A Novel Method for Precise Guided Hole Fabrication of Dental Implant Surgical Guide Fabricated with 3D Printing Technology

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Abstract: A dental implant surgical guide fabricated by 3-dimensional (3D) printing technology is widely used in clinical practice due to its convenience and fast fabrication. However, the 3D printing technology produces an incorrect guide hole due to the shrinkage of the resin materials, and in order to solve this, the guide hole is adjusted using a trimmer or a metal sleeve is attached to the guide hole. These methods can lead to another inaccuracy. The present method reports a technique to compensate for a decreased guide hole caused by shrinkage that can occur when a computer-guided implant surgical guide is fabricated with a 3D printer. The present report describes a technique to adjust the size of the guide hole using a free software program to identify the optimized guide hole size that is fabricated with the 3D printer.

Keywords: surgical guide; 3D printing; guided hole; dental CAD/CAM; dental implant

1. Introduction

The development of dental digital equipment has made computer-guided implant (CGI) surgery possible [1]. The implant can be positioned using a surgical guide that is designed according to the patient's surgical plan [2]. However, the accuracy of the surgical guide is affected by the manufacturing conditions [2]. The fabrication method (3-dimensional (3D) printing or milling), the properties of the materials (shrinkage and deformation), and the accuracy of the equipment can affect the final surgical guide, which can lead to incorrect implant positioning [2–4].

Numerous studies have evaluated the accuracy of the surgical guides [2–6]. Previous studies reported that the inaccuracies in the guided hole of the surgical guide can affect the accuracy of implant positioning [3,7,8]. Previously, a metal drill key was placed on the guided hole of the surgical guide to prevent inaccuracies [7]. Alternatively, the inaccuracy of the guided hole was resolved by fastening a separate metal sleeve to the prepared surgical guide using an adhesive [8]. However, these methods can lead to another inaccuracy [3,8].

An important factor for accurate implant positioning is the tolerance of the guide holes in the surgical guide [3–9]. Although it would be ideal for the drill and guide hole of the surgical guide to be precisely matched, it is impossible to insert the drill into the guide hole without tolerance. Therefore, it is necessary to apply a minimum tolerance. In order to adjust the size of the guide hole with minimum allowable tolerance, either a metal sleeve is applied or the inside surface of the guide hole is removed using a trimmer bur [9] However, these methods can cause inaccuracies in implant positioning [5]. If there is a large tolerance between the guide hole and the drill, the shake during the drilling process and the implant during the handling may be guided to an inappropriate position [3,9].

The use of dental 3D printers is increasing at a rapid pace. Factors such as the type of 3D printer, the light-polymerized resin material used, the accuracy of the equipment,
and the layer thickness can affect the result [10–12]. Since no factors are defined in the dental clinical environment, an optimization process is required [13]. The deviation of the dental implant’s position is caused by cumulative errors in the design and manufacture of the surgical guide [14,15]. The present technical note describes how to make guided holes with minimum tolerances using a 3D printer in dental clinical environments.

Inaccuracies in the placement of the placed dental implant can lead to surgical failures, such as nerve damage and complications that may occur in the maxillary sinus [16,17]. Therefore, the accuracy of the surgical guide is an important factor for the success of implant surgery [18]. In order to improve the accuracy of the surgical guide, there have been many studies to improve the accuracy of cone-beam computed tomography and intraoral impressions, and the accuracy of registration in software [19–22]. However, there are still insufficient studies to compensate for the shrinkage of the guide hole due to the shrinkage of the light-polymerized resin for 3D printing.

Although many software programs and 3D printers for CGI surgery are available, there is still a need for a method that can be optimized for more accurate implant positioning. This report describes a technique that uses free software to adjust the size of the guide hole in the 3D printing surgical guide. This technical note describes a method for creating a 3D printing surgical guide with minimal tolerance of guide holes in clinical practice.

2. Materials and Methods

This technical note was performed as shown in Figure 1.

2.1. Technical Note: Adjustment of the Virtual Surgical Guide before Fabrication

1. Plan the implant placement according to the patient’s treatment using CGI software (R2GATE v1.1.1; Megagen, Daegu, Republic of Korea) (Figure 2A). Then, export the CGI surgical guide from the CGI software into a standard tessellation language (STL) format file (Figure 2B).

Figure 1. Schematic of the procedure.

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2. Import the STL format file into a mesh editing software (Meshmixer; Autodesk Co, San Rafael, CA, USA) (Figure 3A).

![Figure 3](image)

**Figure 3.** Method to adjust the size of the guide hole using Meshmixer. (A) Importing virtual surgical guide. (B) Creating a cylinder. (C) Partial segmentation of the cylinder and surgical guide. (D) Setting a reference point at the base of the cylinder. (E) Setting a reference point in the guide hole of the surgical guide. (F) Alignment with the cylinder and surgical guide. (G) Identification of alignment. (H) Cylinder movement. (I) Deletion of the overlapping parts of the cylinder and surgical guide. (J) Identification of the adjusted guide hole.

3. Create the cylinder using a mesh editing software (Figure 3B). Then, adjust the size of the cylinder to a diameter of 5.2 mm by adding 0.2 mm to the original hole-size (5 mm) to compensate for the shrinkage of the resin material.

4. Use the “Face Group” function to separate the base of the cylinder and the guide hole in the surgical guide (Figure 3C).

5. Use the “Create Pivot” function to set up a reference point for alignment. Set the reference point at the base of the cylinder and the guide hole of the surgical guide (Figure 3D,E).

6. Use the “Align” function to superimpose the reference point. Select the reference point of the cylinder and hold down the Shift key while selecting the reference point of the surgical guide (Figure 3F). Make sure it is aligned to the correct position (Figure 3G).

7. Use the “Transform” function to move the cylinder so it can contact the entire guide hole (Figure 3H).

8. Use the “Boolean Difference” function to adjust the size of the guide hole. Select the surgical guide, hold down the Shift key while selecting the cylinder, and then select the “Boolean Difference” function (Figure 3I).

9. Check the adjusted guide hole (Figure 3J). Then, export the surgical guide with a guide hole of 5.2 mm diameter from the mesh editing software into a STL format file.

2.2. **Technical Note: Identification of the Surgical Guide for the Optimized Guide Hole Size**

1. Fabricate the surgical guides with guide hole sizes of 5.0 mm (original size) and 5.2 mm (+0.2 mm) in diameter using a 3D printer (MegPrinter; Megagen, Daegu, Republic of Korea) with photosensitive liquid resins (RAYDENT SG; Ray, Seoul, Republic of Korea).

2. Assess the size of the hole by inserting an implant surgical guide drill (R2GATE; Megagen, Daegu, Republic of Korea) into the hole of the surgical guides with guide hole sizes of 5.0 mm and 5.2 mm in diameter (Figure 4). The insertion of the drill was impossible at 5.0 mm (Figure 4A), while it was possible at 5.2 mm (Figure 4B).
3. Perform ‘Adjustment of the virtual surgical guide’ steps for the fabrication of surgical guides with guide hole sizes of 5.19 mm, 5.18 mm, and 5.17 mm in diameter. Using this process, it is possible to determine the minimum usable clearance between the hole and the drill.

4. Perform the 2 steps for assessment of the surgical guides with guide hole sizes of 5.19 mm, 5.18 mm, and 5.17 mm. The insertion of the drill was possible at 5.19 mm and 5.18 mm (Figure 5A,B), but was not possible at 5.17 mm (Figure 5C). Therefore, the value of 5.18 mm between 5.19 mm and 5.17 mm was determined as the minimum usable tolerance.

5. Fabricate 10 surgical guides with guide holes of 5.18 mm for repeatability. Then, assess the size of the hole by inserting an implant surgical guide drill.

6. Measure the size of the guide holes using a digital vernier caliper (500-197-20; Mitutoyo, Tokyo, Japan).

3. Results

The actual hole size of the surgical guide fabricated under the 5.18 mm diameter guide hole was measured to be a mean 5.06 ± 0.03 mm. Since no errors were observed in drill insertion, a 5.18 mm diameter guide hole was suggested as the size with minimum tolerance suitable for the conditions presented in this method.

4. Discussion

The size of the hole with minimum tolerance was proposed as 5.18 mm when preparing the surgical template as described in this technical note. These results may vary depending on the manufacturing conditions (equipment, material). If the described technique was used to fabricate surgical templates with minimum tolerance in the clinical environment with various manufacturing conditions, it will have a positive effect on the ac-
accuracy of implant positioning. If the equipment and materials do not change, the proposed hole size can be applied to other patients. Therefore, through this technical note, a dental clinician can create a surgical guide optimized for 3D printers and materials owned by the dental clinic.

Schneider et al. [9] reported that drill tolerance was reduced by decreasing the sleeve diameter of the surgical guide. Apostolakis et al. [5] reported that the maximum errors that could be caused by drill tolerance were 2.8 mm and 5.9° at the apex of the implant and implant axis, respectively. Koop et al. [6] reported that the maximum errors that could be caused by the type of sleeve were 1.3 mm, 2.4 mm, and 5.2° at the implant apex, implant shoulder, and implant axis, respectively. Therefore, minimum tolerance between the sleeve and the drill can improve the accuracy of the computer guide implant.

In a systematic review, the reliability, accuracy, and precision of implant surgical guides were reported [23,24]. It was concluded that the average deviations from the entry and apex of the implant placed using the surgical guide were 1.2 mm and 1.4 mm, and the maximum deviations were 4.5 mm and 7.1 mm [23,24]. Each step in computer-assisted guided surgery, from examination to planning and execution, has been reported to affect the final accuracy of implant placement [23,24]. The large tolerance between the guide hole and the drilling bur guides the implant to the wrong position [3,9]. In this technical note, a way to minimize tolerances was presented.

This technical note explains how to make a surgical guide with a guide hole of minimum tolerance. Guide holes with minimal tolerances prevent inadequate horizontal movement and allow the implant to be accurately guided to the planned position [3,9]. The minimum tolerance guide hole made with this technical note can minimize horizontal movement, but the vertical movement is associated with the stopper of the surgical guide, which can control the drilling bur vertically [25].

The spread of dental 3D printers is increasing, and the use of guides during implant surgery is being made and applied at the dental chairside environment [1–9]. The method presented in this technique is proposed to fabricate a surgical guide with minimum tolerance without the use of a metal drill key or a separate metal sleeve with the equipment (implant planning software and 3D printer) and printing materials readily available to clinicians. This technical note can also allow the clinicians to eliminate the need for pretreating the sleeve, which saves cost and time.

There is a limitation in that additional in vitro or clinical studies are required to verify the improvement of the accuracy of the computer guide implant with the present technique. In addition, the lack of visibility and small mouth opening may be a limitation of this note during implant placement. This technical note can be used as information for more accurate placement for clinicians who use 3D printers to create surgical guides and use them for surgery.

5. Conclusions

The method presented in this technical note allows the use of free software to fabricate the 3D printing surgical guide with minimal tolerances between the guided hole and drill without metal guide keys or metal sleeves. The present technical note gives baseline information that will be valuable for future investigations.

Author Contributions: Conceptualization, K.S.; methodology, K.S.; software, K.S.; validation, K.S.; formal analysis, K.S.; investigation, K.S.; writing—original draft preparation, K.S.; writing—review and editing, K.S.; visualization, K.S.; supervision, K.-b.L.; project administration, K.-b.L.; funding acquisition, K.-b.L. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the Industrial Strategic Technology Development Program (10062635, New hybrid milling machine with a resolution of less than 10 µm development, using open CAD/CAM S/W integrated platforms for one-day prosthetic treatment of 3D smart medical care system) funded by the Ministry of Trade, Industry and Energy (MOTIE, Korea).

Institutional Review Board Statement: Not applicable.
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