	0.0 – 0.36	0.36 – 1.14	0.24 – 1.95	116.469^*	$<0.001^*$
Mean ± SD.	0.15 ± 0.08	0.84^a ± 0.27	1.57^{ab} ± 0.40		
Sig. bet. grps.		$p_1<0.001^*, p_2<0.001^*, p_3<0.001^*$			
Shoulder radial deviation					
Min. – Max.	0.0 – 1.40	0.0 – 1.40	1.32 – 1.68	25.628^*	$<0.001^*$
Mean ± SD.	0.73 ± 0.46	1.20^a ± 0.32	1.51^{ab} ± 0.11		
Sig. bet. grps.		$p_1<0.001^*, p_2<0.001^*, p_3=0.019^*$			
Apex depth deviation					
Min. – Max.	0.37 – 0.77	0.61 – 1.77	1.49 – 2.30	107.252^*	$<0.001^*$
Mean ± SD.	0.51 ± 0.13	1.04^a ± 0.39	1.89^{ab} ± 0.27		
Sig. bet. grps.		$p_1<0.001^*, p_2<0.001^*, p_3<0.001^*$			
Apex radial deviation					
Min. – Max.	0.0 – 1.39	0.0 – 1.39	1.0 – 1.84	19.402^*	$<0.001^*$
Mean ± SD.	0.65 ± 0.54	0.99^a ± 0.29	1.47^{ab} ± 0.31		
Sig. bet. grps.		$p_1=0.037^*, p_2<0.001^*, p_3=0.002^*$			

SD: **Standard deviation**

F: F for One way ANOVA test, ***Pairwise comparison bet. each 2 groups was done using*** **Post Hoc Test (Tukey)**

p: p value for comparing between the three studied groups

p_1: p value for comparing between **SLA** ***and*** **DLP**

p_2: p value for comparing between **SLA** ***and*** **FDM**

p_3: p value for comparing between **DLP** ***and*** **FDM**

****: Statistically significant at $p \leq 0.05$***

a: Significant with **SLA** ***b: Significant with*** **DLP**

Regarding mesiodistal deviations, there was statistically significant difference between SLA, DLP and FDM regarding deviations in entry point, apex point, and angular deviation and this significant difference was in favor to SLA surgical guide. Add more, there was significant difference between DLP and FDM and this significant was in favor to DLP group.

TABLE (3) Comparison between the three studied groups according to average of (Buccolingual and Mesiodistal)

	SLA (n = 18)	DLP (n = 18)	FDM (n = 18)	F	p
Angular deviation					
Min. – Max.	1.96 – 5.60	3.73 – 7.12	4.74 – 8.64	50.929^*	$<0.001^*$
Mean ± SD.	3.31 ± 1.04	5.11^a ± 0.70	6.72^{ab} ± 1.23		
Sig. bet. grps.		$p_1<0.001^*, p_2<0.001^*, p_3<0.001^*$			
Shoulder depth deviation					
Min. – Max.	0.00 – 0.31	0.42 – 1.07	0.48 – 1.92	134.807^*	$<0.001^*$
Mean ± SD.	0.14 ± 0.09	0.73^a ± 0.19	1.32^{ab} ± 0.31		
Sig. bet. grps.		$p_1<0.001^*, p_2<0.001^*, p_3<0.001^*$			
Shoulder radial deviation					
Min. – Max.	0.53 – 1.26	0.72 – 1.45	1.36 – 1.75	66.483^*	$<0.001^*$
Mean ± SD.	0.91 ± 0.23	1.32^a ± 0.16	1.57^{ab} ± 0.09		
Sig. bet. grps.		$p_1<0.001^*, p_2<0.001^*, p_3<0.001^*$			
Apex depth deviation					
Min. – Max.	0.47 – 0.74	0.58 – 1.60	1.52 – 2.23	177.197^*	$<0.001^*$
Mean ± SD.	0.57 ± 0.08	1.04^a ± 0.30	1.90^{ab} ± 0.21		
Sig. bet. grps.		$p_1<0.001^*, p_2<0.001^*, p_3<0.001^*$			
Apex radial deviation					
Min. – Max.	0.13 – 1.24	0.65 – 1.33	1.16 – 1.80	47.427^*	$<0.001^*$
Mean ± SD.	0.78 ± 0.30	1.17^a ± 0.15	1.52^{ab} ± 0.21		
Sig. bet. grps.		$p_1<0.001^*, p_2<0.001^*, p_3<0.001^*$			

SD: **Standard deviation**
F*: F for One way ANOVA test, Pairwise comparison bet. each 2 groups was done using* Post Hoc Test (Tukey)
p: p value for comparing between the three studied groups ***p_1: p value for comparing between* SLA *and* DLP**
***p_2: p value for comparing between* SLA *and* FDM** ***p_3: p value for comparing between* DLP *and* FDM**
****: Statistically significant at p ≤ 0.05***
***a: Significant with* SLA** ***b: Significant with* DLP**

Regarding the average (mean value) of both buccolingual and mesiodistal deviations, there was statistically significant difference between SLA, DLP and FDM regarding deviations in entry point, apex point, and angular deviation and this significant difference was in favor to SLA surgical guide in the all five parameters that was measured. Add more, there was significant difference between DLP and FDM and this significant was in favor to DLP group.

DISCUSSION

The results of the current study showed significantly increased difference between the study groups as regard to the accuracy of implant position, so the null hypothesis was rejected.

This study investigated whether the overall accuracy of implant positions was affected by three different additive printing technologies. The accuracy was determined by three measurements: angular deviation, 3D deviation at the entry point, and 3D deviation at the apex. Therefore, the study concluded that there were statistically significant differences among all additive printing technologies, and the null hypothesis was rejected. According to the experiment, based on the implant position

Several factors influence the accuracy of the static guided implant surgery such as study design, surgical guide design, type of guided surgery, implant characteristics, operator's experience, and printing technique. This study, therefore, minimized the overall effect of confounding factors as much as possible through various techniques. To minimize confounding factors, we utilized the same guide design, drill protocol, surgeon, and type of surgical models. The implant placement using different printed guides was also done at random to reduce the drilling memorization of the surgeon. Considering the study design, this study was performed in vitro aspect.

The variations in implant position precision observed in this study may be attributed to several operator-related factors.These factors include the tolerance between the guiding tools, the length of the dental implant used and the separation between the guide sleeve and implant site. In addition, the hexagon location was visually aligned during installation requiring the operator to mark the reference position which may contribute to large rotational deviation and data with a widespread. As guided surgery technologies continue to advance such variations may be reduced.

Moreover, the Amr Semary, et al. precision of implant position can be influenced by the surgeon's level of experience, as experienced clinicians demonstrated reduced variation in placement accuracy. Due to the need to block out undercuts for complete seating of the surgical guide, it may not have been as stable as intended, leading to some of the deviation observed. During osteotomy preparation holding the surgical guide and the cast simultaneously can be challenging resulting in inconsistent surgical guide positioning.

The variances observed in the DLP printed surgical guides could be attributed to printing-related factors such as the offset values necessary for the cylinder sleeve and space between the guide and teeth, leading to difficulties in mounting the sleeve and seating the guide. Additionally, the DLP printer used had a lower degree of photo polymerization than the SLA printer necessitating a post-polymerization process that could cause deformities in the guide.

Other factors that could influence the final implant position include the presence of a metal sleeve, the resolution of the 3D printer, the surface polish of the material used, the reproducibility of the printing process, the accuracy of offset settings, the effectiveness of post-processing techniques and the calibration of the equipment. Moreover, the epoxy resin used to create the models has a different density, elasticity and hardness than natural bone, which may affect the accuracy of the implant drills, leading to heat generation and bur clogging. However, epoxy resin is still commonly used in research as a bone simulant.

Previously, implant procedures focused on putting the implant in a bone location that supported a functional prosthesis. However, prosthetic restorations did not always match aesthetic requirements. To overcome this drawback, prosthetically driven implant surgery was developed, which entails designing implant placement depending on the eventual prosthesis. However, the implant location continues to diverge from the anticipated position owing to numerous circumstances[14-18].

The proper placement of dental implants depends on the 3D printed surgical guides being accurate. The precision of implant placement was assessed using three widely utilized additive techniques: digital light processing (DLP), fused deposition modelling (FDM), and stereolithography (SLA).

Numerous aspects, including study design, surgical guide design, type of guided surgery, operator experience, implant characteristics, and printing process, affect the accuracy of static guided implant surgery. Using a number of strategies, we attempted to standardize these parameters as much as feasible in this study. To reduce confounding variables, we employed the same surgeon, surgical model, drilling process, and guide design. To lessen the memory and imprint of the surgeon's drill, implant placement was additionally randomized using several printed guidelines.

The SLA group reported the best level of accuracy (lowest degree of deviation) among the study groups regarding deviations in entry point, apex point, and angular deviation, since there was a significant statistical difference in implant position accuracy between them. These results are consistent with a number of previously published research [16, 19-21]

However, a study by **Gjelvold et al.** found no statistically significant difference between SLA and DLP in terms of the alignment of the implant in the final position compared to the planned position. The DLP and SLA groups in this study showed minimal variation between the preoperative and postoperative placements of the dental implants [22].

The greater offset values required for the master cylinder sleeve and between guide and teeth for the SLA printer utilized may have affected the model's sleeve mounting and surgical guide seating, which would account for some of the statistically significant discrepancies. Additionally, because there was less photopolymerization during 3D printing, the surgical instructions for the SLA printer required a lengthier post-polymerization procedure than the DLP procedures [22].

This study confirmed the findings of earlier research, [14, 20, 21] which showed that the vertical locations often showed greater variance than the horizontal positions.

The tolerance between the guiding instruments, the length of the dental implant, and the separation between the guide sleeve and the implant site might all contribute to the aberrations in the current study [23].

Such variances may decrease as guided surgical technologies develop further. Furthermore, the amount of expertise of the surgeon might affect the accuracy of implant location; skilled clinicians showed less variance in insertion accuracy.

Variations in the DLP produced surgical guides may be due to printing-related variables such the offset values required for the cylinder sleeve and the distance between the guide and teeth, which can cause issues with seating the guide and mounting the sleeve. Furthermore, a post-polymerization procedure was required since the DLP printer's degree of photo polymerization was lower than that of the SLA printer, which might result in guide deformities [24].

CONCLUSION

Stereolithography surgical guides were more precise than fused deposition modelling and digital light processing regarding deviations in entry point, apex point, and angular deviation, according to the study's findings.

List of abbreviations

SLA: Stereolithography

FDM: Fused Deposition Modeling

DLP: Digital Light Processing

CAD/CAM: Computer-aided-Design/Computer-aided-Manufacturing

Dicom: Digital Imaging and Communications in Medicine

STL: Standard Triangle Language or Standard Tessellation Language

Declarations

In order to fulfil the criteria for another degree, I hereby certify that no portion of this dissertation has been submitted to Pharos University or any other university in Egypt or outside.

Ethics approval and consent to participate.

Not applicable

Consent for publication

Not applicable

Availability of data and materials

This published paper contains all of the datasets and materials used and/or analysed during the present investigation.

Competing interests

The authors declare that they have no conflicts of interest.

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Authors' contributions

S.M. The study was conceptualized by M.Z. and R.A. R.A. gathered the necessary information, carried out the investigation, and evaluated the findings. S.M. examined the information. The manuscript draft was written by R.A. The manuscript was reviewed and revised by M.Z. and R.A. All of the writers approved the final manuscript.

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