Accuracy of Implant Placement using Static CAIS among Four Types of Bone at the Anterior Single Tooth Missing in vitro Study

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Abstract

Purpose: To compare the precision of implant placement in the single space missing of anterior tooth in different circumstances of bone type using static CAIS system (Co-diagnostic system, Straumann ®). The author hypothesized that the accuracy of implant placement among four type of bones are not different when using static CAIS. *Methodology*: 20 maxillary models with artificial bone density D1-D4, 5 models for each group, were prepared with single space edentulism on tooth no.11.Virtual implant position were planed according to CBCT using co-DiagnostiX™ software. After 20 stereolithographic surgical stents were designed and printed out, the single surgeon placed the implant according to the protocol of the software. Then the samples were taken CBCT again, after obtain postoperative CBCT, the DICOM file of samples were superimposed with virtual planed of individual model to perform accuracy measurement. *Result* The data from 20 models, 5 models for each bone types, involving 20 implants were evaluated. There were no significant different among four bone types when compare to the overall precision placed implants via static CAIS system. The mean angular deviation was 0.71±0.20°, the mean base 3D offset deviation was0.85±0.23 mm. and the mean tip 3D offset deviation was 0.87±0.24 mm. *Conclusions*: Using the static CAIS system for implant placement show small deviation from virtual planning among four bone types. The result reflected accuracy and precision that can be achieved from CAIS system when placing implant in any density of bone.

Keywords: *Accuracy, Static CAIS, Implant placement, Anterior tooth, Single space, bone density*

1. Introduction

Nowadays dental implants are considered a good choice for using to replace teeth loss. The benefits of implant has overcome the benefit of others alternative restoration such as removable denture or bridges. Implant can maintain and stabilize alveolar bone from collapsing and reduce rate of bone resorption. However placing implant come with many challenges for example narrow bone, limitation of crucial structure and bony types. The concept of implant placement is prosthetic driven. To achieve the success of the work, implant must be placed according to the proper position with good treatment plan and well prepare surgical procedure. Moreover the position and angle of placed implant should support the restoration esthetically and functionally align with over all dentition and occlusion. Conventional implant placement methods had shown unpredictable result and periodically may lead to unwanted complications (Vermeulen, 2017; Hinckfuss et al.,2012; Danza, Zollino & Carinci, 2009). Therefore this problem can be solved with the recent developed of assistance tools in order to improve the precision of implant planning and assist in accurate placement by using computer assisted implant placement system (CAIS). CAIS can be categorized into two groups of static and dynamic CAIS. This study will focus on static CAIS in which virtual plan implant position was planed properly then surgical stent were fabricated with computer-aided design and computer aided manufacturing (CAD/CAM) base on 3D scan of the models. Surgical stent were made of polymerize photosensitive liquid acrylic from computer guided laser beam. Subsequently metal cylinder tube was used as the drill guide will be put into the acrylic stent to guide the drilling. In the esthetic zone, 3D positioning implant is very important in order to execute optimum esthetic and functional outcome. Proper implant position as well as optimum volume of hard and soft tissue support are the important factors for successful treatment. On the other hand malposition of dental implant placement may cause complication in couple ways. First is malposed implant in relation to bone and peri-implant tissue may cause more risk of biological failure. Second improper position implant related to planned prosthesis result in esthetic failure and mechanical failure by difficulty of oral hygiene practice.

Previous studied had proved the accuracy of implant surgery with surgical guide. The deviation at the apex was 0.59 mm. in the maxilla and 0.4 mm. in the mandible in an experimental model with CAD/CAM template (D'haese et al., 2012). Besides, from the review of accuracy in computer guided surgery (Widmann & Bale, 2006) showed maximum difference between the planing versus the actual position were 1.2 to 2.0 mm. However, recently there are still no accepted standard for the accuracy of implant placed with surgical guide (Toyoshima et al.,2015). Also no study had reported the precision of placing implant in solely esthetic zone among different types of bone density. According to Misch's classification (Misch, 1990; Turkyilmaz, Ozan, Yilmaz, & Ersoy, 2008) it had categorized bone into four groups based on macroscopic cortical and trabecular bone characteristics. D1 bone contains homogenous compact bone with almost no trabeculae. D2 bone consists of thick layer of compact bone surround with dense trabeculae bone. D3 bone has a thin compact bone surround with dense trabeculae bone and D4 bone is a thin layer of compact bone enclose with core of low density trabeculae bone. Determination of available bone is particularly important in implant placement in term of quality of bone is able to reflect the long term success of implant placement position and stability also in aspect of healing process and prosthetics loading.

2. Objectives

The aim of this study was to evaluate the accuracy of implant placement using guided surgery in four different types of bones only in esthetic zone in vitro study.

3. Materials and Methods

Artificial maxillary model with single edentulism space of tooth no.11 were prepared as a mother model (Nissin primary PE-ANA003, Nissin,Kyoto,Japan). Subsequencely twenty models were made out from the mother model by using polyurethane and integrated the synthetic bone for each bony type (Misch's classification) into the model and divided into five models in each group of individual bone types (fig1.) with the quality that mimic natural bone (Sawbone®; Pacific Research Laboratories Inc., Washington,USA), which made out from polyurethane foam for mechanical testing that had considered to be used as a standard for performing orthopedic implant mechanical testing. Moreover the synthetic bone provide 95% consistent material with properties in range of human bone. D1 bone stimulation used 40 pound per cubic foot (pcf) with bone density of 0.64 g/cm^3 polyurethane foam. D2 bone was stimulated using 30 pcf polyurethanefoam with density of bone 0.48 g/cm^3. D3 bone imitated 20 pcf polyurethane foam with density of bone 0.32 g/cm^3, and D4 bone using 10 pcf with 0.16 g/cm^3 to stimulate the artificial bone. The samples size, that used in this study, were preliminary apply as a pilot study. After model preparation, the study models were taken with cone-beam CT scan (i-CAT machine; Imaging Science International LLC.Hatfeild,PA,USA) at standard setting of 120 kV,15mA, exposure time of 9.6 s, and voxel size of 0.2mm, to achieve CBCT. After all models were scanned by CBCT, Digital imaging and comunications in medical (DICOM) files were obtained. The DICOM files were then transferred to implant planning software (co-DiagnostiX™; Straumann,Basel,Switzerland). Moreover 20 maxillary models were scanned by 3D model scanner machine individually (Omnica CEREC;Sirona,Densply,Erlangen,Germany) and the files were converted into STL file before uploading to the software in order to match with the DICOM file of each individual sample. After both Dicom and STL file of each sample was paired then crowns forms were created via the software in relation to bone as well as the 20 implants position were digitally planed along with prosthetic driven concept. Virtual planed implants are done according to manufacturer's instruction beside the guide sleeve of size 5 mm in diameter was selected to be incorporated with the templates. In the meantime stereolithographic surgical templates had been printing out by 3D printing according to the virtual plane (Figure 2).

3.1 Implants placement

Single surgeon with experience of implant placement performed the experiment. Twenty polyurethane models with four different bony types with opposing mandibular arch were mounted on the mannequin head to stimulate intraoral situation (Nissim type1 advance, Nissin, Kyoto Japan). Each stereolithographic surgical templates was positioned into individual models and fit was checked and controlled visually and manually before begin the surgery. Afterward implant placement at tooth site 11 was performed under the protocol of the software with blind technique of each bone type, using implant diameter 3.3 length 10 mm. (BLT, Straumann, Basel, Switzerland) with the guided surgery kit (Straumann) for delivering all implants.

3.2 Accuracy measurement

Then the models were retaken CBCT scan (i-CAT) after all the experiments and DICOM files of placed implant were achieved. The DICOM files of virtual planed and postoperative placed were superimposed into the same coordination system, via the co-DiagnostiX™ software for 3-dimensional implant precision measurement. Deviation was measured in three dimension at the center of virtual planed and postoperative implant. To calculate the planed and actual implant position, vertical line and middle of occlusal plan line of both implant were drawn and the intersection distance was measured (Figure 3). These are the parameters outcomes; deviation of the axis (degree angle), deviation of 3D offset at base (mm), deviation 3D offset at tip of implant (mm). The negative value describe the opposite direction of implant placement compare with the planned position. To calibrate the precision of software measurement error, accuracy was recalculated four times for each sample (Figure 4).

Figure 1 Model with integrated artificial bone with variable in density (type I-IV) according to Misch's classification(left) and the model with stereolithographic surgical guided full templates with sleeve at the surgical site (right)

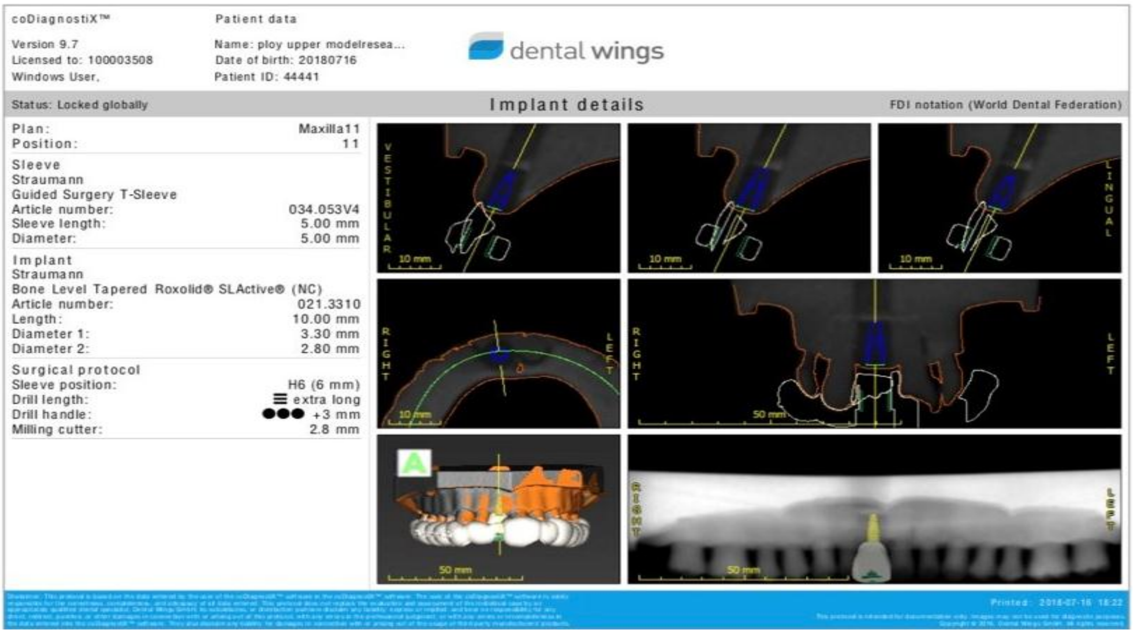

Figure 2 Virtual implant planning according to prosthetic driven concept of each model and stereolithographic surgical guided stents were designed with co-DiagnostiX™ software

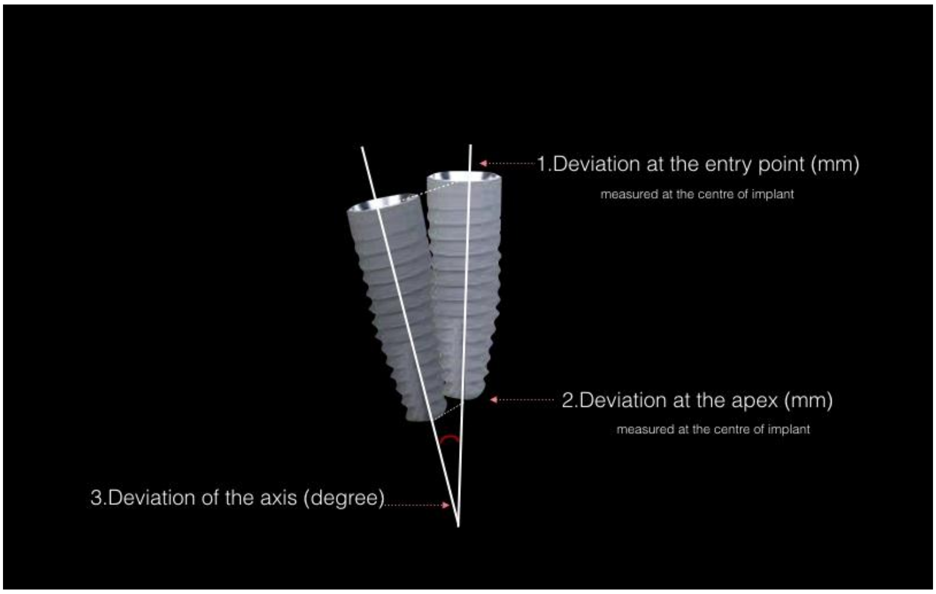

Figure3 Deviation measurement by drawing the vertical line and middle of occlusal plan line at center of both implants diameter with the intersection distance then were calculated

Figure 4 Superimposed position of virtual planed and postoperative placed implant, to compare the 3D precision of using computer guided surgery

4. Results

The mean 3D offset accuracy of bone type 1 deviated at base, at the tip and angle deviation was 0.80±0.15 mm, 0.80±0.21 mm and 0.76±0.23°respectively. For bone type 2, 3D offset deviation was 1.00±0.31 mm at the base, 1.02±0.27mm at the tip and 0.64±0.11° for angle. Density of bone type 3, 3D offset deviation at the base was 0.89±0.24 mm, at the tip was 0.87±0.28 mm and angle deviation was 0.74±0.22°. For type 4 bone, 3D offset deviation at the base was 0.72±0.16 mm, 0.80±0.20 mm for 3D offset deviation at the tip and angle deviation was 0.69±0.25°. (table1)

Table 1 The deviation of postoperative implant insertion when compare with planned virtual position, this demonstrate parameters of each bone density group

Deviation of postoperative placed implants

Bone density	Angle	Base3d offset	Tip3d offset
D1			
Mean	.76	.80	.80
n	5	5	5
Std.deviation	.23	.15	.21
D2			
Mean	.64	1.00	1.02
n	5	5	5
Std.deviation	.11	.31	.27
D3			
Mean	.74	.89	.87
n	5	5	5
Std.deviation	.22	.24	.28
D4			
Mean	.69	.72	.80
n	5	5	5
Std.deviation	.25	.16	.20
Total			
Mean	.71	.85	.87
N	20	20	20
STD.DEVIATION	.20	.23	.24

Total 20 models and 5 models for each group of bone types (n=5) displayed implant displacement raw data of mean and standard deviation described 3D offset at base deviation, 3D offset at tip deviation, and angular deviation of the samples which contain bone type 1,2,3 and 4 demonstrated in Table2. There were no significant different of implant placement precision found among four types of bone. Therefore the hypothesis is accepted ($P<0.05$). Overall precision of all the bone density groups demonstrated; the mean angular deviation was 0.71±0.20°, the mean 3D offset at base deviation was 0.85±0.23 mm. and the mean global apical position deviation was 0.87±0.24mm.

Table2 The statistical of all parameter show no significant different between each group

Anova

	Sum of squares	df	Mean square	F	Sig
Angle					
Between group	.043	3	.014		
Within group	.711	16	.044	.321	.810
Total	.725	19			
Base 3D offset					
Between group	.281	3	.073		
Within group	.785	16	.049	1.481	.257
Total	1.003	19			
Tip 3D offset					
Between group	.159	3	.053		
Within group	.932	16	.058	.907	.459
Total	1.091	19			

5. Discussion

Regarding overall result it show that using static CAIS for implant placement provide promising result with any bone type. The densities of bone are considered as an important factor that should be determined prior to place implant due to the process of healing period, which primary stability occur at the time when implant is first delivered, that related with contact of bone and biomechanical properties of surrounding bone. Later on secondary stability begin to play a role with osseointegration. In addition densities of the bone are able to affect implant position according to the previous study described that dense bone may offer better implant placed position. Besides bone densities affect the determination of treatment planning, selection of implant design, surgical approach, and initial loading of prothesis. Poor bone density associate with increasing risk of implant failure due to the lack of implant stability and excessive bone resorption. Therefore densities of bone and implant planing position at the recipient site has to be precisely recognized prior, during and after delivered implant for the long term success. According to the result it can be implied that guided surgery can be able to use with any site intra orally not only maxillary arch but mandible can also be apply with this appliances since individual area may consist of variety bone type thank to the outcome that demonstrated no different accuracy among bone types. Therefore the null hypothesis is accepted for all the parameters.

Static CAIS can minimize injuries of the critical anatomic structure like mandibular nerve, maxillary sinus floor and incisive canal (Gaggl, Schultes, & Kärcher, 2001; Ruppin et al.,2008). According to the finding of Ozan, Orhan and Turkyilamaz (2011) ; Noharet, Pettersson, & Bourgeois (2014) stated that lower bone density can cause greater deviation when using free hand technique to place implant however guided surgery can reduce malposition and overcome this problem in poor bone quality. The study outcome of computer guided surgery in this study is similar to others studied that had published in accuracy. Furthermore previous studied had illustrated that type of arch, age and gender had no statistically significant different outcome when using computer guided surgery (Zhou et al., 2017; Chugh et al.,2013). In single space loss using static CAIS for implant placement clinically provide statistically accurate in posterior and anterior tooth in both arches (Keawsiri, (2018 In press).

There are some limitations of this study, since there are some limited amount number of sample sizes as well as the model study does not reflect the real life clinical situation such as no bleeding and saliva, no movement of patient and no patient in compliance. In addition the differences of software may provide variable result due to mode of precision measurement has sensitivity, also fit of stereolithographic surgical stent is a very important factor if misfit of surgical stent occurred, result would be inaccurate. Moreover experiences of surgeon is another cause that can affect outcome in particularly vertical dimension is the most inaccurate influence by the surgeon level of experience (Rungcharassaeng et al, 2015; Schneider et al.,2009; Marchack, 2005). Thus further study should be done in clinical situation and measurement of the implant placement accuracy should include scanning technique besides the experiment should comprise of larger amount of samples size.

6. Conclusion

The result of this in vitro study demonstrated the promising accuracy of static CAIS when delivering implant through four different bone densities also the software provide predictable result when placing a single implant at the esthetic area which periodically had difficulty with defect of bone as well as a limitation of narrow bone. Moreover the application of guided surgery is usefulness when transfer a virtual plane implant position to the clinical situation accordingly it also provides reliable and beneficial outcome.

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8. References

Chugh, T., Jain, A. K., Jaiswal, R. K., Mehrotra, P., & Mehrotra, R. (2013). Bone density and its importance in orthodontics. *Journal of Oral Biology and Craniofacial Research*, *3*(2), 92-97.

Danza, M., Zollino, I., & Carinci, F. (2009). Comparison between implants inserted with and without computer planning and custom model coordination. *Journal of Craniofacial Surgery*, *20*(4), 1086-1092.

D'haese, J., Van De Velde, T., Komiyama, A. I., Hultin, M., & De Bruyn, H. (2012). Accuracy and complications using computer-designed stereolithographic surgical guides for oral rehabilitation by means of dental implants: a review of the literature. *Clinical Implant Dentistry and Related Research*, *14*(3), 321-335.

Gaggl, A., Schultes, G., & Kärcher, H. (2001). Navigational precision of drilling tools preventing damage to the mandibular canal. *Journal of Cranio-Maxillofacial Surgery*, *29*(5), 271-275.

Hinckfuss, S., Conrad, H. J., Lin, L., Lunos, S., & Seong, W. J. (2012). Effect of surgical guide design and surgeon's experience on the accuracy of implant placement. *Journal of Oral Implantology*, *38*(4), 311-323.

Kaewsiri. (2018).The Accuracy of Static versus Dynamic Computer Assisted Implant Surgery in Single Tooth Space: A Randomize Controlled Trial. *Clinical Oral Implant Research*,(in press).

Marchack, C. B. (2005). An immediately loaded CAD/CAM-guided definitive prosthesis: a clinical report. *The Journal of Prosthetic Dentistry*, *93*(1), 8-12.

Misch, C. E. (1990). Density of bone: effect on treatment plans, surgical approach, healing, and progressive boen loading. *The International Journal of Oral Implantology: Implantologist*, *6*(2), 23-31.
Noharet, R., Pettersson, A., & Bourgeois, D. (2014). Accuracy of implant placement in the posterior maxilla as related to 2 types of surgical guides: a pilot study in the human cadaver. *The Journal of Prosthetic Dentistry*, *112*(3), 526-532.
Ozan, O., Orhan, K., & Turkyilmaz, I. (2011). Correlation between bone density and angular deviation of implants placed using CT-generated surgical guides. *Journal of Craniofacial Surgery*, *22*(5), 1755-1761.
Ruppin, J., Popovic, A., Strauss, M., Spüntrup, E., Steiner, A., & Stoll, C. (2008). Evaluation of the accuracy of three different computer-aided surgery systems in dental implantology: optical tracking vs. stereolithographic splint systems. *Clinical Oral Implants Research*, *19*(7), 709-716.
Rungcharassaeng, K., Caruso, J. M., Kan, J. Y., Schutyser, F., & Boumans, T. (2015). Accuracy of computer-guided surgery: a comparison of operator experience. *The Journal of Prosthetic Dentistry*, *114*(3), 407-413.
Schneider, D., Marquardt, P., Zwahlen, M., & Jung, R. E. (2009). A systematic review on the accuracy and the clinical outcome of computer-guided template-based implant dentistry. *Clinical Oral Implants Research*, *20*, 73-86.
Toyoshima, T., Tanaka, H., Sasaki, M., Ichimaru, E., Naito, Y., Matsushita, Y., ... & Nakamura, S. (2015). Accuracy of implant surgery with surgical guide by inexperienced clinicians: an in vitro study. *Clinical and Experimental Dental Research*, *1*(1), 10-17.
Turkyilmaz, I., Ozan, O., Yilmaz, B., & Ersoy, A. E. (2008). Determination of bone quality of 372 implant recipient sites using Hounsfield unit from computerized tomography: a clinical study. *Clinical Implant Dentistry and Related Research*, *10*(4), 238-244.
Vermeulen, J. (2017). The Accuracy of Implant Placement by Experienced Surgeon: Guided vs Freehand Approach in a Stimulated Plastic Model. *International Journal of Oral & Maxillofacial Implant*,*32*(3), 617-624.
Widmann, G., & Bale, R. J. (2006). Accuracy in computer-aided implant surgery--a review. *International Journal of Oral & Maxillofacial Implants*, *21*(2), 855-863.
Zhou, W., Liu, Z., Song, L., Kuo, C. L., & Shafer, D. M. (2018). Clinical factors affecting the accuracy of guided implant surgery-A systematic review and meta-analysis. *Journal of Evidence Based Dental Practice*, *18*(1), 28-40.