Effects of Operator's Experience on the Accuracy of Single Implant Position with Computer-Guided Surgery: A Pilot Study

Arissa Amnuaychottawe*[1] and Atiphan Pimkhaokham[2]

[1]Department of Esthetic Restorative and Implant Dentistry, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand
[2]Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand
*Corresponding author, E-mail: morningmeme11@gmail.com

Abstract

At present, dental implants are the best treatment for tooth replacement, and the basic necessity of successful implant therapy is an appropriate implant position. Computer-aided implant surgery (CAIS) becomes a standard approach for the implant installation process; nevertheless, current research is still not consistent on the effect of the surgeon's skill and the accuracy of the implant position. The purpose of this study was to analyze the accuracy of the implant position placed by experienced and inexperienced surgeons.

Six experienced and six inexperienced operators had participated in this study. One operator placed one implant on the right central incisor on the model using a computer-guided template that had been planned with implant planning software (3Shape Implant Studio® program). After the implant installation process was completed, all models were scanned and the placed implant position was determined. The amount of coronal, horizontal, vertical, and angular deviations of planned and placed implant positions were calculated and compared between experienced and inexperienced groups using the independent *t-test*.

For the inexperienced group, the mean errors of coronal, horizontal, depth, and angular deviations were 0.60 ± 0.21 mm, 0.33 ± 0.12 mm, -0.52 ± 0.19 mm, and 1.71 ± 0.29 degrees, respectively. For the experienced group, the mean errors of coronal, horizontal, depth, and angular deviations were 0.66 ± 0.19 mm, 0.22 ± 0.09 mm, -0.67 ± 0.13 mm, and 1.69 ± 0.20 degrees, respectively. The analysis showed no statistically significant difference between the two groups for all parameters. Nonetheless, these experimental results should be carefully applied to clinical reference because some limitations of this study were that it was an in vitro study and performed only a single implant by a limited number of participants.

To summarize, the operator's experience had no effect on the accuracy of single implant position performed under computer-guided implant surgery protocol.

Keywords: *Dental implants, Accuracy, Static surgical guided system, Guided surgery, Deviation, Implant placement*

1. Introduction

During the last decade, dental implants are one of the excellent options for the replacement of missing teeth. It is accepted that dental implant therapy is a predictable option for tooth substitution. Successful dental implant placement depends on the osseointegration, the function, and the esthetic of the final restorations (Margonar, Queiroz, Luvizuto, Betoni-Junior, & Zocal, 2012; Motta et al., 2016; Pyo, Lim, Koo, & Lee, 2019). The recent philosophy of prosthetic-driven implant placement has developed to enhance the esthetic consequence of the final restoration with proper mechanical and biological conditions (Van Assche et al., 2012).

Implant-supported restoration in the esthetic zone is one of the most challenging procedures because the major consequence following an anterior tooth extraction is the resorption of the alveolar bone which leads to the recession of gingival tissue and compromises the esthetic outcome. Complete reconstruction of the tooth and gingival tissue is the primary goal to achieve. The achievement of an esthetic result of the implant restoration is contributed from several factors, including tooth position, tooth shape, root position of the adjacent teeth, gingival biotype, the anatomy of bone, and the dental implant position (Jivraj & Chee, 2006).

To accomplish the proper implant position, the concept of three-dimensional (3D) implant placement has become a necessity. The purpose of this concept is to highlight the risk of potential complications if implants are not correctly positioned in relation to the adjacent natural teeth (Chen, Buser, & Dent Dr, 2015). In the past, the conventional method for implant placement, the freehand approach, is commonly used; however, in recent year, personalized surgical templates have risen in popularity for delivering the virtual plan to the actual situation since dental implant installation through the surgical template provides a surpassing accuracy in comparison with freehand insertion or freehand final drilling (Behneke, Burwinkel, & Behneke, 2012).

Computer-aided implant surgery (CAIS) is the new technology using a cone-beam computed tomography (CBCT) and computer-aided design/computer-assisted manufacture (CAD/CAM). Several advantages of this approach have been reported in previous studies. The advantage of the CAIS is decreasing postoperative discomfort as a consequence of flapless surgery. Furthermore, the CAIS provides a shorten surgical time, lessens the crestal bone alteration, decreases the inflammation and bleeding (Becker, Goldstein, Becker, & Sennerby, 2005; Beretta, Poli, & Maiorana, 2014; Van de Wiele et al., 2015). However, the disadvantages of this technique have also been reported. The important one is the limited access and visibility resulting from the flapless technique. Moreover, some authors revealed a number of complications found in computer-aided implant surgery (Hultin, Svensson, & Trulsson, 2012).

Definition of the accuracy in guided implant surgery is paralleling the virtual implant position in the planning software with the actual implant position in the patient's mouth (Vercruyssen et al., 2014). Documentation of the accuracy of computer-aided implant surgery is insufficient, and numerous factors are influencing the accuracy. The possible causes of reducing the accuracy of implant placement are the errors that may occur during each step, such as image acquisition, data processing, and surgical template fabrication. Moreover, movement of the template during drilling, flap approach, and type of template also related to the accuracy (Zhou, Liu, Song, Kuo, & Shafer, 2018).

Furthermore, there are limited reports available describing the effect of the operator’s level of experience on the accuracy of computer-aided implant surgery. Surgical experience has been reported to enhance the precision of implant placement and the success rate of osseointegration (Albrektsson, 1988; Cushen & Turkyilmaz, 2013; Hinckfuss, Conrad, Lin, Lunos, & Seong, 2012; Preiskel & Tsolka, 1995). On the other hand, some authors concluded that the operator’s experience did not affect the accuracy of implant installation (Cassetta & Bellardini, 2017; Hinckfuss et al., 2012; Rungcharassaeng, Caruso, Kan, Schutyser, & Boumans, 2015).

Numerous scientific reports have been investigated the accuracy of stereolithographic surgical templates. Hinckfuss et al. (2012) evaluated the effect of surgical guide design, operator’s experience, and size of the edentulous area on the accuracy. They concluded that the surgeon’s experience statistically significantly affects the accuracy of implant placement; furthermore, they found that an angular deviation in the buccolingual aspect was less in the experienced group. These results coincide with those of a study conducted by Cushen and Turkilmaz (2013). These authors determined the effect of surgeon’s experience on the accuracy of implant placement with bone support stereolithographic surgical template and reported a statistically significant difference between surgeons with and without experience groups for angular and horizontal deviation at implant platform and apex.

On the other hand, Cassetta and Bellardini (2017) revealed a statistically significant difference when considered the positioning error, whereas no statistically significant differences were found when considered the coronal, apical, and angular deviations.

The study of Rungcharassaeng et al. (2015) had evaluated the effect of the operator’s experience on the accuracy of implant placement using a computer-guided surgery protocol, in which the experiment was performed by ten experienced and ten inexperienced surgeons. They reported that there was no significant difference in the angular and linear deviations between the two groups (P>.01); nevertheless, they found that the amount of the vertical deviation at the platform and the apex was about twice in the inexperienced operators compared with the experienced operators.

According to the study of Park and others (2017) which investigated the accuracy of a surgical template regarding the different levels of operator experience and site of implant placement. Implants were placed in a model with and without the surgical guide by two experienced surgeons and two inexperienced surgeons. They revealed that no significant differences were found in all deviation parameters between experienced and inexperienced surgeons when using the surgical guide.

This study aimed to evaluate whether the operator's skill had an impact on the positioning error in single implant placement with a computer-guided surgery protocol.

2. Objectives

To determine the accuracy of implants inserted by experienced surgeons who had placed more than twenty implants compared with inexperienced surgeons who had no experience in placing the dental implants. The null hypothesis was that the correctness of the implant installation by the inexperienced surgeons does not differ from that of the experienced surgeons when using a step-by-step static computer-guided surgery. The advantage of this study was to verify the benefit and necessity of the use of computer-guided surgery systems.

3. Materials and Methods

3.1 Materials

3.1.1 Maxillary bony dentate models of custom polyurethane Nissin models (P9-x.1143-U, Nissin, Kyoto, Japan) with a single missing space at the right central incisor were used for the study models. D3 bone type was used for representing the anterior maxillary region (Figure 1A).

3.1.2 Straumann® Bone Level Taper implant 3.3, 10 mm (Straumann®, Switzerland) was used in this study.

3.1.3 Surgical guided templates fabricated by one template to one model protocol were used in this study (Figure 1B).

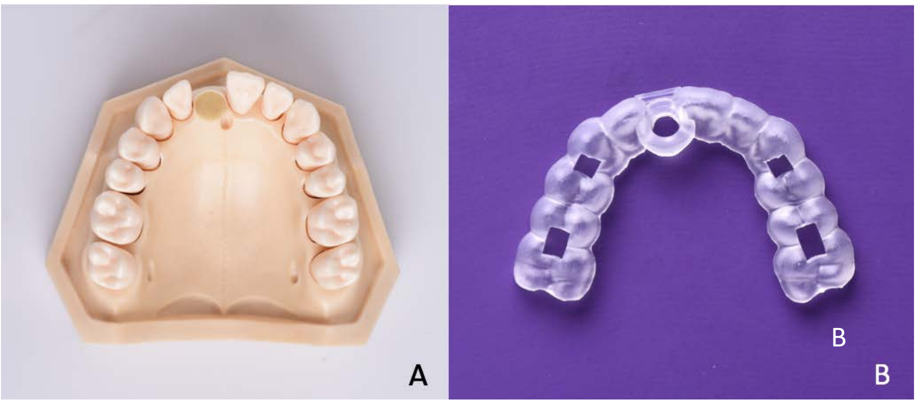

Figure 1 (A) The maxillary model with a single space missing at tooth number 11 and (B) The stereolithographic surgical template

3.2 Methods

All maxillary bony dentate models were scanned by standard cone-beam computed tomography (CBCT) with a 3D I-CAD machine (Imaging Science International LLC. Hatfield, PA, USA) and were scanned by 3Shape Trios® intraoral scanner (3shape A/S, Copenhagen, Denmark).

All scanned data were transferred to the 3Shape Implant Studio® program (3shape A/S, Copenhagen, Denmark) that was used to designate the position of the virtual implant. The planned implant was Straumann® Bone Level Taper 3.3 x 10 mm (Straumann®, Switzerland). The optimal position of the implant was adjusted manually by one dentist (Figure 2). After the dental implants were planned, the digital drill guides with sleeves were designed, and this information was sent to a dental laboratory for surgical template fabrication.

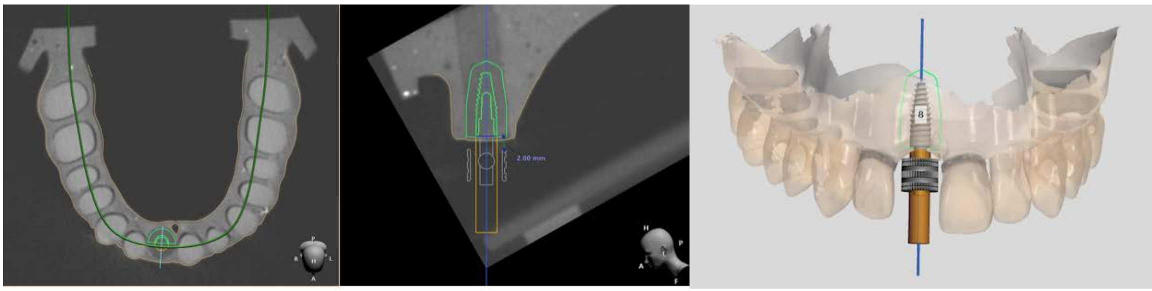

Figure 2 Planning of implant position with 3Shape Implant Studio® software

Six inexperienced operators were recruited from fifth-year dental students who received an implant lesson about computer-guided surgery but did not have any experience in placing the dental implants. Another six experienced surgeons were recruited from the dentists who graduated from the Esthetic Restorative and Implant Dentistry Program and had placed more than twenty implants with no less than three years of experience.

Before the surgical procedure started, the fit of each surgical guide was verified via inspection windows and adjusted manually. Fully guided placement systems were used in the present study. All maxillary models were fixed into a dental manikin head to simulate the clinical situation. The implant placement was performed by the experienced and inexperienced groups. One surgeon performed one implant placement. A step-by-step computer-guided surgery was explained to each operator. The osteotomy site preparation was performed as per the manufacturer's recommendation. After the osteotomy site preparation was completed in all blocks. The implants were inserted with an electronic surgical device until they reached the crestal bone level.

Postoperative model scans with the scan body were taken for all models with 3Shape Trios® intraoral scanner. The STL files of the planned and placed implant were superimposed and measured the deviation of the 3Shape® Implant position comparer tool (3shape A/S, Copenhagen, Denmark).

Four parameters used for the measurement of the outcomes were as follows: (1) coronal displacement (mm), (2) horizontal displacement (mm), (3) depth deviation (mm), and (4) angular deviation (degree) (Figure 3). The coronal displacement was calculated as a three-dimensional distance between the centers of the planned and the placed implant platforms. The horizontal displacement was defined as the distance between the center of the implant platform of the horizontal axis. The depth deviation was the distance of the longitudinal axis between the coronal centers of the planned and the placed implants. The angulation error was measured as the angle between the virtual and actual implant axis.

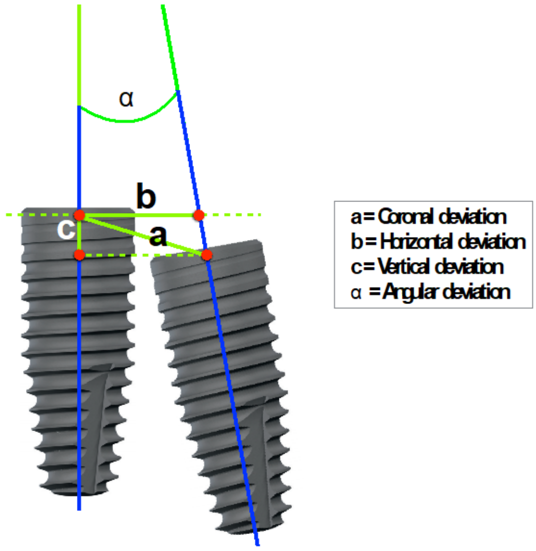

Figure 3 Measurement of deviation parameters: coronal (a), horizontal (b), vertical (c), and angular deviations (α)

4. Results and Discussion

Six experienced and six inexperienced operators were included in this study. One surgeon inserted one implant on the right central incisor. For the inexperienced group, the mean errors of coronal, horizontal, depth, and angle deviations were 0.60 ± 0.21 mm, 0.33 ± 0.12 mm, -0.52 ± 0.19 mm, and 1.71 ± 0.29 degrees, respectively. For the experienced group, the mean errors of coronal, horizontal, depth, and angle deviations were 0.66 ± 0.19 mm, 0.22 ± 0.09 mm, -0.67 ± 0.13 mm, and 1.69 ± 0.20 degrees, respectively. The mean and standard deviations of all parameters of the experienced and inexperienced operators are shown in Table 1.

The statistical analysis was performed with SPSS software (IBM Corp., NY, USA). All data were analyzed and compared using an independent *t*-test. The results did not show any statistically significant difference when the coronal (P = 0.818), horizontal (P = 0.545), vertical (P = 0.383), and angular (P = 0.109) deviations were considered (P>.01: Table 1).

Table 1 Accuracy of all parameters measured for the inexperienced and experienced group

	Inexperienced		**Experienced**		
Parameter	**Mean**	**SD**	**Mean**	**SD**	**P**
Coronal displacement (mm)	0.60	0.21	0.66	0.19	.818
Horizontal displacement (mm)	0.33	0.12	0.22	0.09	.545
Error depth (mm)	-0.52	0.19	-0.67	0.13	.383
Error angle (degree)	1.71	0.29	1.69	0.20	.109

The results of this study support the agreement of the null hypothesis. The level of the operator’s experience would not affect the accuracy of the implant position. There are several pieces of literature investigating the influence of a clinician’s experience on the accuracy when using a computer-guided surgery. The mean amount of the coronal error found in this study was 0.60 ± 0.21 mm in the inexperienced group and 0.66 ± 0.19 mm in the experienced group, which were in the range of similar investigations (Cassetta & Bellardini, 2017; Cushen & Turkyilmaz, 2013; Rungcharassaeng et al., 2015). Therefore, the result confirmed the conclusion of all the previously mentioned studies stating that experience had a limited influence on accuracy. Moreover, the mean amount of the angular deviation of this study was 1.71 ± 0.29 degrees in the inexperienced group and 1.69 ± 0.20 degrees in the experienced group, which is less than those found in similar studies. Rungcharassaeng et al. (2015) found a mean error of 3.21 ± 1.99 degrees in the inexperienced group and 4.11 ± 0.76 degrees in the experienced group, Cushen and Turkyilmaz (2013) found a mean angular deviation of 3.96 ± 1.64 degrees in the inexperienced group and 2.60 ± 1.25 degrees in the experienced group, and Cassetta and Bellardini (2017) found mean angle error of 3.07 ± 2.70 degrees in the inexperienced group and 3.21 ± 1.57 degrees in the experienced group. The less angular deviation may arise because this study was performed only one implant on the anterior region and used a tooth-borne surgical guide template, which is easier to control the stability of the surgical guide and accessibility of the drills.

Clinical reports previously revealed the learning curve. There is still an ambiguous conclusion about the chronological changes of surgeons on the report of gaining of placement skills. Vasak et al. (2011) found the effect of the learning curve, while another study by Valente, Schiroli, and Sbrenna (2009) did not found any implication. Therefore, this study used one operator to place one implant to eliminate the influence of the learning curve. Furthermore, the experienced and inexperienced operators in this investigation were not the same operator. This experiment did not use only one operator to place the implants at the first time as inexperienced and at the second time as experienced because this study focused on the accuracy regarding the level of experience. Therefore, the two groups should be completely dissimilar in the experience level. The surgery skill of placing implants might not that much gain within a couple of times of the operation.

The absence of a significant difference in positioning error between the experienced and inexperienced surgeons seems to propose that the static surgical guided system could improve the accuracy of the implant placement, especially for the operator with limited experience in placing implants.

However, limitations of this investigation were that it was an in vitro study executed under the controlled condition without limited mouth opening situation and tissue interruption by the patient's tongue and cheek, and may consequently underestimate an error. Besides, this study did not consider and compare the time spent in the implant placement process between the experienced and inexperienced operators. Further investigation may examine the time of the implant installation. Another limitation was that this study was a pilot study performed by a limited number of participants; therefore, these experimental results might not be able to be referred to in the clinical situation. Moreover, at present, most studies compared the effect of the operator's experience within only one system of surgical guide whereas the study emphasizing experience and accuracy according to different guided surgery systems has not been reported. Future research may be done with more participants or considered more than one system.

5. Conclusion

Within the limitations of this study, the operator's experience had no significant effect on the accuracy of the single implant placement under step-by-step computer-guided implant surgery. However, further investigations with a larger number of clinicians are recommended to confirm the results.

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