The Effect of Inter-implant Distance on Angular Error of Implant Scan Abutments Generated by Intraoral Scanners

Tharathip Kulchotirat[1] and Chuchai Anunmana[*2]

[1]Master of Science Program in Implant Dentistry, Faculty of Dentistry, Mahidol University, Bangkok 10400, Thailand
[2]Department of Prosthodontics, Faculty of Dentistry, Mahidol University, Bangkok 10400, Thailand
*Corresponding author, E-mail: chuchai.anu@mahidol.edu

Abstract

In digital implant dentistry, the accuracy of the scanned dental models is important. Error from stitching the same pattern of the edentulous ridge is possible while using intraoral scanners. It could cause a diagonal error of the scanned surfaces that leads to an angular error of the implant axes. The purpose of this study was to investigate the angular error of the scan bodies in different inter-implant distances from using two intraoral scanners. The models of 7- and 14-mm inter-implant distance were prepared. A desktop scanner, 3shape® D900L, was used to prepare the reference data. The Trios3™ and Cerec™ Omnicam intraoral scanners were used to collect test data. Ten scans were performed for each model and scanner. The angular error was, then, analyzed in GOM Inspect™ software and statistical estimation was performed using SPSS 18. Trios3 had median angular errors of 0.390 (0.515, 0.285) and 0.472 (0.620, 0.375) degrees in the 7- and 14-mm groups, respectively, and the result was not statistically significant. The angular errors of Cerec Omnicam were 0.355 (0.455, 0.135) and 0.505 (0.725, 0.305) degrees in the 7- and 14-mm groups, respectively. It was statistically significant for this scanner ($p<0.05$). There was no statistical difference in the angular error between the two scanners. It is suggested in this study that the large inter-implant distance creates a greater angular error of the scan bodies as computerized data, which could affect the passive fit of the final restorations.

Keywords: *Intraoral scanner, Angular error, Inter-implant distance, Dental implant, Digital dentistry*

1. Introduction

In implant dentistry, especially in a multiple-unit restoration, the accuracy of oral impression for final prostheses is significant. According to the implant biomechanics (Kim, Oh, Misch, & Wang, 2005), a 50-µm movement of an osseointegrated implant was reported as a maximal implant movement. Exceeding biomechanical acceptability could lead to pathological bone strain (Misch, 2015). Andriessen and colleagues reported that 0.194 degrees of angular movement due to non-passive restoration could create the 50-µm movement of an implant (Andriessen, Rijkens, van der Meer, & Wismeijer, 2014). Therefore, the error of the restoration for two implants should not exceed 100 µm or less than 0.4 degrees. Thus, intraoral data collection should be a meticulous procedure to avoid future implant complications.

Intraoral scanners are the device for collecting anatomical physiognomy in oral cavities. Similar to analogous oral impression, the models from the device will be used for prostheses fabrication. Several studies also reported that the accuracy of models from intraoral scanners was greater than the traditional impression (Alikhasi, Siadat, Nasirpour, & Hasanzade, 2018; Cappare, Sannino, Minoli, Montemezzi, & Ferrini, 2019; Lee & Gallucci, 2013; Papaspyridakos et al., 2016; Seelbach, Brueckel, & Wöstmann, 2013; Yuzbasioglu, Kurt, Turunc, & Bilir, 2014). However, some studies reported poorer accuracy (Ajioka, Kihara, Odaira, Kobayashi, & Kondo, 2016; Basaki, Alkumru, De Souza, & Finer, 2017). It depends on the surrounding factors of the scanned area. These factors include surrounding ambient light, moisture, keratinized tissues, tooth preparation geometries, patient movement, scanner systems, or length of the edentulous span (Abduo & Elseyoufi, 2018; Andriessen et al., 2014; Arakida, Kanazawa, Iwaki, Suzuki, & Minakuchi, 2018; Braian & Wennerberg, 2019; Jivanescu et al., 2019; Keeling, Wu, & Ferrari, 2017; Mangano et al., 2019).

Several studies reported that the accuracy of intraoral scanners used in the larger edentulous span was more inferior to the smaller span (Andriessen et al., 2014; Flügge et al., 2018; Fukazawa, Odaira, & Kondo, 2017; Imburgia et al., 2017; Mangano et al., 2019; Vandeweghe, Vervack, Dierens, & De Bruyn, 2016). It is because the scanner captures similar pictures of the scanned surfaces, which could cause the wrong stitching of the surfaces and lead to diagonal errors. Therefore, in implant dentistry, the diagonal error of the models could cause the angular error of the implant axes. However, only one clinical study reported the angular error from the scan bodies. Andriessen and colleagues reported a wide range of angulation errors of the scan bodies on the edentulous arch (Andriessen et al., 2014). The angles seemed not related to the distance between the implants. Also, some of the scanned data had wrong stitching due to the mobility of the mucosa, which could lead to difficulty of scanning. It leads to the objective of this study. The purpose of this study was to investigate the angular error of scan bodies generated by intraoral scanners in 7-mm inter-implant distance and 14-mm inter-implant distance.

2. Objectives

1) To compare the angular error of the scan abutment generated by intraoral scanners among the models with 7- and 14-mm inter-implant distances.

2) To compare the accuracy of the two intraoral scanners in the angular error aspect.

3. Materials and Methods

A brief workflow is illustrated in Figure 1. Two dental models were designed by Meshmixer™ (Autodesk Inc., California, USA), and printed by using Form2™ SLA 3D printer (Formlabs, Massachusetts, USA). In the 7-mm distance model, the right maxillary canine (13) and first premolar (14) were replaced with the Straumann® (Straumann Holding AG, Basel, Switzerland) Regular CrossFit™ implant analogs and scan abutments. Two scan abutments were 7 mm apart, measured from the center of the abutments. In the 14-mm model, the same manner was performed in tooth 13 and right second premolar (15).

The 3shape® D900L dental laboratory scanner (3Shape, Copenhagen, Denmark), a highly precise non-contact optical scanner, was used to prepared two references scanned models. Then, two intraoral scanners, 3Shape® TRIOS3™ (3Shape, Copenhagen, Denmark) and Dentsply Sirona® CEREC™ Omnicam (Dentsply Sirona, North Carolina, USA), were used to prepare test models. Ten scans were performed for each model and scanner following the manufacturers' instructions.

All analytic processes were performed in GOM Inspect™ software (GOM GmbH, Braunschweig, Germany). Prior to performing the analysis, "Pre alignment" and "Local best-fit alignment" were used to ensure the accurate superimposition of reference and test data. Then, the cylinders of the scan bodies were generated from Gaussian best-fit. These cylinders provided axes of the scan bodies. The axes between reference and test models were compared using the "Angle" function (Figure 2). Two angles from the anterior and posterior scan bodies were averaged for the angular error of a model. All tested data were recorded and analyzed in IBM SPSS 18 (IBM SPSS Statistics for Windows, IBM Corp, USA) using Levene's Test of Equality of variances between two variables, and the Mann-Whitney U test.

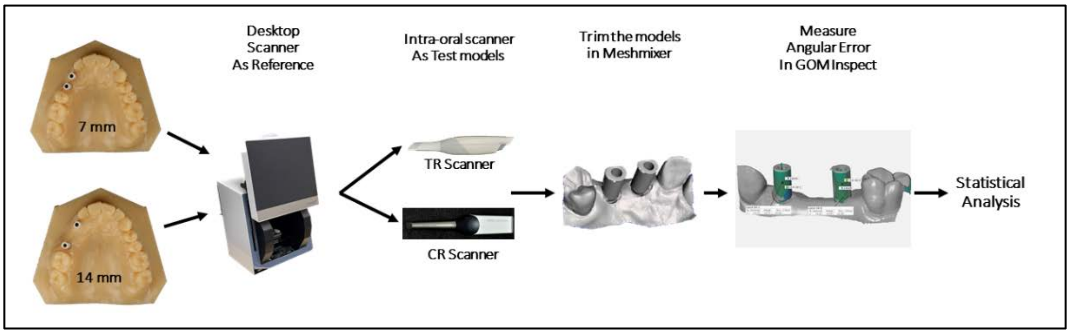

Figure 1 A Brief workflow of the study

Proceedings of RSU International Research Conference (2021)

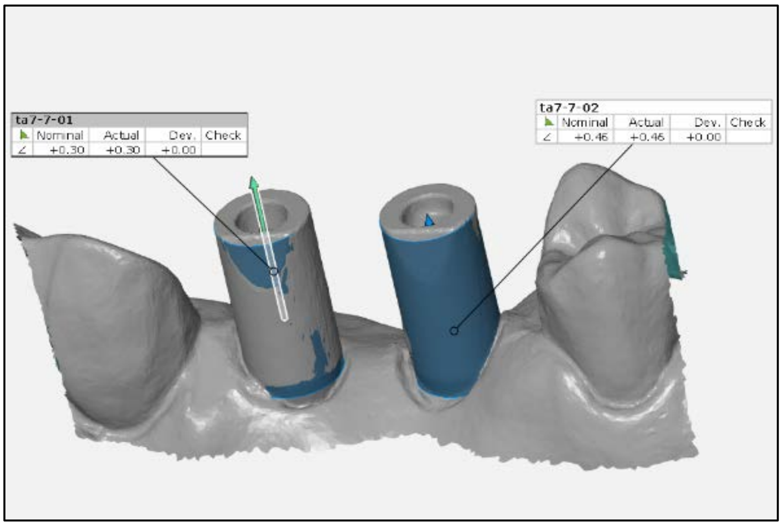

Figure 2 demonstrates the angular error analysis of 7-mm inter-implant distance in GOM Inspect™ software

4. Results and Discussion

Table 1 illustrated the analyzed data of angular error between two distances and scanners. A significant difference was found in CEREC™ Omnicam intraoral scanner between 7- and 14-mm inter-implant distance ($p<0.05$). The medians of a 14-mm group of both scanners exceed the acceptable angular error, according to Andriessen and colleagues (2014). Between the two scanners, there was no significant angular error ($p>0.05$). The result of this study was not consistent with some studies (Andriessen et al., 2014, van der Meer et al., 2012). Andriessen et al. studied angular errors in a clinical situation. Factors related to actual oral cavities, such as saliva, the amount of keratinized tissues, or patient movement, resulted in various ranges of angular errors. Another study by van der Meer et al. was also different from this experiment. The study was performed in a partially edentulous arch, but there were single implants distributed in three positions in the arch. The implants were surrounded by natural teeth. These teeth were reference objects of the intraoral scanners, which affect the accuracy and ease of scanning. Compared to the authors' experiment, the study's design was related to different sizes of edentulous spans with implants at each end. Similar smooth surface texture and geometry affected the scanning accuracy.

To compare the different technological principles between TR and CR, TR was confocal microscopy, and CR was active triangulation. The mechanism of confocal microscopy was capturing the images in the focal range of the receiver. The focused images were included to form a scanned model. This technique requires a larger image receiver. Whereas, the active triangulation technique was based on the trigonometric calculation of the coordinates X, Y, and Z captured from two points of the receiver's view. Due to different sizes of the receiver, the active triangulation requires more images to form a 3D model. Stitching a greater amount of images resulted in more errors (Amornvit, Rokaya, Peampring, & Sanohkan, 2021). However, in 7-mm inter-implant distance, the large tip of TR's confocal microscopy affected accessibility to the smaller area. Thus, the error of the TR scanner for 7-mm distance was greater than the CR scanner.

Table 1. Median (Max, Min) (degree) of the angular error of TRIOS3 (TR) and CEREC Omnicam (CR) among the inter-implant distance of 7 and 14 mm.

		Inter-implant Distance		
		7 mm	**14 mm**	**p**
Scanner	**TR**	0.390 (0.515, 0.285)	0.472 (0.620, 0.375)	0.35
	CR	0.355 (0.455, 0.135)	0.505 (0.725, 0.305)	0.009*
	p	0.315	0.631	

* Significant by Mann-Whitney U test ($p<0.05$)

According to Figure 3, 17 out of 40 samples among the groups had angular error higher than 0.4 degrees, 42.5% of the entire samples. It may be considered a high chance of angular error.

Because this study was an in vitro study, several factors in actual oral cavities were not included. Further investigation was recommended to ensure the clinical application and conclusion. This study suggested that the larger span of the edentulous ridge between two implants creates a greater angular error when using an intraoral scanner.

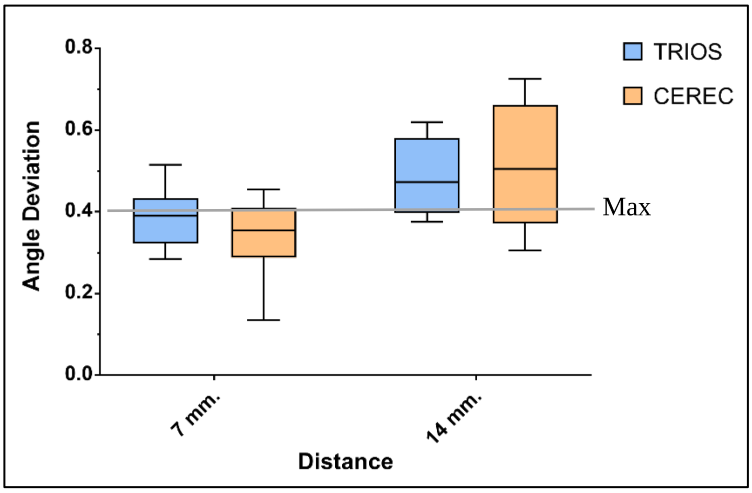

Figure 3 Angular error from using two intraoral scanners, the gray horizontal line indicates the acceptable maximal angular error according to Andriessen et al., 2014

5. Conclusion

The digital oral impression is one of the effective ways to collect the data for prostheses fabrication. Not only patient comfort was achieved from using intraoral scanners, but also higher accuracy and better communication among dentists, patients, and dental laboratory technicians. However, the factors that may affect the accuracy should be considered. The size of the edentulous span is a factor that often leads to wrong surface stitching. Its consequence is the inferior accuracy of the scanned models and causes diagonal and angular errors.

With the limitation of this study, the angular errors were greater, while the inter-implant distance increased.

6. Acknowledgements

The author would like to express appreciation to Associate Professor Dr. Chuchai Anunmana, a supervisor for guidance and advice to the finale of this project. Also, the author thanks all staff that was taking care of candidates in a Master’s degree of Implant Dentistry, Mahidol University, Bangkok, Thailand for assisting.

7. References

Abduo, J., & Elseyoufi, M. (2018). Accuracy of Intraoral Scanners: A Systematic Review of Influencing Factors. *Eur J Prosthodont Restor Dent, 26*(3), 101-121. doi:10.1922/EJPRD_01752Abduo21

Ajioka, H., Kihara, H., Odaira, C., Kobayashi, T., & Kondo, H. (2016). Examination of the Position Accuracy of Implant AbutmentsReproduced by Intra-Oral Optical Impression. *PLOS ONE,* 1-12. doi:10.1371/journal.pone.0164048

Alikhasi, M., Siadat, H., Nasirpour, A., & Hasanzade, M. (2018). Three-Dimensional Accuracy of Digital Impression versus Conventional Method: Effect of Implant Angulation and Connection Type. *International Journal of Dentistry, 2018*. doi:10.1155/2018/3761750

Amornvit, P., Rokaya, D., Peampring, C., & Sanohkan, S. (2021). Confocal 3D Optical Intraoral Scanners and Comparison of Image Capturing Accuracy. *Computers, Materials and Continua, 66*, 303-314.
Andriessen, F. S., Rijkens, D. R., van der Meer, W. J., & Wismeijer, D. W. (2014). Applicability and accuracy of an intraoral scanner for scanning multiple implants in edentulous mandibles: a pilot study. *J Prosthet Dent, 111*(3), 186-194. doi:10.1016/j.prosdent.2013.07.010
Arakida, T., Kanazawa, M., Iwaki, M., Suzuki, T., & Minakuchi, S. (2018). Evaluating the influence of ambient light on scanning trueness, precision, and time of intra oral scanner. *Journal of Prosthodontic Research, 62*(3), 324-329. doi:https://doi.org/10.1016/j.jpor.2017.12.005
Basaki, K., Alkumru, H., De Souza, G., & Finer, Y. (2017). Accuracy of Digital vs Conventional Implant Impression Approach: A Three-Dimensional Comparative In Vitro Analysis. *Int J Oral Maxillofac Implants, 32*(4), 792-799. doi:10.11607/jomi.5431
Braian, M., & Wennerberg, A. (2019). Trueness and precision of 5 intraoral scanners for scanning edentulous and dentate complete-arch mandibular casts: A comparative in vitro study. *J Prosthet Dent, 122*(2), 129-136.e122. doi:https://doi.org/10.1016/j.prosdent.2018.10.007
Cappare, P., Sannino, G., Minoli, M., Montemezzi, P., & Ferrini, F. (2019). Conventional versus Digital Impressions for Full Arch Screw-Retained Maxillary Rehabilitations: A Randomized Clinical Trial. *International journal of environmental research and public health, 16*(5), 829. doi:10.3390/ijerph16050829
Flügge, T., van der Meer, W. J., Gonzalez, B. G., Vach, K., Wismeijer, D., & Wang, P. (2018). The accuracy of different dental impression techniques for implant-supported dental prostheses: A systematic review and meta-analysis. *Clin Oral Implants Res, 29*(S16), 374-392. doi:10.1111/clr.13273
Fukazawa, S., Odaira, C., & Kondo, H. (2017). Investigation of accuracy and reproducibility of abutment position by intraoral scanners. *J Prosthodont Res, 61*(4), 450-459. doi:10.1016/j.jpor.2017.01.005
Imburgia, M., Logozzo, S., Hauschild, U., Veronesi, G., Mangano, C., & Mangano, F. G. (2017). Accuracy of four intraoral scanners in oral implantology: a comparative in vitro study. *BMC Oral Health, 17*(1), 92. doi:10.1186/s12903-017-0383-4
Jivanescu, A., Rotar, P., Hategan, S., Pricop, C., Rus, R., & Goguta, L. (2019). Clinical Factors Influence the Trueness of Intra-oral Scanning. *Eur J Prosthodont Restor Dent, 27*(1), 51-55. doi:10.1922/EJPRD_01861Jivanescu05
Keeling, A., Wu, J., & Ferrari, M. (2017). Confounding factors affecting the marginal quality of an intra-oral scan. *J Dent, 59*, 33-40. doi:10.1016/j.jdent.2017.02.003
Kim, Y., Oh, T. J., Misch, C. E., & Wang, H. L. (2005). Occlusal considerations in implant therapy: clinical guidelines with biomechanical rationale. *Clin Oral Implants Res, 16*(1), 26-35.
Lee, S. J., & Gallucci, G. O. (2013). Digital vs. conventional implant impressions: efficiency outcomes. *Clin Oral Implants Res, 24*(1), 111-115. doi:10.1111/j.1600-0501.2012.02430.x
Mangano, F. G., Hauschild, U., Veronesi, G., Imburgia, M., Mangano, C., & Admakin, O. (2019). Trueness and precision of 5 intraoral scanners in the impressions of single and multiple implants: a comparative in vitro study. *BMC Oral Health, 19*(1), 101. doi:10.1186/s12903-019-0792-7
Misch, C. E. (2015). Stress Treatment Theorem for Implant Dentistry: The Key to Implant Treatment Plans. In C. E. Misch (Ed.), *Dental Implant Prosthetics* (2nd ed., pp. 169 - 198): Elsevier Mosby.
Papaspyridakos, P., Gallucci, G. O., Chen, C. J., Hanssen, S., Naert, I., & Vandenberghe, B. (2016). Digital versus conventional implant impressions for edentulous patients: accuracy outcomes. *Clin Oral Implants Res, 27*(4), 465-472. doi:10.1111/clr.12567
Seelbach, P., Brueckel, C., & Wöstmann, B. (2013). Accuracy of digital and conventional impression techniques and workflow. *Clinical Oral Investigations, 17*(7), 1759-1764. doi:10.1007/s00784-012-0864-4
Vandeweghe, S., Vervack, V., Dierens, M., & De Bruyn, H. (2016). Accuracy of digital impressions of multiple dental implants: An in vitro study. *Clin Oral Implants Res, 28*. doi:10.1111/clr.12853
Yuzbasioglu, E., Kurt, H., Turunc, R., & Bilir, H. (2014). Comparison of digital and conventional impression techniques: evaluation of patients' perception, treatment comfort, effectiveness and clinical outcomes. *BMC Oral Health, 14*(1), 10. doi:10.1186/1472-6831-14-10