Research Square

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Assessment Of The Reproducibility And Precision For Milling And 3d Printing Surgical Guides

Sueli Mukai
Guarulhos University
Eduardo Mukai
Universidade de Sao Paulo
Jamil Awad Shibli DDS
Universidade Guarulhos
GABRIELA GIRO (gabi.giro@gmail.cim)
Guarulhos University https://orcid.org/0000-0002-7590-8158

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Abstract

Objective: The aim of the present study was to evaluate the reproducibility and precision of two types of surgical guides, obtained by using 3D printing and milling methods. Methods: A virtual model was developed, which allowed the virtual design of surgical guide project that were milled (n = 10) or 3D printing (n = 10). Surgical guides were digitally oriented and overlapped on the virtual model that had generated them. For milling guides, it was used the Sirona Dentsply system, while 3D printing guides were produced at the Perfactory P4K Life Series, the EnvisionTEC's E-Guide Tint. In this way, average mismatches from the master model were determined. Moreover, coefficients of variation, root mean square deviations, and mismatches during an overlap were evaluated after obtaining individual misalignments for each guide, in order to verify the reproducibility of the guides and the precision of the methods for obtaining the guides Results: The evaluations showed that both groups presented the same degree of mismatch during overlap, with no statistically significant differences between the groups. However, the intragroup evaluation for misalignment, 3D printing surgical guides had a higher coefficient of variation than the milled guides, since a statistically significant difference was observed between groups in the RMS of the guide from the master model. Conclusions: Milling of the guides resulted in smaller misalignments from the master model.

Backgrounds

Rehabilitating a patient with an implant requires precise planning and special care during surgery. Placing a badly planned implant can cause real problems, such as perforation of important anatomical structures, increased surgical duration, and patient anxiety, pain, and stress. Therefore, presurgical planning, using instruments such as tomography and surgical guides is extremely important [1-3].

The use of surgical guides in dentistry has provided patients and dental surgeons with greater flexibility, accuracy, and control of the procedure being executed [4, 5] resulting in a more comfortable postoperative experience for the patient and, in accordance with reverse planning, delivery of the immediate prosthesis or optimization of the final prosthetic result [6-8]. Different types of guides may be used during surgery. Conventional surgical guides are made of acrylic resin that, unfortunately, does not provide the important anatomical information needed for the surgical procedure. In order to a careful positioning of the implants, trying to avoid bone augmentation procedures and optimizing the surgical procedure, cone-beam computed tomography (CBCT) guided implant surgery have been best option up to date, since Implants inserted with the help by virtually guided procedures are more precise than those involving conventional ones [9-11]. The surgical guide for the CBCT guided surgery are made by using a combination of software, which, together with CBCT, transfer anatomical data for the presurgical planning of the implant [2,9,10]. These guides began with the creation of a combination of systems that integrated tomography and chairside CAD/CAM to optimize and simplify planning from the first consultation through implant installation [13]. This technology has revolutionized dentistry by allowing the dental surgeon to generate the surgical guide using a completely virtual approach and to plan the surgery so that implants are inserted based on available bone, thereby reducing the duration of the surgery and the possibility of complications [14,15]. Several authors have been investigating different materials for this purpose, in order to evaluate the implant positioning and its deviations along implant body with the use of different techniques [16]. There are some other factors that could influence in the success of implant positioning as practitioner experience, and surgical approach and tissue support. [17-19] The literature shows that the use of materials that allow higher flexure or deformations may increase implant positioning deviations [16], specially in edentulous space with multiple missing teeth.

The technology developed to produce these surgical guides is an innovative system, but its use remains quite restricted, since few studies are available on the production and use of this type of procedure, making the development of new studies a priority. Therefore, the objective of this study was to evaluate and compare the reproducibility and precision of milled and three-dimensionally (3D) printing surgical guides compared to the initial virtual projection.

Methods

This study used a partially edentulous area model with a Kennedy class IV for the comparison between both groups. The same model selected for the study was used to create all surgical guides, which were divided into two distinct groups: MILLED GROUP, consisting of 10 milled surgical guides; and 3D PRINTING GROUP, consisting of 10 3D printing surgical guides.

Production of surgical guides

The model used in this study was digitized by using an intraoral scanning system (Cerec AC®, Sirona Dentsply, Germany). The scanning process generated a projection in SSI language that enabled virtual planning of the ideal position for inserting the implant. After that, it was generated an image in DXD language enabling file import to the inLab 15 software (Sirona Dentsply, Germany), which is possible to create the appropriate design of the surgical guide.

The surgical guide design started by defining the ridge boundaries and length of the surgical guide (Figure 1A) and determining the position and size of the ring responsible for guiding implant insertion (Figure 1B). After this step, a preview of the surgical guide design was generated., as shown in Figure 1C. After verification and approval of the planned guide, the project is ready for manufacture. For miling guides, the file was sent to the MCXL milling machine (Sirona Dentsply, Germany) for production in polymethyl methacrylate (PMMA), using the manufacturer standardized parameters. 3D printing guides were produced after converting the DXD archive into STL extension, which was then sent to a 3D printer (Perfactory P4K Life Series, EnvisionTEC, Germany). This printer uses DLP technology with a 4M pixel projector with a UV wavelength of 385nm. The resin used was EnvisionTEC's E-Guide Tint (Dearborn, USA) which is a biocompatible Class I certified material. The guides were posicioned in a 45 degrees angle. After printing, the guides were immersed in isopropyl alcohol to perform the surface cleaning and, then, the light curing was performed using the manufacturer’s parameters.

Once the surgical guides were completed, an individual digitization of each surgical guide was performed using a Data Sheet camera (stereoSCAN^{3D} R8, 8.0 megapixel, Germany), thereby creating a mathematical model (STL) so that the guides could be superimposed overlapped the virtual master model (best-fit alignment). Therefore, it was evaluated the average mismatch of the guide relative to the master model. After obtaining individual misalignments for each guide, and compared the root mean square (RMS) and standard deviation for each sample compared to the master model, in order to verify the reproducibility of the guides and the precision of the methods for obtaining the guides.

Data analysis

After testing normality of the data by the Kolmogorov–Smirnov test, Student's *t*-test was used to compare groups and calculated the intraclass coefficient of variation for the sample. The alpha level for significance was set at 5%.

Results

Figure 2 shows a representation of the best-fit alignment data for the superimposition of each guide with the master model. Both groups showed the same degree of mismatch during overlap, with no statistically significant differences between the groups (Figure 3). However, in the intragroup evaluation for misalignment, the coefficients of variation were 31.08% for the milled group and 96.25% for the 3D printing group, revealing greater variation in the reproducibility of the 3D printing guides. Also, statistically significant difference was observed between groups in the RMS of the guide from the master model. The 3D printing group showed greater deviation than the milled group (Figure 4). The misalignments were quite evident when a colorimetric scale was used to illustrate the different superimposition situations, illustrated in Figure 5.

Discussion

The objective of this study was to compare two different surgical guides confection in terms of their reproducibility and precision relative to the initial virtual projection. Despite being an in vitro study, this study evaluated the accuracy on the reproductivity of the main methods used to fabricate surgical guides in the era of digital dentistry, since no other study performed this comparison. This evaluation was performed by superimposing images, a procedure that allows for a point-by-point evaluation of any discrepancy in the guide characteristics. Although no difference was found regarding the best fit alignment between the groups, 3D printing group presented higher variation on the reproducibility of the surgical guides. These results corroborate those of a study by Park et al. [2], who observed that milled surgical guides had less deviation than 3D printing guides ($p < 0.05$). Other studies also showed greater precision for milled guides in relation to the final implant position [10, 12, 15, 20]. Clinically, this error seems not to influence in the final result of the rehabilitation. Bell et al. [16] evaluated 2 different surgical guide material, in relation to the angular deviation of the implant inserted with using a thermoplastic surgical guide and 3D-printed one. The authors demonstrated that no clinical difference was shown between both groups, although implants placed using the thermoplastic surgical guide are less accurate on the apex positioning.

Results of the other studies that compared the final implant position obtained using both guides are questionable, as various factors can influence the precision of guided surgery, such as scanning errors, errors in producing the guides, mechanical errors, data transmission errors, and human error [8,-10,12,17,21]. These factors are cumulative and interactive and can occur at any time during the process. This study supports the findings of these authors because it used the reproduction of guides based on the same scan of the same model, confirming that using CAD/CAM-assisted surgical guides is a more precise technique than using 3D printing guides. However, although this results suggest that milled guides are superior to 3D printing guides, the literature still controversial, since some authors have shown the advantages of using 3D printing over conventional surgical guides produced on top of models and over implants that are positioned freehand [9,10,19,22], while other studies showed no significant difference implant survival rate and effectiveness using conventional or digital implant placement procedures [11].

The literature also shows that 3D printing surgical guides may be associated with surgical complications caused by problems during their production. These problems include a lack of calibration of the printing equipment, changes to the physical properties of the resin, difficulty in positioning or fixing the guide in the oral cavity, or limitations in mouth opening [7,9,23]. It is important to know the limitations of the prototyping guide technique to minimize the potential for complications during the surgical procedure. Van Assche et al. [1] observed that, to avoid deforming 3D printing guides, it is essential that the guide have a total thickness of 2.5 to 3.0 mm. This deformity is not observed in milled guides because the resin blocks are ready to be machined, without suffering any change to their structure [12].

Despite the precision found in this study's results, the literature suggests that errors may occur during the manufacture of either type of surgical guide. Thus, it is recommended that a 2-mm safety margin be maintained around important and vital structures [2,21] and that cone-beam computed tomography images be used, in order to achieve a correct evaluation of the essential anatomical structures [9,20,24, 25].

Clinically, the goal of precise surgical guides is to avoid damaging the noble structures and to offer an ideal treatment plan that meets the patient's aesthetic and functional objectives [3,15], with a shorter duration of surgery and fewer complications during surgery. Although the results of this study showed a difference in reproducibility and precision for the different methods of making surgical guides, future studies are needed to gauge the implications that such differences might have on surgical positioning. It is also necessary to evaluate the cost/benefit ratio of both types of guides for the patient and dental surgeon.

List Of Abbreviations

CBCT: cone beam computed tomography

3D printing: Three-dimensionally printing

CAD/CAM: computer-aided design and computer-aided manufacturing

DXD and STL language: mathematical models computer softwares

RMS: root mean square

Declarations

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PARTICIPATION OF EACH AUTHOR:

1. **Sueli Mukai**: responsible for study design, data acquisition and paper preparation.

2. **Eduardo Mukai:** responsible for the development of the virtual surgical guides and data acquisition

3. **Jamil Shibli:** responsible for draft of the study and interpretation of data.

4. **Gabriela Giro:** responsible for draft of the study, conducting the research interpretation of data and paper preparation.

AVAILABILITY OF DATA AND MATERIALS

- The datasets analyzed during the current study are available from the corresponding author.
- No ethical approval was need for this study.

There is no COMPETING INTEREST related to this study.

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Figures

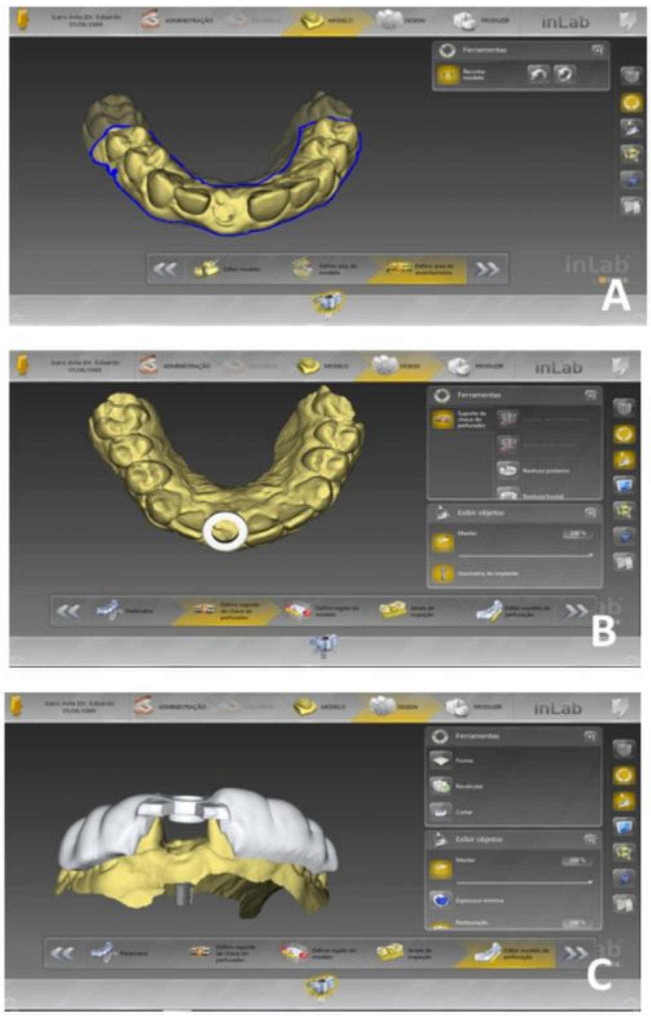

Figure 1

(A) Definition of the limits of the surgical guide. (B) Ring position. (C) Projection of the final surgical guide.

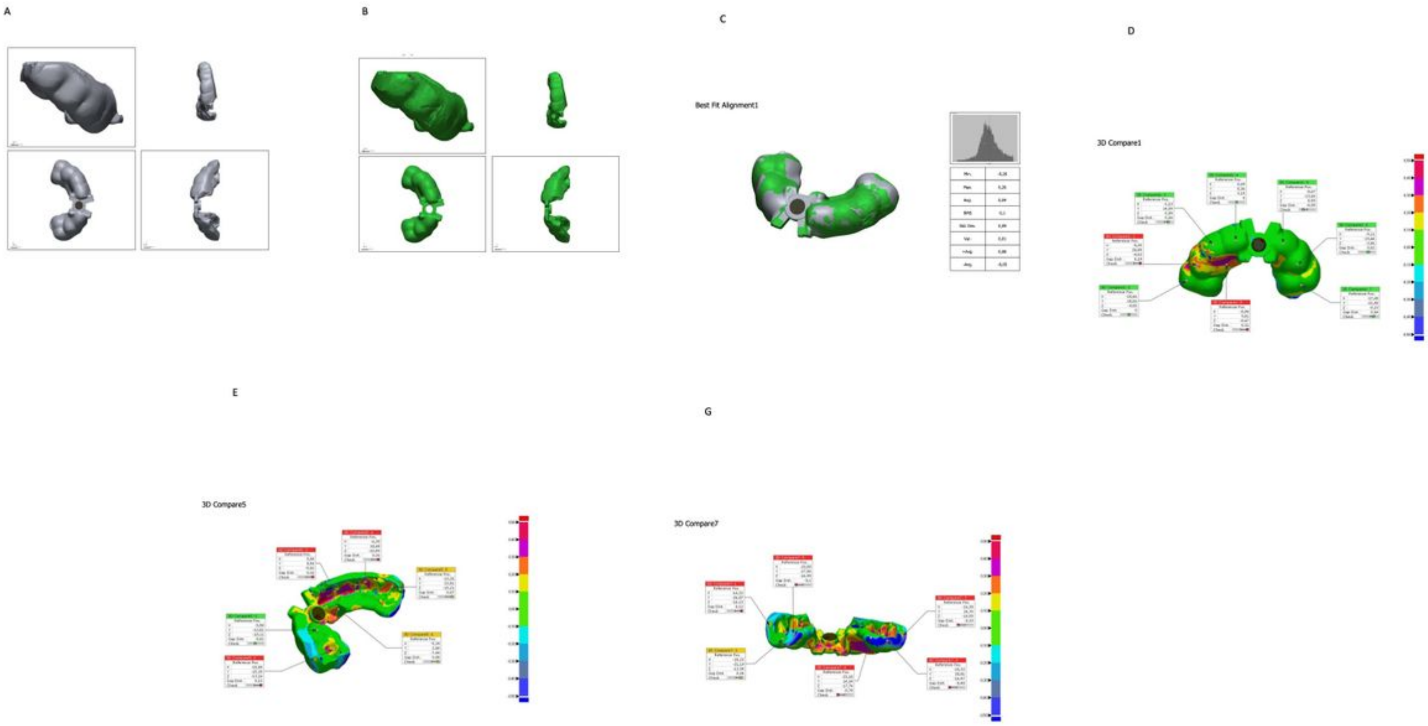

Figure 2

Representative sample of the comparison between the virtual guide and the test one after the best superimposition on the master model was achieved: (A) virtual surgical guide generated in the master model; (B) 3D printing surgical guide; (C) Best fit aligment of the superimposition of both guides; (D) Front view of the comparisons between guides; (E) inside view of the best fit aligment comparison between guides; (F) back view of the surgical guides comparison.

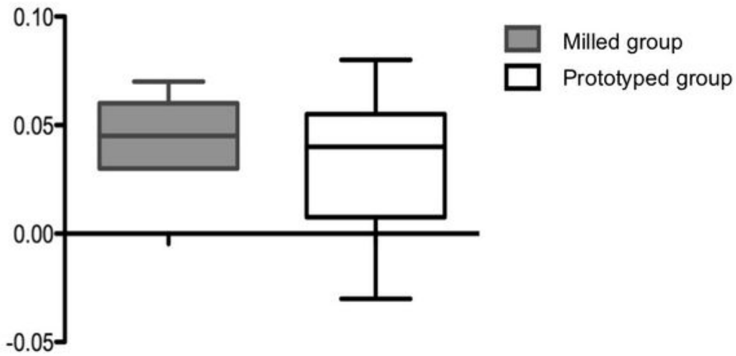

Figure 3

Comparison between study groups for misalignment in the superimposition of the guide on the master model.

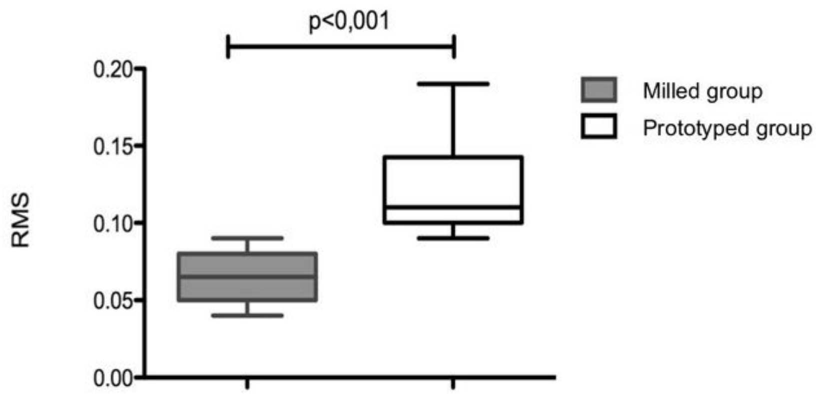

Figure 4

Comparison between study groups of the root mean square (RMS) of the sample for the average variation in the superimposition of the guide on the master model.

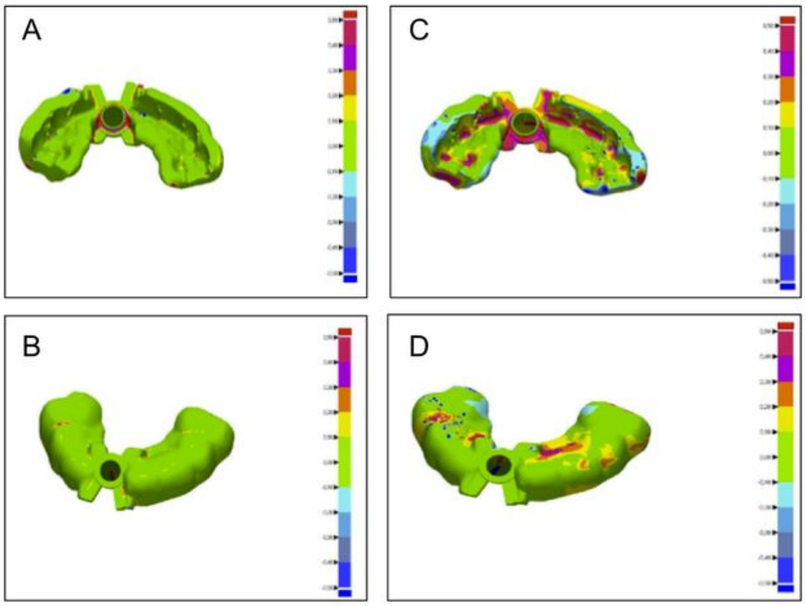

Figure 5

Internal and front views of the superimposition of the models for the milled (A, B) and prototyped (C, D) groups, respectively, and their patterns of variation.