Original Article

Accuracy of two 3D printing technologies in manufacturing of dental implant surgical guides (An in vitro study)

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ABSTRACT

The development of guided implant surgery helps to optimize the placement of dental implants. Planning softwares used and then the guide manufactured using 3D printing with different technologies that may affect the manufactured guide . Stereolithography and fused deposition modeling are presently the two primary 3D printing techniques. In order to produce objects, both procedures add material layer by layer. Fused deposition modeling (FDM) creates items by extruding semi-liquid plastic in a predetermined arrangement, while Stereolithography (SLA) employs a UV light source to cure resin selectively.
The aim of this study is to determine the accuracy of two 3D printing technologies in manufacturing dental implant surgical guides. Eighteen dental stone models with twenty five missing teeth were CBCT scanned and planed for implant placement using the same software then 3D printed using stereolithography (SLA) and fused deposition modeling (FDM) 3D printing technologies. The surgical guide tubes diameter was measured and compared to the planed tube diameter.
The results showed no statistically significant difference between the accuracy of the two 3D printing technologies with the FDM showing lower accuracy.

Key Words: 3D printing, guided implant surgery, surgical guide

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INTRODUCTION

Computer-guided surgery is a static assistance that requires a physical surgical guide. The guide is 3D-printed and reproduces the virtual drilling planning directly from computerized tomographic and surfacic data. Guided surgery, compared to traditional techniques, allows to a more accurate implant placement. Indeed, computer-guided surgery was shown to provide more accuracy than freehand surgery [1].

The production of a surgical guide for guided implant surgery involves three stages: (i) gathering patient data; (ii) processing data; and (iii) manufacturing the guide. The patient's bone geometry is obtained through Cone Beam Computed Tomography (CBCT) or CT-scan examination, and is recorded in the Digital Imaging and Communication in Medicine (DICOM) format. Simultaneously, the surface geometry is registered through optical scanning (3D intra-oral scanner, IOS) and processed to produce a digital model in Standard Tessellation Language (STL) format. Subsequently, specialized software facilitates the alignment of DICOM and STL files, enables surgical planning, and creates a surgical guide. Next, the guide's STL file that is ready to print is exported [2].

In the field of dental implantology, the most widely utilized 3D printing methods for creating surgical guides are inkjet, PolyJet®, DLP, and stereolithography (SLA). Nonetheless, alternative additive manufacturing technologies exist, including Fused Deposition Modeling (FDM), 3-Dimensional Printing (3DP), and Selective Laser Sintering (SLS). Plastics, resin, and materials derived from plastic are the materials most frequently utilized in dental applications, while a wide range of materials can be used with these technologies. Co-Cr surgical guides have been produced using Direct Metal Printing (DMP) technology; however, this technology is not commonly used for this purpose, most likely due to its more complicated use and higher total costs (including consumables and printer device) compared to resin printers. But until recently, SLA was the most popular method to manufacture surgical guides using resins and called (Stereolithography) [3,4].

SLA is a method that uses a laser beam to polymerize monomer resin. The moving platform is lowered into the reservoir tank after a layer is created, and this procedure is repeated layer by layer until the printed part is finished.A heated nozzle head is used in the FDM manufacturing process to melt a filament of material in preparation for extrusion. After that, the content is printed on a receiving platform layer by layer [5].

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Because of the thinnest possible layer thickness, post-curing shrinkage, and model shrinking during construction, 3D printing procedures may result in variations in the final model output. These factors could have all had an impact on the 3D printing models [6].

The difference between the dimensions of a standard tesselation language (STL) file and the printed object is known as 3D-printing accuracy, and it is usually less than 0.5 mm. Research on FDM printing technology has revealed accuracy as high as 0.013 mm and as low as 0.5 mm. [7,8,9].

A 50 µm layer thickness in SLA printing results in less intaglio deviations, increased printing consistency, and fewer tube linear deviations. This is in keeping with the widely held belief that printing accuracy increases with decreasing layer thickness [10,11,12,13].

Aim of the study

The aim of this study is to determine the accuracy of two 3D printing technologies in manufacturing of dental implant surgical guides.

MATERIALS AND METHODS

Models selection

A total of eighteen demonstration dental stone models were selected of partially edentulous cases with a total of twenty five missing teeth.

CBCT scan

Cranex 3D,Soredex,Finland CBCT machine was used to scan the selected plaster dental models

using scanning parameters FOV 8cm, mA 10, KvP 90 and voxel size 0.2 mm.

Surgical guide planning software

Blue sky plan 4 was used for planning and designing the surgical guides for each missing tooth and then guide tube diameter was selected and guide was fabricated virtualy then converted to STL file to be printed. **Figure 1**

Figure.1 showing surgical guide planning software

3D printing

• SLA printing

STL files transferred for 3D printing using Formlabs 3B SLA printer using surgical guides resin material and printing resolution 25 micron. Using liquid photopolymers SLA printer software automatically calculated the placement of the polymer and the support material and the 3D guide was printed in fine layers. **Figure 2**

Figure.2 showing Formlabs 3B SLA printer

• FDM printing

UPMINI FDM 3D printer was used for guide printing using PLA (poly lactic acid) filament material with printing resolution of 200 micron after STL files were exported for 3D printing.
FDM starts with a software procedure that mathematically slices and orients the model for the building process, processing STL files in a matter of minutes. Using Addition the FDM printer added materials up in layers through the extrusion nozzle which is heated automatically for melting the plastic material. **Figure 3**

Figure.3 showing UPMINI FDM printer

Measuring guide tube diameter

For each 3D printing technology tube diameter was measured in mm using a digital caliber adjusted to fit to the internal surface of guide tube and compared to the selected diameter in the planning software as a control group. **Figure 4**
Data collected and imported for statistical analysis.

Figure.4 showing measuring guide tube diameter using digital caliber

RESULTS

SPSS software was used to calculate standard deviation and mean for both groups then compared to the control group. Study groups compared using one way ANOVA test. Accuracy of both 3-D printers was calculated and represented.

Comparison between the study groups:

SLA printer showed mean guide tube diameter in mm of 5.956±0.73 while FDM printer showed 5.630±0.83.
Table 1

Table 1 showing mean and standard deviation of guide tube diameter in mm.

	n=20 Mean	Std. Deviation	Minimum	Maximum	Std. Error of Mean
Control	6.0000	0.79	5.00	7.00	0.353
SLA guide	5.956	0.73	5.08	7.05	0.329
FDM guide	5.630	0.83	4.55	6.70	0.371

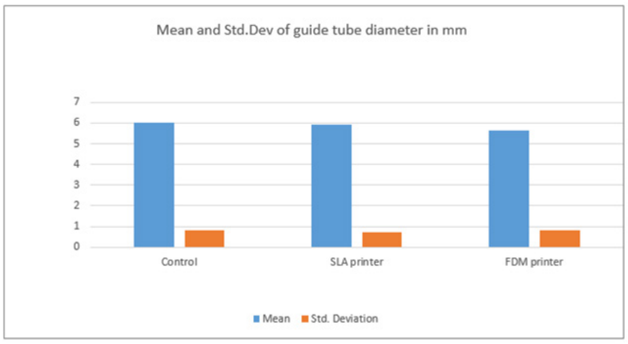
The results showed no statistically significant difference P> 0.05 between the two studied groups compared to the control group. Table 2

Table 2 comparing between the study groups.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8.500	11	0.773	1.545	0.399
Within Groups	1.500	3	0.500		
Total	10.000	14			

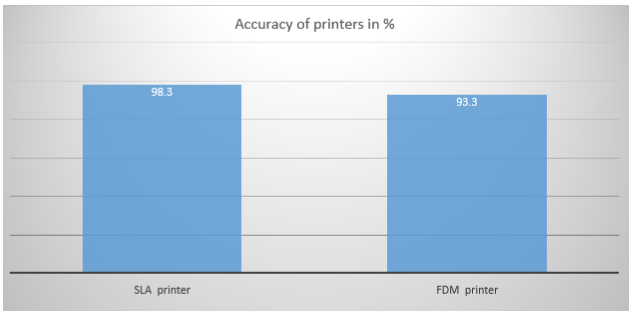
Significant at $P \leq 0.05$

Mean tube diameter and standard deviation for the control and studied groups were represented. **Graph 1.**



Graph.1 showing mean and standard deviation of guide tube diameter in mm

SLA printer showed acuracy of 98% while FDM printer showed accuracy of 93%. **Graph 2**



Graph.2 showing accuracy of 3D printers in %

DISCUSSION

The precision of surgical guides is particularly important because they can reduce operation errors, enhance accuracy and time efficiency in clinical treatment, and make treatment outcomes more predictable for dentists [14,15,16].

The production of surgical guides, data processing, and data gathering are only a few of the many variables that can impact the precision and repeatability of 3D printed dental implant surgical guides. This is contingent upon both the 3D printer and the dental technician using it. An error in precision causes the implant's location to deviate. Therefore, in order to increase accuracy and reproducibility, components must be identified and studied separately [17].

This study was conducted to compare between the accuracy of FDM and SLA printing technologies in manufacturing dental implant surgical guides. Our study showed higher accuracy for SLA printing technology in fabrication of surgical guides compared to FDM printing with no statistically significant difference between mean guide tube diameter of guides fabricated by both technologies.

These results are in agreement with Pieralli et al.2020 [18] which concluded that Comparable levels of accuracy in implant placement were achieved when utilizing FDM and SLA printed surgical guides This coincides with Hromadnik et al. 2020 [19] which reported that when comparing the four evaluated groups (SLA-S, SLA- NS, FDM- S, FDM- NS), no statistically significant differences regarding to the implant site were found. In addition to the study Sun et al 2019 [20] which concluded that An FDM 3D-printed surgical template for implant insertion produced a comparatively acceptable level of precision

These results are in opposite to Ishida and Miyasaka 2016 [21] which reported significant lower accuracy for FDM compared to SLA printer, and this may be attributed to that they used a non dental open source software which is different from our study in which we used a specialized implant planning software (blue sky plan) which shows high planning accuracy as reported by Bilal et al 2018 [22].

Our study showed higher accuracy for SLA printers compared to FDM and this coincides with the results of Ersoy et al 2008 [23] which reported high printing accuracy for SLA printers.

The results agree with Alzit et al 2022 [4] which reported higher precision and trueness of SLA printers compared to FDM printers.

The higher SLA printer accuracy is attributed to reduced FDM printer guide surface smoothness, which could have an impact on the printed surfaces accuracy as mentioned by Tian et al 2021 [24].

CONCLUSION

SLA and FDM printing technologies can be used for implant surgical guides fabrication.

The higher SLA printing accuracy may has a clinical significance on the accuracy of the manufactured surgical guides.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

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