

# Assessment of The Reproducibility And Precision For Milling And Prototyped Surgical Guides

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## Research article

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# Abstract

**Background:** Technological advancements in dentistry in the past decade have led to many innovations and improvements. These advances have led to faster procedures that are more comfortable for the patient and dental surgeon compared to standard methodologies, such as conventional impressions and implant placement surgeries performed without surgical guides or with conventional handmade guides, which generate less predictable results. Use of CAD/CAM technology, both in manufacturing prostheses and in surgical planning, has led to optimization of the procedures and reductions of patient morbidity. Techniques have been developed for the preparation of surgical guides with the goal of optimizing the surgical procedure. Therefore, the aim of the study was to evaluate the reproducibility and precision of two types of surgical guides, obtained by using prototyping and milling methods.

**Methods:** A virtual model was developed, which allowed the virtual design of surgical guide projections that were milled ( $n = 10$ ) or prototyped ( $n = 10$ ). Surgical guides were digitally oriented and overlapped on the virtual model that had generated them. In this way, mismatches from the master model were determined. Coefficients of variation, root mean square deviations, and mismatches during an overlap were evaluated.

**Results:** The evaluations showed that the prototyped surgical guides had a higher coefficient of variation than the milled guides.

**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], 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 [5,6]. 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. Prototyped and milled surgical guides are made by using a combination of software, which, together with cone-beam computed tomography, transfer anatomical data for the presurgical planning of the implant [2,7]. Implants inserted with the help of virtually generated surgical guides are more precise than those involving conventional guides [8].

Use of milled 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 [9]. 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 [10,11]. The technology developed to produce milled surgical guides is an innovative system, but its use remains quite restricted. The technique was introduced only recently, and acquiring the equipment is expensive. In addition, 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 prototyped surgical guides compared to the initial virtual projection.

## Methods

This study used a partially edentulous area model with a Kennedy class IV. The 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 prototyped group, consisting of 10 prototyped surgical guides.

### *Production of surgical guides*

The model used in this study was digitized by using an intraoral scanning system (Cerec AC<sup>®</sup>, Sirona Dentsply, Germany). Based on the scan of the model, it was obtained 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 so that the image could be imported by the inLab 15 software (Sirona Dentsply, Germany), to track the virtual planning of the case and the design of the surgical guide.

Planning began with defining the boundaries and length of the surgical guide (Figure 1A) and determining the position and size of the ring required by the guide for implant insertion (Figure 1B). After this step, a preview of the projection to be impressed was created, as shown in Figure 1C. After verification and approval of the planned guide, this projection was sent to the milling machine (Sirona Dentsply, Germany) for production of the surgical guide belonging to the milled group. Prototyped guides were produced after converting the DXD archive into STL language, which was then sent to a 3D printer (Perfactory Vida, EnvisionTEC, Germany).

Once the surgical guides for both groups were completed, an individual digitization of each surgical guide was performed using a Data Sheet camera (stereoSCAN<sup>3D</sup> 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). In this way, 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 prototyped group, revealing greater variation in the reproducibility of the prototyped guides.

A statistically significant difference was observed between groups in the RMS of the guide from the master model. The prototyped 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. This evaluation was performed by superimposing images, a procedure that allows for a point-by-point evaluation of any discrepancy in the guide characteristics. It was found that milled guides had better reproducibility than prototyped guides, conferring greater precision to the surgical guides relative to the master model. These results corroborate those of a study by Park et al. [2], who observed that milled surgical guides had less deviation than prototyped guides ( $p < 0.05$ ). Other studies also showed greater precision for milled guides in relation to the final implant position [8,9,12,13].

Results of the few 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 [7,9,14]. 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 prototyped guides. However, although this study's results suggest that milled guides are superior to prototyped guides, various authors have already shown the advantages of using prototyped over conventional surgical guides produced on top of models and over implants that are positioned freehand [7,8,15].

The literature also shows that prototyped surgical guides may be associated with surgical complications caused by problems during their production. These problems include a lack of calibration of the

prototyping 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 [6,7,16]. 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 prototyped 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 [9].

Despite the precision found in our 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 [2,14] and that cone-beam computed tomography images be used, in order to achieve a correct evaluation of the essential anatomical structures [7,13,17,18].

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 [3,12], 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.

According to the results obtained in this study, it is possible to suggest that prototyped surgical guides presented higher coefficient of variation than milled guides. Moreover, milled guides lead to fewer misalignments relative to the master model.

## **Declarations**

### *ACKNOWLEDGMENTS*

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### *PARTICIPATION OF EACH AUTHOR:*

- Sueli Mukai: responsible for study design, data acquisition and paper preparation.
- Eduardo Mukai: responsible for the development of the virtual surgical guides and data acquisition
- Jamil Shibli: responsible for draft of the study and interpretation of data.
- 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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### *LIST OF ABBREVIATIONS*

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

DXD and STL language: mathematical models computer softwares

RMS: root mean square

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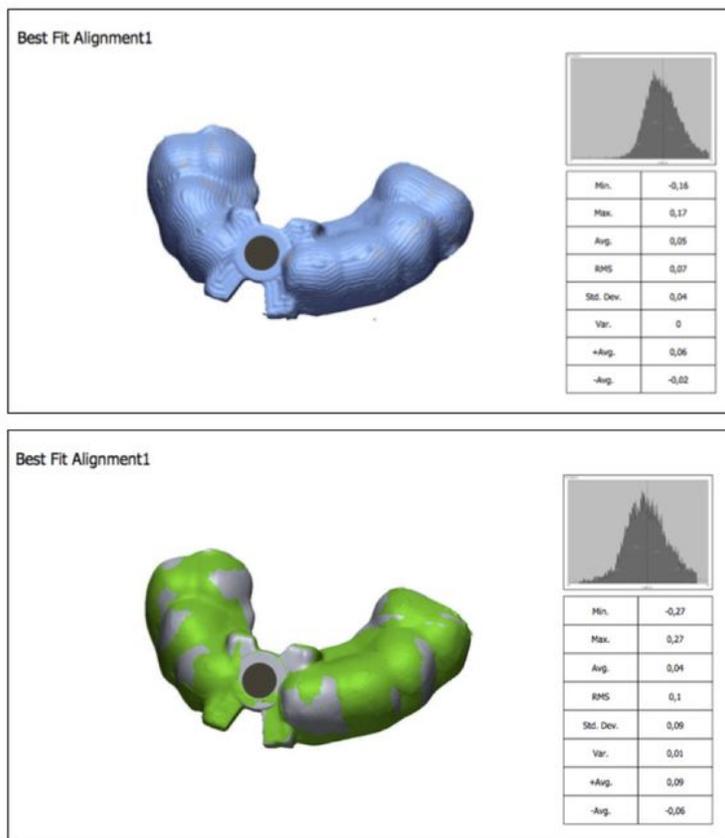
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## Figures



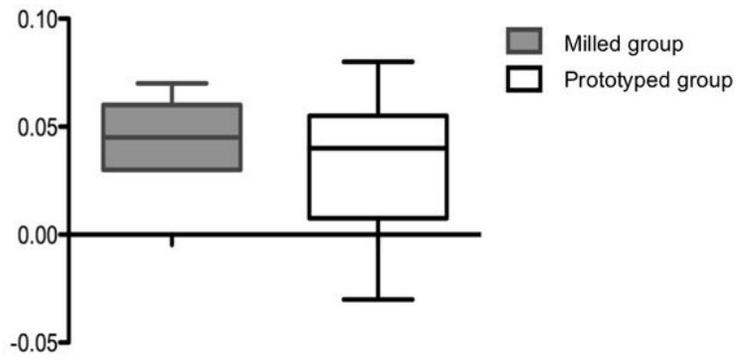
**Figure 1**

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



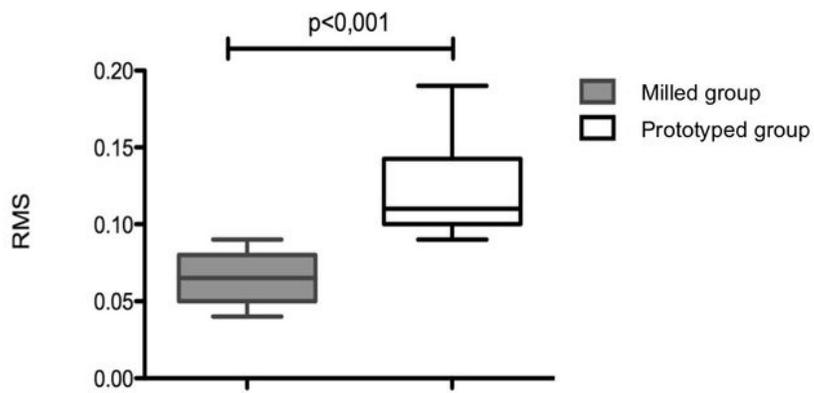
**Figure 2**

Representative guide from the milled (A) and prototyped (B) groups, after the best superimposition on the master model was achieved.



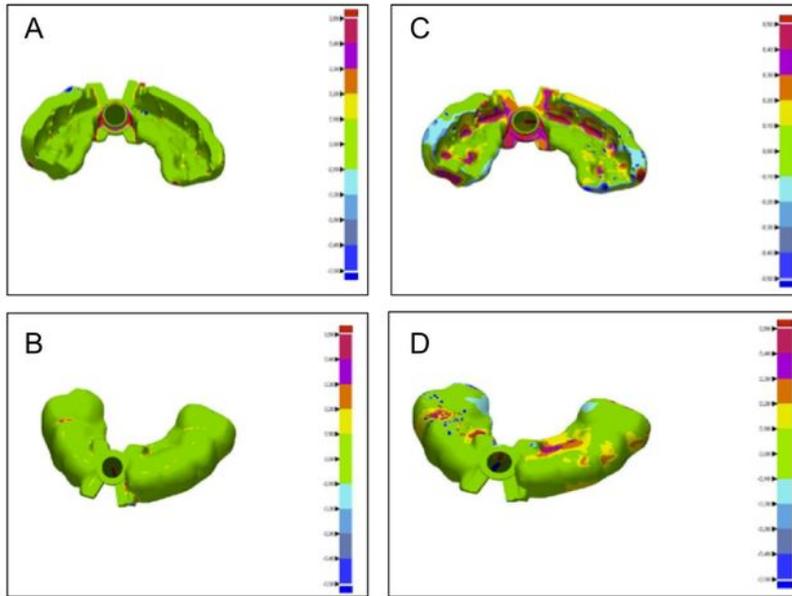
**Figure 3**

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.