Comparing the Accuracy of Implant Placement between using Sleeve-in-sleeve and Sleeve-on-drill Drilling Systems: An Experimental Study

Papon Pattanasirikun* and Atiphan Pimkhaokham

Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chulalongkorn University, Bangkok Thailand
*Corresponding author, E-mail: papon.p36@hotmail.com

Abstract

In order to perform static Computer-Assisted Implant Surgery (sCAIS), various surgical drilling system designs have been developed, but currently there are a few evidences supporting which sCAIS design provide better accuracy when possible confounding factors are controlled. The objective of the study was to compare the accuracy of implant placement between sleeve-in-sleeve sCAIS and sleeve-on-drill in a controlled experimental setting. Two distinct drilling systems; sleeve-in-sleeve sCAIS and sleeve-on-drill sCAIS were assigned to 16 digitally printed models with two edentulous bilateral premolar areas filled with bovine bone. Models were scanned using CBCT and an intraoral scanner. 32 Implants were planned and 16 implants were placed in each group. Angular, platform, and apex deviation were measuring parameters used to calculate 3D deviation of the placed position from the planned position. Independent T-tests were used to assess the data (P-value 0.05). The mean angular, 3D platform and 3D apex deviation in sleeve-in-sleeve sCAIS group were 1.16 ± 0.63 degree, 0.49 ± 0.25 mm and 0.57 ± 0.31 mm respectively. The mean angular, 3D platform and 3D apex deviation in sleeve-on-drill sCAIS group were 2.25 ± 0.95 degree, 0.66 ± 0.22 mm and 0.80 ± 0.25 mm respectively. The results showed sleeve-on-drill sCAIS provided higher deviation in all parameters than sleeve-in-sleeve sCAIS. To conclude, there were significant differences between sleeve-in-sleeve and sleeve-on-drill sCAIS in all parameters which suggested that the design of the sCAIS affects the accuracy of implant placement which sleeve-in-sleeve design provides more accuracy.

Keywords: *Accuracy, Computer Assisted Implant Surgery, Dental Implant, Deviation*

1. Introduction

Dental implants have been utilized for more than 50 years and are a highly successful treatment option for the long-term restoration of missing teeth. The 10-year survival rate was estimated to be 96.4 percent (Howe, Keys, & Richards, 2019). Nonetheless, proper implant positioning is now regarded an essential prerequisite for achieving excellent treatment outcomes as well as long-term prosthesis maintenance and peri implant tissue health. Improper treatment planning and surgical techniques can result in a compromised implant position, which can lead to poor outcomes and complications (Buser et al., 2012; Mailoa et al., 2015; Testori, Weinstein, Scutellà, Wang, & Zucchelli, 2018).

In 1995, computer-assisted implant surgery (CAIS) was introduced to allow for a precise reproduction of the planned ideal implant position at the operative site (Fortin, Loup Coudert, Champleboux, Sautot, & Lavallée, 1995). Static computer-assisted implant surgery (sCAIS) refers to a virtual implant designed based on CT data in order to accurately guide the surgery under the guidance of a surgical guide template; however, the surgical guide template is not permitted to change the implant position during implant placement procedures (Hämmerle, Stone, Jung, Kapos, & Brodala, 2009; Wu et al., 2020). Numerous studies have demonstrated that sCAIS increases the accuracy of dental implant surgery in comparison to freehand surgery (Alevizakos, Mitov, Stoetzer, & von See, 2019; Varga et al., 2020; Younes, Eghbali, De Bruyckere, Cleymaet, & Cosyn, 2019).

Various elements of the sCAIS system are utilized to control and guide the drills during implant placement. The designs of sCAIS varied from a metal sleeve fitted into the surgical guide with the handheld "drill key" to newly designed drills with metal sleeve integrated into the drill. A metal sleeve inserted in the surgical guide and a portable drill key are used in the sleeve-in-sleeve system. The drill key is cylindrical in shape which fits precisely into the guide's sleeve (Neugebauer et al., 2010). New template design called sleeve-on-drill were recently launched with the goal of expediting and simplifying guided surgery workflow by having the metal sleeve integrated into the drills (Sittikornpaiboon et al., 2021; Tallarico, Kim, Cocchi, Martinolli, & Meloni, 2019).

Several studies have approached the factors affecting the accuracy of sCAIS. Sittikornpaiboon et al. has demonstrated significant lower angular, platform and apex deviation in sleeve-in-sleeve system comparing to sleeve-on-drill system. However, the implant macrodesign, sleeve height and sleeve position are different among experimental groups (Sittikornpaiboon et al., 2021). According to the study of Schnutenhaus, Edelmann and Rudolph (2021) it was reported that the macrodesign of the implant affects vertical deviation at platform of implants (Schnutenhaus et al., 2021). Another study of Kholy et al. also demonstrated that implant's macrodesign may affect the accuracy of sCAIS. Tapered implants had less angle, platform and apex deviation than cylindrical implants (El Kholy, Ebenezer, Wittneben, Lazarin, Rousson, & Buser, 2019). The study of Kholy et al., Safi et al. has also demonstrated the statistically significant between implant type and implant malpositioning which cylindrical type show more malposition (Safi, Amid, Zadbin, Ghazizadeh Ahsaie, & Mortazavi, 2021). The total drilling distance was reported to affect the deviation of implant. Angular, platform and apex deviation values became significantly higher when total drilling distance below the guided sleeve increased (El Kholy, Janner, Schimmel, & Buser, 2019).

The sCAIS systems are continuously evolving in terms of the various drilling guidance configurations and surgical guide designs. Although several designs are provided by manufacturers, little is known about the effect of surgical guide designs on accuracy and performance. Consequently, the purpose of this study was to compare the accuracy of implant placement between sleeve-in-sleeve and sleeve-on-drill sCAIS system based on an In Vitro experiment which allows for the elimination of most confounding factors.

2. Objectives

To compare the accuracy of implant placement between sleeve-in-sleeve and sleeve-on-drill sCAIS system

3. Materials and Methods

This study is a simulation-based experimental study. The study was performed at Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chulalongkorn University. All of the implants were placed by one experienced surgeon. The placement of implant was follow the ITI protocol using sCAIS which was design by implant planning program (coDiagnostiX).

3.1 Materials

- Model with edentulous area of tooth 14 and 24 filled with bovine bone
- 4.1 x 8 mm bone level tapered implant (Straumann AG, Basel, Switzerland)
- Cone beam CT (CBCT) machine (X-mind Trium, Acteon Group, Varese, Italy)
- ACTEON® Imaging Suite software (.-Acteon Group, Varese, Italy)
- Stereolithographic (SLA) surgical template (Straumann Guided Surgery, Straumann AG, Basel, Switzerland)
- Stereolithographic (SLA) surgical template (Straumann Guided Surgery, Straumann AG, South Korea)
- BLT guided surgery kit (Straumann Guided Surgery, Straumann AG, Basel, Switzerland)
- BLT guided surgery kit (Straumann Guided Surgery, Straumann AG, South Korea)
- Sleeve (5 mm sleeve height)
- TRIOS intra oral scanner (3shape, Denmark)
- Meshmixer software version 3.5.474 (Autodesk Inc., California)
- Netfabb Premium 2020 software (Autodesk Inc., California)
- surgical guide resin material (P Pro Master Model Gray, Straumann AG, Basel, Switzerland)

- 3D printer (Straumann CARES P30+, Straumann AG, Basel, Switzerland)
- Isopropyl alcohol
- Bovine bone
- Implant planning software (coDiagnostiX software version 9.7, Dental WingsGmbH, Chemnitz, Germany).

3.2 Methods

Model fabrication

In order to fabricate the models for the experiment, the intra-oral scan data (Standard Tessellation Language [STL]) from a patient who have bilateral edentulous areas at the maxillary first premolar were used. To design and create a horseshoe-shaped model, the STL file was created and imported into Meshmixer software. At both edentulous areas, a hollow space with a cylindrical shape with a diameter of 7 mm and a length of 15 mm was designed. After that, the final model file was imported into the Netfabb Premium 2020 software. A 3D printer was used to print digital models using a model resin material. The models were cured with UV after being rinsed with isopropyl alcohol. To simulate human cancellous bone of D2 and D3 density at the implant insertion site, hollow spaces at each edentulous site were filled with bovine bone. The 16 models were divided into 2 groups according to two drilling protocols under investigation; sleeve-in-sleeve sCAIS and sleeve-on-drill sCAIS. Eligible models were randomly assigned to one of the two groups; sleeve-on-drill sCAIS and sleeve-in-sleeve sCAIS using block randomization method via an online random sampling generator (research randomizer, https://randomizer.org/). Concealment was archived by using sealed opaque envelopes.

Implant planning procedure

Digital Imaging and Communications in Medicine (DICOM) file was genereated by having all models scanned with a cone beam CT (CBCT) scanner. The models were then scanned to create an STL file using an intraoral scanner. Implant planning software (coDiagnostiX software) was used to import the DICOM and STL files. The next step was to plan 32 implants, 16 for each drilling protocol. Each protocol had its own surgical kit. Both experimental groups had the same sleeve position, sleeve height and implant design. The free-drilling-distance (FDD) was controlled by using the same implant in both experimental groups to reduce the discrepancy between the surgical drill's tip and most apical point of the guided sleeve. The implant used in the study was a 4.1x8 mm bone level tapered implant. On the prosthesis design program (CARES Visual software), a digital wax up with the proper crown shape and size for bilateral first premolars were created. One researcher prepared all 16 surgical guides and planned all implants in the ideal prosthetic position, with the goal of having the same implant position and angulation in all cases.

The surgical guides were designed using coDiagnostiX software. In summary, FDI teeth #16, 15, 13, 12, 11, 21, 22, 23, 24, 25 and 26 with four inspection windows were supported by all 16 surgical guide templates. All surgical guides were manufactured using a 3D printer and 2 mm thick medical grade surgical guide resin material.

Surgical protocol

The surgical guide's fit on the model was validated via the inspection window before the implant surgery. The surgery was performed in the supine position with the models mounted on a phantom head and the operator seated in the right rear position (11 o'clock). All implant placements were performed by one experienced operator. The following are descriptions of the 2 different drilling systems.

Group A: sleeve-in-sleeve sCAIS system

Group B: sleeve-on-drill sCAIS system.

Both groups are shown in Figure 1.

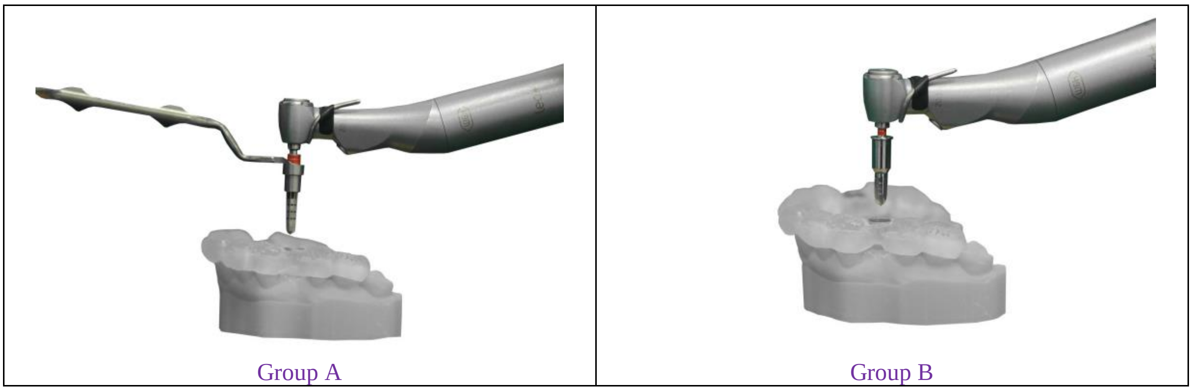

Figure 1 Group A demonstrated the sleeve-in-sleeve sCAIS and Group B demonstrated the sleeve-on-drill sCAIS

The drilling protocol was performed in accordance with the manufacturer's instructions. Using each system's guided template, the implants were placed fully guided.

3.3 Measurement parameter

All placed models were scanned with another investigator who was blinded and do not know which sCAIS was used in each model. CBCT was done after the implants were inserted. The DICOM files were then imported into the coDiagnostiX software and segmented at 540 to 3500 H threshold. By using surface-based registration, the postoperative CBCT were superimposed onto the preoperative CBCT, which contained the virtual plan implant. One operator was in charge of all processes and measurements. The treatment evaluation module calculated the 3D deviation between the planned and placed positions automatically.

Platform deviation - The displacement between the virtually planned and actual placed implant at the implant shoulder in total direction, measure in millimeter.

Apex deviation - The displacement between the virtually planned and actual placed implant at the implant apex in total direction, measure in millimeter.

Angular deviation - The angle difference between the axis line of the virtually planned implant and the axis line of the actual placed implant that cross the center of the implant shoulder and the center of the implant apex. The deviations were demonstrated in Figure 2.

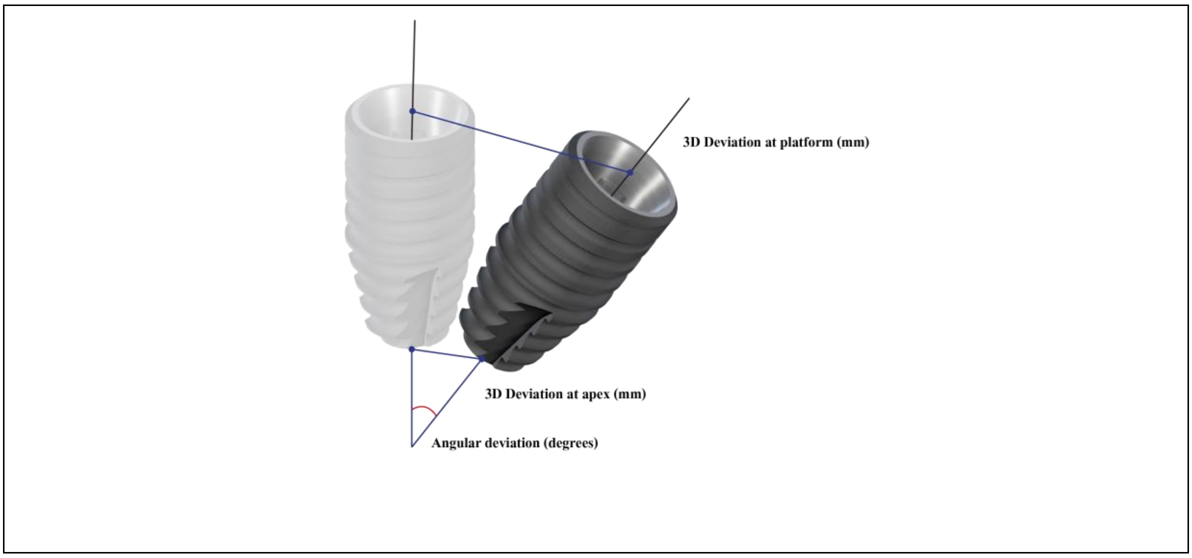

Figure 2 Angular, platform and apex deviation

3.4 Statistic analysis

IBM SPSS Statistics software was used to collect and calculate measurement data (version 24 software SPSS Inc., Chicago, IL) between utilizing sleeve-in-sleeve and sleeve-on-drill sCAIS. The mean difference between the virtually planned and actually placed implants in each model were compared. The Shapiro-Wilk test was used to determine the distribution of data. The independent T-test was used to compare the difference between sleeve-in-sleeve and sleeve-on-drill sCAIS. The level of significance was set at 0.05 with a confidence interval of 95%.

4. Results and Discussion

32 implants were placed in 16 models in this study. The main results of 3D deviation are presented in Table 1. The mean angular, 3D platform and 3D apex deviation in sleeve-in-sleeve sCAIS group were 1.16 ± 0.63 degree, 0.49 ± 0.25 mm and 0.57 ± 0.31 mm, respectively. The mean angular, 3D platform and 3D apex deviation in sleeve-on-drill sCAIS group were 2.25 ± 0.95 degree, 0.66 ± 0.22 mm and 0.80 ± 0.25 mm, respectively. Independent T-test demonstrated that there were significant differences between sleeve-in-sleeve and sleeve-on-drill sCAIS in all parameters (P value < .05) which were shown in Figure 3.

Table 1 Mean and standard deviation of measurement

sCAIS	Deviation	Mean	SD	Minimum	Maximum
Sleeve-in-sleeve	Angular (º)	1.16	0.63	0	2.60
	Platform (mm)	0.49	0.25	0.13	0.96
	Apex (mm)	0.57	0.31	0.07	1.15
Sleeve-on-drill	Angular (º)	2.25	0.95	1.0	4.0
	Platform (mm)	0.66	0.22	0.35	1.10
	Apex (mm)	0.80	0.25	0.43	1.26

sCAIS, Static computer assisted implant surgery; SD, Standard deviation; º, degree; mm, millimeter

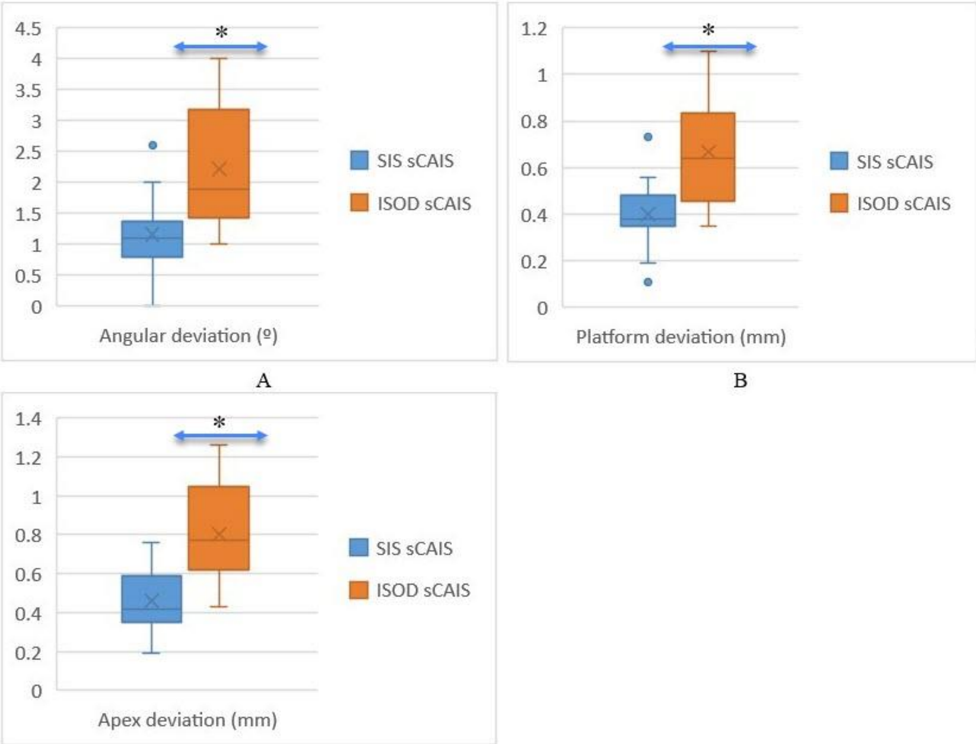

Figure 3 (A) Angular deviation in degree, (B) platform deviation in millimeter and (C) apex deviation in millimeter. SIS sCAIS, sleeve-in-sleeve static computer assisted implant surgery; ISOD sCAIS, Sleeve-on-drill static computer assisted implant surgery; *, statistically difference

In a strictly controlled in vitro setting, this study aimed to examine the potential impact of the design of two guided surgery devices and protocols on the accuracy of implant placement. The mean deviations of the angle, platform and apex for both groups were 1.69 degree, 0.53 mm and 0.63 mm, respectively.

Despite this, there were significant differences in accuracy between both systems examined, indicating that the clinical outcomes may be considerably influenced by guide designs, drilling protocol and instruments used.

Due to the present quick evolution of sCAIS, numerous alternative designs are being suggested and used. In order to discover the best practices, optimize processes, and increase the accuracy of sCAIS, it would be imperative to have more data about how alternative designs affect clinical outcomes. However, this data are currently quite limited.

Many previous studies have demonstrated the deviation between planned and placed position. (Alevizakos et al., 2019; Buser et al., 2012; Di Giacomo, Cury, de Araujo, Sendyk, & Sendyk, 2005; Ersoy, Turkyilmaz, Ozan, & McGlumphy, 2008; Nickenig, Wichmann, Hamel, Schlegel, & Eitner, 2010; Ozan, Turkyilmaz, Ersoy, McGlumphy, & Rosenstiel, 2009; Pettersson, Komiyama, Hultin, Nasstrom, & Klinge, 2012; Smitkarn, Subbalekha, Mattheos, & Pimkhaokham, 2019; Valente, Schiroli, & Sbrenna, 2009). In this study, the 3D deviation at platform, apex and angulation were shown to be similar to the previous studies. The results of this study demonstrated more accuracy in sleeve-in-sleeve sCAIS group comparing to sleeve-on-drill sCAIS group which was similar to the previous study of SittiKornpaiboon et al.

The results showed sleeve-on-drill sCAIS to present with higher deviation in all parameters than sleeve-in-sleeve sCAIS. These differences might be related to the design of the surgical guide in each systems. The design of sleeve-in-sleeve sCAIS system allowed the drill to have more guiding channel. This study is in agreement with the study of Choi et al., which demonstrated that the angle deviation, in degrees, at a channel length of 9.0 mm was significantly smaller than at a channel length of 6.0 mm which suggested that making the drill guiding channel longer can reduce angular deviation values in dental implants (Choi, Romberg, & Driscoll, 2004).

5. Conclusion

There were significant differences between sleeve-in-sleeve and sleeve-on-drill sCAIS in all parameters which suggested that the design of the sCAIS affects the accuracy of implant placement in which sleeve-in-sleeve design provides more accuracy.

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