Comparison of the Accuracy between Digital and Conventional Impression Techniques in Angulated Implants by 3D Super Imposition Soft-Ware

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Abstract

This study aims to compare the accuracy of three-dimensional changes in position and angulation between digital and conventional impression techniques in different angulated implants at the mandibular partial edentulous area with the use of a mandibular partial edentulous reference model with 2 dental implants in different angulations (15 degrees buccally and lingually). Conventional and digital impression techniques were used for master model and fabricated 10 conventional master casts and 10 three dimensional printing models. Each scan body was connected with implant or analog to transfer implant positions. All of the master model, master casts, and printing models were scanned with computer measuring machine and evaluated with Polywork software program. Dimensional change of positions and angulations ware calculated and statistically analyzed. Models with lingually and buccally placed implants showed the distance to reference at 37 and 36 areas of 23.637, 31.984 mm while conventional impression and digital impression models displayed 23.942, 32.238 mm and 23.592, 32.137 mm, respectively. Angulation of 37 and 36 areas in the reference model was 69.628 and 78.455. Conventional method exhibited angulation of 71.076 and 78.395 along with angulation of 69.298 and 78.399 in digital technique Within the limitation of this vitro study, partially digital impression technique by the 3Shape intraoral scanner with 3D printing models presented significantly superior accuracy of 3- dimensional distance and angulation to conventional one. Angulated dental implants decreased the accuracy of the conventional approach. Both techniques were clinically acceptable to treat the patients. However, the digital technique is recommended to have more accuracy and decreased chair time. A digital impression of angulated implants was presented more accurate than conventional one in both of distance and angulation

Keywords: *Impression, Dental Implant, Angulation, Digital, Conventional, Dimensional change.*

1. Introduction

In restorative implant dentistry, constant problems regarding communication between dentist and laboratory technician are found, for example, shade selection, abutment selection, and model accuracy. To create an accurate model for multiple implant restorations with conventional impression technique, the dentist must select proper impression materials and techniques to obtain an accurate master model. Conventional impression technique in implant dentistry can divide into two categories which are impression via impression coping (open or closed tray) and direct impression from the final abutment. Both techniques z elastomer impression material and models were made from dental stone. However, errors can occur during each step of the workflow process. The dimensional deformation of an elastomer impression material and expansion of dental stone can cause an error, especially in multiple and angulated implants which presented more than 3 implant positions in the master cast (Vandeweghe et al., 2016). It also resulted in the misfit of the final restoration, especially in connected multiple implant units (Conrad et al., 2007). With this conventional technique, the dentist must know how to verify and correct the master model prior to sending it to the laboratory.

With the advent of digital technology in restorative implant dentistry, the workflow of fixed prosthodontic dentistry can be simplified and improved. These technologies are subjected to produce the most accurate models with reduction of workflow process compared to a conventional fashion. Digital workflow process starts with an impression by the intraoral scanner to positioning implant using implant scan body. Data from the scanner can be directly sent to the laboratory for a final restoration fabrication or a master model printing. These technologies allow the dentist to make an impression without any other materials used and reduce errors during a laboratory process (Miyazaki et al., 2009). However, some errors had been reported from these technologies. For example, Intraoral scanner showed less accuracy in the arch curve especially at maxilla and mandibular anterior residual ridge (Akalin et al., 2013). Also, Digital printing models from additive manufacturing technologies presented significant distortion at multiple implant positions in horizontal dimension especially in multiple angulated implant (Papaspyridakos et al., 2014). Moreover, accuracy and precise restorations can be affected by several factors such as different types of an intraoral scanner, milling machine systems, coordinating software program, and material printing selections (Seelbach et al., 2013). Therefore, many research selected the CEREC system which claimed to have high accuracy and also eliminate data compatibility in the workflow. Nonetheless, this system is a closed system and the chance to cooperate with other hardware and software are limited. Since the development of digital dental workflow become abundant to various companies, intraoral scanner as 3 Shape system (open system) has claimed to be the effective accurate system and easily available to connect to other software programs. Interest was found in 3 shape system to study the accuracy of digital impression in multiple dental implants compare with the conventional method.

2. Objectives

The purpose of this study was to measure and compare the accuracy in three dimensions of working casts which fabricated from digital and conventional impression techniques in angulated implant positions by comparing the distance and angulation relationships in the conventional and digital working cast to the reference model.

3. Materials and Methods

3.1 Reference model

Mandibular model without molar teeth (X-761: Nissin, Kyoto, Japan) was fixed with three calibrated metal sphere balls (φ10.0 mm steel ball: a grade 28 (JIS B 1501, ISO 3290), Sato Tekkou, Japan) using self-cured acrylic resin (UnifastIII: GC, Tokyo, Japan) to be reference position following to articulating arm computer coordinating measuring machine (Arm CMM)(RA-7525 SEI: Hexagon, Stockholm, Sweden) instruction. Implant planning software program (co-DiagnostiX; Straumann, Basel, Switzerland) was used to plan implant position at the lower left edentulous area in different angulations. Implant position 15 degrees buccally and 15 degrees lingually to reference line which was perpendicular to the occlusal plane was planned at the first and second molar area, respectively. Straumann bone-level implants (diameter 4.1mm, length 10mm) were placed following Straumann surgical guided protocol.

3.2 Conventional implant impression

Conventional implant impression was prepared with open-tray implant technique. Self-cured acrylic resin (COE Tray Plastic: GC, Tokyo, Japan) was used to fabricate individual tray with 2 punched holes for open access. Impression copings were inserted to implant fixtures tightly and properly checked by visual test and x-ray. Polyether (Impregum Penta Soft: 3M Espe, Saint Paul, USA) was utilized for impression taking of bone-level implant following manufacturer’s instruction. After completely setting time for at least 6 minutes for impression material, the individual tray was removed from the reference model and waited 30 minutes to 2 hours until the material recovered from deformation. After complete set of impression material, the individual tray was removed from the reference model and waited until the material recovered from deformation. After that, transferred analogs were connected with impression copings and the working cast was fabricated using stone type IV (UniRock, Kentucky, USA) by mixing machine (171971: Wassermann, Hamberg, Germany). Ten conventional implant impressions were performed by a single dentist for 10 conventional working casts.

3.3 Digital implant impression

For digital implant impression methods, the reference model was inserted with a digital scan-body (RC: Straumann, Basel Switzerland) to the bone-level implant, then scanned by the intraoral scanner (D900: 3Shape, Copenhagen, Denmark), in which visual and tactile senses for proper seating were performed. After scanning, all documents were reported as STL files which were transferred and connected with the implant position in Straumann Library software program using point cloud technique to replicate the implant position correctly. After calculating the digital files, printed 3D models were fabricated using the printing machine (ProMaker D35: PROADWAYS, Ostwald, France). This process was repeated 10 times to achieve 10 3D printing models.

A B C

Figure 1 (A) Reference model. (B) Conventional working cast. (C) 3D printing model.

3.4 Measurement procedures

To compare the accuracy of digital and conventional techniques to reference model, a measuring Arm CMM was selected to scan the whole specimens, and the results were calculated using a software program (PolyWorks: Hexagon, Stockholm, Sweden). Each dental implant was connected with cylinder digital scan-body (RC) to represented implant position and angulation as shown in Figure 1. Three center points of calibrated sphere ball no.1 (S1), no.2 (S2), and no.3 (S3) were set as a reference plan, Origin point (ORG) was located at the center between S1 to S3, and ORG to S2 set as axis datum. After setting the reference plane and points, the highest point of cylinder digital scan-body at 37 and 36 implants were compared to ORG for distance. An axis of the cylinder scan-body compared to the reference plane was measured for angulation as presented in Figure 2. To evaluate the 3-dimensional changes, the scanned files from each technique were superimposed with the reference model as shown in the polygonal color mapping in Figure 3.

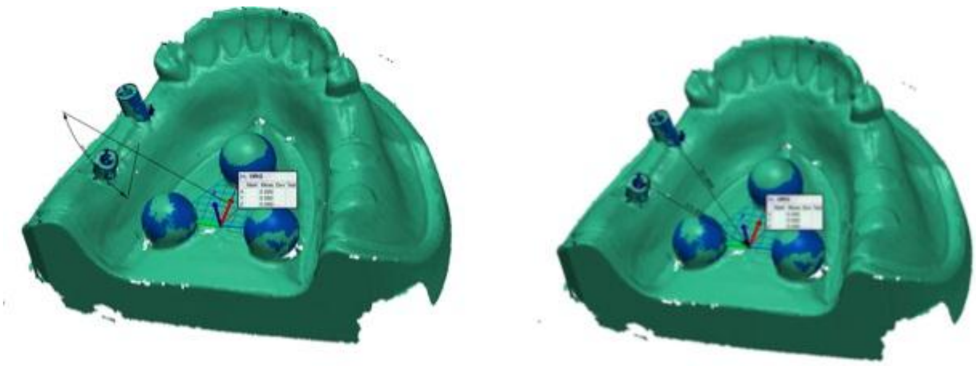

Figure 2 Distance (Left) and angulation (Right) measurement by PolyWork software program

Figure 3 Superimposed pictures of comparison between reference model with conventional working cast (left) and digital printing model. (right)

3.5 Data collection and analysis

The mean values and standard deviations of the data among each experimental group were analyzed by descriptive statistics, using statistical software (SPSS 16.0, SPSS, Chicago, IL, USA). The data were categorized according to the differences in the value of the distance and angle deviation in 3 dimensions. The Kolmogorov- Smirnov test used to examine the data for normal distribution. To compare dimensional change between conventional and digital technique, paired-sample T- test was used. Results were considered to have a statistically significant difference at p-value < 0.05.

4. Results and Discussions

Means and standard deviations of distances were calculated from buccally and lingually implant positions. The reference model showed a distance of 23.637 and 31.984 mm at 37 and 36 areas respectively. Besides, the conventional method showed a distance of 23.942 mm at 37 areas and 32.238 mm at 36 areas. Furthermore, the digital method presented 23.592 mm at 37 areas and 32.137 mm at 36 areas as shown in Table 1.

Table 1 Means and standard deviation values of distances of dental implant in buccal and lingual locations in three groups: reference model, conventional cast, 3D printing model

Measurement	Implant position	Technique	Mean	SD
Distance	37 area (Ligually, D1)	Reference	23.637	0.000
		Conventional	23.942	0.265
		Digital	23.592	0.227
	36 area (Buccally, D2)	Reference	31.984	0.000
		Conventional	32.238	0.459
		Digital	32.137	0.209

(Note: D1= distance of 37 implant, D2= distance of 36 implant)

Means and standard deviations of the angulation presented in the reference model were 69.628 degrees at 37 areas and 78.455 degrees at 36 areas. The conventional method displayed the angulation of 71.076 and 78.395 degrees at 37 and 36 areas. The digital method exhibited 69.298 and 78.399 degrees in angulation of 37 and 36 implants as shown in Table 2.

Table 2 Means and standard deviation values of angulations of dental implant in buccal and lingual locations in three groups: reference model, conventional cast, 3D printing model

Measurement	Implant position	Technique	Mean	SD
Angulation	37 area (Ligually, A1)	Reference	69.628	0.000
		Conventional	71.076	1.384
		Digital	69.298	0.713
	36 area (Buccally, A2)	Reference	78.455	0.000
		Conventional	78.395	0.861
		Digital	78.399	0.951

(Note: A1= angulation of 37 implant, A2= angulation of 36 implant)

According to the distance and angulation, mean values of the digital technique were closer to the reference model compared to the conventional one in both of angulated implants. From the paired sample T-test analysis, the digital impression technique presented a significantly superior accuracy in both of buccally and lingually placed implant positions in comparison to the conventional technique (P < 0.05) as shown in Table 3.

Table 3 Results of Paired-Sample T test for dimensional change of 3D distances and angulations between conventional and digital technique compared to reference model.

Compared Conventional vs digital Techniques	SD	t	SIG (P<0.05)
D1	0.202	5.236	0.001
D2	0.232	2.289	0.048
A1	0.933	5.913	0.00
A2	0.523	4.763	0.001

4.1 Discussion

The accuracy of the impression has been a major concern in fabricating multiple restorations. Since the open-tray impression technique was introduced, the accuracy of multiple implants impression has been improved. This research showed that the digital technique was more accurate than the conventional one, which was in agreement with the study of Lee and Gallucci in 2013. However, the study of Andriessen found that the conventional technique generated less error than the digital method in a long edentulous area which affected the loss of a landmark. Besides, other factors could influence the precision of conventional impression approaches such as polymerization shrinkage of impression material, errors or misfit of the connecting impression coping to transferred analog, and dimensional change of dental stone. Polymerized shrinkage of impression material was found to occur with more deformation in angulated implants situation (Conradd et al., 2007).

In addition, the dimensional change of the dental stone has been reported. Dental stone type IV showed 0.07% of expansion when pouring, as claimed by UniRock manufacturer's instruction. This study showed that the angulation of the implant placement affect the accuracy of the conventional impression technique. Similarly, another study exhibited less accuracy in the implant angulations between 10 to 20 degrees (Choi et al., 2007) and performed significantly different in 10 and 30 degrees in the buccal and lingual angulations as same as the results in Conradd study which concluded that divergent or convergent implant had no significant difference in direction (Conradd et al., 2007).

The digital method was available to produce 3D printing model without using impression materials and dental stones. This method also showed improved satisfaction of both patients and dentists (Birnbaum et al., 2008). Nevertheless, the digital approach still had some limitation. Distortion of polyurethane which was used in 3D printing and digital files transfer can affect the accuracy of the 3D printing models. Moreover, different oral scanning machines exhibited different values, especially in full edentulous area, of which TRIOS had the most accuracy (Vandeweghe et al., 2016)

In addition, the scan-body height can influence the accuracy of the digital impression. The 10-mm height scan-body showed better accuracy than the 5-mm scan-body (Ajioka et al., 2016). The digital technique showed more accuracy in transferring angulated implants position into a digital program. However, both techniques were clinically acceptable to treat the patients but the digital technique was highly recommended because of its superior accuracy, decreased chair time, and more patients' satisfaction.

5. Conclusion

Within the limitation of this vitro study, partially digital impression technique by the 3Shape intraoral scanner with 3D printing models presented significantly superior accuracy of three-dimensional distances and angulations to definitive working cast from conventional one.

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