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In vitro comparison of the accuracy (precision and trueness) of eight dental scanners for dental bridge scanning

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ABSTRACT

Background: Dental scanners play a critical role in computer-aided design/computer-aided manufacturing technology. This study aimed to compare the accuracy (precision and trueness) of eight dental scanners for dental bridge scanning.

Materials and Methods: In this *in-vitro* experimental study, a typodont model with a missing maxillary right first molar was prepared for a 3-unit fixed partial denture. Each scanner (Sirona inEos inLab, Sirona X5, Dentium, Imes icore 350I 13D, Amann Girrbach map 100, 3Shape D100, 3Shape E3) performed seven scans of the typodont, and the data were analyzed using 3D-Tool software. The abutment length, abutment width, arch length, and interdental distance were measured. To assess the accuracy of each scanner, trueness was evaluated by superimposing the scanned data on true values obtained by the 3shape Triosscanner as the reference. Precision was evaluated by superimposing a pair of data sets obtained from the same scanner. Precision and trueness of the scanners were compared using the one-way ANOVA followed by the *post-hoc* Tukey's HSD test and one-sample *t*-test ($P<0.05$ was considerer significant).

Results: The precision of scanners ranged from 14 μm (3Shape Trios) to 45 μm (Imes icore 350i), whereas the trueness ranged from 38 μm (3Shape d700) to 71 μm (Sirona X5).

Conclusion: The reported trueness values for 3Shape Trios, Sirona inEos inLab, Sirona x5, Dentium, Imes icore350i, Amann Girrbach, 3Shape d700, and 3Shape e3 were 63, 45, 71, 67, 70, 53, 38, and 42 μm, respectively, whereas the precision values were 14, 29, 44, 34, 45, 44, 30 and 28 μm, respectively.

Key Words: Accuracy, dental scanner, precision, trueness

INTRODUCTION

Nowadays, computer-aided design/computer-aided manufacturing (CAD/CAM) technology is becoming increasingly popular due to fewer clinical sessions, leading to higher patient comfort.[1-3] This technology has been popular since the 1980s and is currently used to manufacture a wide range of dental prostheses such as fixed partial dentures, removable partial frameworks, maxillofacial prostheses, and complete dentures.[4-6] The processing chain of CAD/CAM technology consists of three different steps, namely scanning, designing, and manufacturing of the

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prosthesis, which can be milled or 3D-printed using different types of materials.[7]

There are two types of scanners based on the method of fabrication of CAD/CAM crowns: intraoral scanners which directly scan the dental arch and extraoral scanners, scanning either the dental impressions or the laboratory-fabricated casts. Intraoral scanners mainly use the tenets of active triangulation, confocal microscopy, and wave-front sampling. The output of these scanners can be divided into two subgroups of camera image impressions and video image impressions.[4,8-11] Extraoral scanners are divided into three subgroups, namely laser, structured light, and contact scanners.[4] Laser and light scanners produce scans faster and are not influenced by the density of the object. Despite this advantage, these types of scanners are affected by the optical properties of the object being scanned such as shininess of the surface and brightness. Contact scanners use a contact probe touching a cast, which is highly accurate but can potentially damage the scanned surface. The slow scanning speed of this group of scanners is another drawback of this type of scanners.[1,4,12-14]

Enhancement of accuracy is among the most important goals of digital dentistry, and computer-aided technology can decrease discrepancies which occur during the conventional method of impression making and crown fabrication.[15-18] According to different technologies of intraoral and extraoral scanners, different companies produce different types of scanners. There is inconsistent information about the accuracy of crowns made with these systems. Accuracy of scanners consists of precision (how close the repeated measurements are to each other), trueness (how far the measurements are aberrant from the actual dimensions), and marginal adaptation.[15,19-21]

The purpose of this study was to compare the accuracy (precision and trueness) of eight dental scanners for dental bridge scanning. The null hypothesis was assumed for this investigation was that there would be no differences between different dental scanners with regard to accuracy.

MATERIALS AND METHODS

This *in-vitro* experimental study compared the accuracy (precision and trueness) of eight dental scanners. The accuracy of Sirona inEos inLab (Dentsply Sirona, USA), Sirona X5 (Dentsply Sirona, USA), Dentium Rainbow™ (Dentium, Korea), imes icore 350I I3D (imes-icore, Germany), Amann Girrbach map 100 (Amann Girrbach, Austria), 3Shape D100 (3shape, Denmark), and 3Shape E3 (3shape, Denmark) was evaluated, and data of each scanner were compared with the data received from the 3shape Trios intraoral scanner (3shape, Denmark) as the reference.

A typodont model (Hossbm, Iran) with a missing maxillary right first molar was prepared for a 3-unit fixed partial denture by a prosthodontist according to the principles of Rosenstiel *et al*.[7] Next, three points were created on the surface of the prepared tooth as reference points. Each scanner performed seven scans of the typodont, and the obtained data were analyzed using 3D-tool software (3D-Tool GmbH and Co., KG, Germany). The abutment length, abutment width, arch length, and interdental distance were measured, as shown in Figure 1. In order to compare the trueness, the prepared typodont was first scanned with 3shape Trios scanner as the reference. This true value was then compared with the measurements made by each scanner. Then, precision was determined based on the differences in values obtained by repeated measurements by each scanner.

The collected data were analyzed using the SPSS software version 19.0 (IBM company, Armonk, New York, USA). Precision and trueness were compared among different scanners using one-way ANOVA followed by the *post-hoc* Tukey's honestly significant difference test and one-sample *t*-test ($P<0.05$ was considerer significant).

RESULTS

The mean and standard deviation of arch length [Table 1], crown width of tooth #14 [Table 2], crown width of tooth #16 [Table 3], interdental distance [Table 4], crown length of tooth #14 [Table 5], and crown length of tooth #16 [Table 6] were compared using the one-way ANOVA [Table 7].

The mean crown width of tooth #14, crown length of tooth #14, and crown length of tooth #16 were significantly different ($P < 0.05$) among the test groups. The results of *post-hoc* Tukey's test showed that the crown width of tooth #14 was significantly different between Sirona inEos and Dentium ($P = 0.007$), Sirona 25 and Imes icore350i ($P = 0.018$), and Imes icore350i and Dentium ($P = 0.002$). The crown length of tooth #14 was significantly different between Sirona inEos and Dentium ($P = 0.031$), Sirona inEos

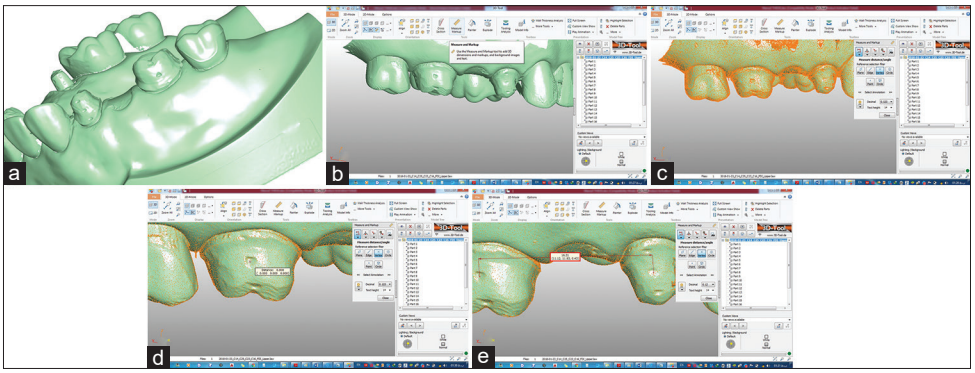

Figure 1: 3D-Tool software and the measurement sequence: (a) Images of abutment with reference points on its surfaces scanned with ATOS scanner. (b) Selecting the measure markup item. (c) Selecting the vortex item. (d) Marking the deepest point on reference area. (e) Measuring the exact distance between the two selected points.

Table 1: Raw data (mm) used for statistical analysis on various scanners for arch length

Arch length	*n*	Mean	SD	SE	95% CI for mean		Minimum	Maximum
					Lower bound	Upper bound		
3Shape Trios	7	39.9243	0.13315	0.05033	39.8011	40.0474	39.73	40.15
Sirona inEos	7	39.9057	0.14351	0.05424	39.7730	40.0384	39.75	40.12
Sirona 25	7	39.8857	0.06655	0.02515	39.8242	39.9473	39.81	39.99
Dentium	7	39.8914	0.17535	0.06628	39.7293	40.0536	39.67	40.15
Imes icore 350i	7	39.8686	0.11568	0.04372	39.7616	39.9756	39.68	40.01
Amann Girrbach	7	39.9000	0.12437	0.04701	39.7850	40.0150	39.71	40.06
3Shape D700	7	39.9186	0.08934	0.03377	39.8359	40.0012	39.75	40.03
3Shape E3	7	39.8986	0.11992	0.04533	39.7877	40.0095	39.80	40.12
Total	56	39.8991	0.11785	0.01575	39.8675	39.9307	39.67	40.15

SD: Standard deviation; SE: Standard error, CI: Confidence interval

Table 2: Raw data (mm) used for statistical analysis on various scanners for crown width of tooth #14

Crown width of tooth #14	*n*	Mean	SD	SE	95% CI for mean		Minimum	Maximum
					Lower bound	Upper bound		
3Shape Trios	7	5.7314	0.04220	0.01595	5.6924	5.7705	5.65	5.78
Sirona inEos	7	5.7986	0.07198	0.02721	5.7320	5.8651	5.69	5.88
Sirona 25	7	5.6800	0.03317	0.01254	5.6493	5.7107	5.62	5.71
Dentium	7	5.6514	0.07925	0.02995	5.5781	5.7247	5.54	5.74
Imes icore 350i	7	5.8143	0.08182	0.03093	5.7386	5.8900	5.71	5.94
Amann Girrbach	7	5.7086	0.09442	0.03569	5.6213	5.7959	5.61	5.88
3Shape D700	7	5.7600	0.08505	0.03215	5.6813	5.8387	5.65	5.89
3Shape E3	7	5.7400	0.05354	0.02024	5.6905	5.7895	5.66	5.83
Total	56	5.7355	0.08444	0.01128	5.7129	5.7581	5.54	5.94

SD: Standard deviation; SE: Standard error, CI: Confidence interval

and Amann Girrbach (P = 0.016), and Sirona inEos and 3Shape E3 (P = 0.012). The crown length of tooth #16 was significantly different between Sirona inEos and Amann Girrbach (P = 0.008).

According to the current results, the reported trueness values for 3Shape Trios, Sirona inEos inLab, Sirona X5, Dentium, Imes icore350i, Amann Girrbach, 3Shape d700, and 3Shape e3 were 63, 45, 71, 67, 70, 53, 38, and 42 µm, respectively, whereas the precision values were 14, 29, 44, 34, 45, 44, 30, and 28 µm, respectively [Table 8].

DISCUSSION

Nowadays, conventional impression making with impression materials is exceedingly replaced with digital impression making utilizing dental scanners. These scanners operate based on different technologies which have some negative and positive points that can affect their accuracy.

This study was conducted to evaluate and compare the accuracy (precision and trueness) of eight dental

Table 3: Raw data (mm) used for the statistical analysis on various scanners for crown width of tooth #16

Crown width of tooth #16	*n*	Mean	SD	SE	95% CI for mean		Minimum	Maximum
					Lower bound	Upper bound		
3Shape Trios	7	8.1986	0.07862	0.02972	8.1259	8.2713	8.09	8.31
Sirona inEos	7	8.1529	0.05376	0.02032	8.1031	8.2026	8.06	8.20
Sirona X5	7	8.1357	0.06901	0.02608	8.0719	8.1995	8.01	8.21
Dentium	7	8.2514	0.09529	0.03602	8.1633	8.3396	8.14	8.37
Imes icore 350i	7	8.2729	0.15424	0.05830	8.1302	8.4155	8.08	8.53
Amann Girrbach	7	8.2314	0.11006	0.04160	8.1296	8.3332	8.05	8.35
3Shape D700	7	8.1786	0.11582	0.04378	8.0715	8.2857	8.03	8.37
3Shape E3	7	8.1914	0.02968	0.01122	8.1640	8.2189	8.14	8.23
Total	56	8.2016	0.09994	0.01336	8.1748	8.2284	8.01	8.53

SD: Standard deviation; SE: Standard error, CI: Confidence interval

Table 4: Raw data (mm) used for statistical analysis on various scanners for distance between teeth #14 and #16

Distance between teeth #14 and #16	*n*	Mean	SD	SE	95% CI for Mean		Minimum	Maximum
					Lower bound	Upper bound		
3Shape Trios	7	16.0957	0.05192	0.01962	16.0477	16.1437	16.04	16.17
Sirona inEos	7	16.1729	0.13889	0.05250	16.0444	16.3013	16.00	16.33
Sirona X5	7	16.1329	0.11898	0.04497	16.0228	16.2429	16.03	16.36
Dentium	7	16.2743	0.08522	0.03221	16.1955	16.3531	16.15	16.38
Imes icore 350i	7	16.1757	0.15241	0.05761	16.0348	16.3167	15.93	16.39
Amann Girrbach	7	16.2300	0.15199	0.05745	16.0894	16.3706	16.06	16.45
3Shape D700	7	16.2043	0.04860	0.01837	16.1593	16.2492	16.15	16.27
3Shape E3	7	16.1814	0.16426	0.06208	16.0295	16.3333	15.94	16.47
Total	56	16.1834	0.12530	0.01674	16.1498	16.2169	15.93	16.47

SD: Standard deviation; SE: Standard error, CI: Confidence interval

Table 5: Raw data (mm) used for statistical analysis on various scanners for crown length of tooth #14

Crown length of tooth #14	*n*	Mean	SD	SE	95% CI for Mean		Minimum	Maximum
					Lower bound	Upper bound		
3Shape Trios	7	4.3171	0.11672	0.04412	4.2092	4.4251	4.20	4.51
Sirona inEos	7	4.4643	0.11223	0.04242	4.3605	4.5681	4.29	4.59
Sirona X5	7	4.3214	0.17535	0.06628	4.1593	4.4836	4.07	4.56
Dentium	7	4.2600	0.13515	0.05108	4.1350	4.3850	4.10	4.46
Imes icore 350i	7	4.3414	0.06012	0.02272	4.2858	4.3970	4.24	4.40
Amann Girrbach	7	4.2457	0.10861	0.04105	4.1453	4.3462	4.10	4.45
3Shape D700	7	4.2900	0.09950	0.03761	4.1980	4.3820	4.19	4.48
3Shape E3	7	4.2400	0.05447	0.02059	4.1896	4.2904	4.16	4.30
Total	56	4.3100	0.12645	0.01690	4.2761	4.3439	4.07	4.59

SD: Standard deviation; SE: Standard error, CI: Confidence interval

scanners. On the basis of the results of this study, the null hypothesis regarding the absence of a significant difference in the accuracy of different dental scanners was rejected.

The measured values were higher than the accuracy declared by the manufacturers (10–20 μm).[22] Such different values may be due to differences in sharp angles or smooth surfaces used to assess the scanners.

Different values have been reported in different studies. Persson *et al*. reported a trueness value of 10 μm for a contact scanner.[23] DeLong *et al*. found 18–30 μm discrepancy for structured light scanners.[24] While Del Corso *et al*. measured a trueness value of 14–21 μm for structured light scanners.[25] In the present study, we found a trueness value of 61 μm for structured light scanners. These differences may be due to the use of different scanners and different preparation of surfaces for scanning.

González de Villaumbrosia *et al*. showed that laser scanners had the highest trueness (35 μm) and

Table 6: Raw data (mm) used for statistical analysis on various scanners for crown length of tooth #16

Crown length of tooth #16	*n*	Mean	SD	SE	95% CI for Mean		Minimum	Maximum
					Lower bound	Upper bound		
3Shape Trios	7	5.0057	0.10659	0.04029	4.9071	5.1043	4.93	5.20
Sirona inEos	7	5.1486	0.11639	0.04399	5.0409	5.2562	4.98	5.26
Sirona X5	7	4.9400	0.22517	0.08510	4.7318	5.1482	4.65	5.20
Dentium	7	4.9371	0.12513	0.04729	4.8214	5.0529	4.69	5.07
Imes icore 350i	7	4.9586	0.15636	0.05910	4.8140	5.1032	4.70	5.10
Amann Girrbach	7	4.8429	0.18136	0.06855	4.6751	5.0106	4.61	5.17
3Shape D700	7	5.0286	0.12967	0.04901	4.9086	5.1485	4.81	5.19
3Shape E3	7	5.0314	0.10511	0.03973	4.9342	5.1286	4.89	5.20
Total	56	4.9866	0.16258	0.02173	4.9431	5.0301	4.61	5.26

SD: Standard deviation; SE: Standard error, CI: Confidence interval

Table 7: Analyzing six different criteria using one-way ANOVA

Different criteria		Sum of squares	df	Mean square	*F*	Significant
Arch length	Between groups	0.016	7	0.002	0.143	0.994
	Within groups	0.748	48	0.016		
	Total	0.764	55			
Crown width #14	Between groups	0.152	7	0.022	4.333	0.001
	Within groups	0.240	48	0.005		
	Total	0.392	55			
Crown width #16	Between groups	0.111	7	0.016	1.730	0.124
	Within groups	0.439	48	0.009		
	Total	0.549	55			
Distance between teeth #14 and #16	Between groups	0.149	7	0.021	1.430	0.215
	Within groups	0.714	48	0.015		
	Total	0.863	55			
Crown length #14	Between groups	0.258	7	0.037	2.852	0.014
	Within groups	0.621	48	0.013		
	Total	0.879	55			
Crown length #16	Between groups	0.395	7	0.056	2.559	0.025
	Within groups	1.059	48	0.022		
	Total	1.454	55			

Table 8: Precision and trueness of different scanners

Scanner	Intra/extraoral	Technology	Trueness (μm)	Precision (μm)
3Shape Trios	Intra	Confocal	63	14
Sirona inEos inLab	Extra	Structured light	45	29
Sirona x5	Extra	Structured light (blue)	71	44
Dentium	Extra	Structured light (white)	67	34
Imes icore350i	Extra	Structured light	70	45
Amann Girrbach	Extra	Structured light	53	44
3Shape d700	Extra	Laser	38	30
3Shape e3	Extra	Blue LED	42	28

precision (44 μm) and the values were higher than those obtained by light scanners.[13] According to their results, none of the scanners had the best-recorded values for all variables and each scanner had higher values for some specific aspects of the scanning procedure. They also showed that the structured light scanners did not present higher values compared to others while they are commonly recommended as the best scanners. The results of the present study were in accordance with those of Gonzalez *et al*. The 3Shape d700 had the highest trueness and the difference in the trueness value of this scanner and that of structured light scanners was significant. The 3Shape Trios intraoral scanner, utilizing the confocal technology, had the highest precision value among all, which maybe because of the ability to sequentially capture

pictures from an object. Superior trueness recorded in our study for 3Shape Trios intraoral scanner was in agreement with the findings of Gonzalez *et al*. Sirona X5 and i3dcam (Imes icore 350i) structured light scanners had lower precision values among all. Structured light scanners which were used in this study did not show higher values in every aspect.

Most previous studies on this topic have some limitations because only single-tooth scans were used to compare accuracy.[22] In this study, complete-arch scan yielded higher validity and reliability.

CONCLUSION

Within the limitations of this study, the results showed that the tested scanners had significant differences with each other in terms of trueness and precision. 3Shape D700 extraoral scanner had the highest trueness while the minimum trueness was noted in Sirona X5. The best precision value was recorded for 3shape trios scanner, whereas Imes icore 350i had the worst precision value.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

REFERENCES

1. Chan DC, Chung AK, Haines J, Yau EH, Kuo CC. The accuracy of optical scanning: Influence of convergence and die preparation. Oper Dent 2011;36:486-91.
2. Miyazaki T, Hotta Y, Kunii J, Kuriyama S, Tamaki Y. A review of dental CAD/CAM: Current status and future perspectives from 20 years of experience. Dent Mater J 2009;28:44-56.
3. Tinschert J, Natt G, Hassenpflug S, Spiekermann H. Status of current CAD/CAM technology in dental medicine. Int J Comput Dent 2004;7:25-45.
4. Lee JJ, Jeong ID, Park JY, Jeon JH, Kim JH, Kim WC. Accuracy of single-abutment digital cast obtained using intraoral and cast scanners. J Prosthet Dent 2017;117:253-9.
5. Goodacre CJ, Garbacea A, Naylor WP, Daher T, Marchack CB, Lowry J. CAD/CAM fabricated complete dentures: Concepts and clinical methods of obtaining required morphological data. J Prosthet Dent 2012;107:34-46.
6. Tamim H, Skjerven H, Ekfeldt A, Rønold HJ. Clinical evaluation of CAD/CAM metal-ceramic posterior crowns fabricated from intraoral digital impressions. Int J Prosthodont 2014;27:331-7.
7. Rosenstiel SF, Land MF, Fujimoto J. Contemporary Fixed Prosthodontics-E-Book: Elsevier Health Sciences. C.V. Mosby Company, Missouri, United States; 2015.
8. Jeong ID, Lee JJ, Jeon JH, Kim JH, Kim HY, Kim WC. Accuracy of complete-arch model using an intraoral video scanner: An *in vitro* study. J Prosthet Dent 2016;115:755-9.
9. Ender A, Attin T, Mehl A. *In vivo* precision of conventional and digital methods of obtaining complete-arch dental impressions. J Prosthet Dent 2016;115:313-20.
10. Ender A, Mehl A. *In-vitro* evaluation of the accuracy of conventional and digital methods of obtaining full-arch dental impressions. Quintessence Int 2015;46:9-17.
11. Nedelcu RG, Persson AS. Scanning accuracy and precision in 4 intraoral scanners: An *in vitro* comparison based on 3-dimensional analysis. J Prosthet Dent 2014;112:1461-71.
12. Rudolph H, Luthardt RG, Walter MH. Computer-aided analysis of the influence of digitizing and surfacing on the accuracy in dental CAD/CAM technology. Comput Biol Med 2007;37:579-87.
13. González de Villaumbrosia P, Martínez-Rus F, García-Orejas A, Salido MP, Pradíes G. *In vitro* comparison of the accuracy (trueness and precision) of six extraoral dental scanners with different scanning technologies. J Prosthet Dent 2016;116:543-500.
14. Persson A, Andersson M, Oden A, Sandborgh-Englund G. A three-dimensional evaluation of a laser scanner and a touch-probe scanner. J Prosthet Dent 2006;95:194-200.
15. Ender A, Mehl A. Accuracy of complete-arch dental impressions: A new method of measuring trueness and precision. J Prosthet Dent 2013;109:121-8.
16. Santoro M, Galkin S, Teredesai M, Nicolay OF, Cangialosi TJ. Comparison of measurements made on digital and plaster models. Am J Orthod Dentofacial Orthop 2003;124:101-5.
17. Zilberman O, Huggare JA, Parikakis KA. Evaluation of the validity of tooth size and arch width measurements using conventional and three-dimensional virtual orthodontic models. Angle Orthod 2003;73:301-6.
18. Mously HA, Finkelman M, Zandparsa R, Hirayama H. Marginal and internal adaptation of ceramic crown restorations fabricated with CAD/CAM technology and the heat-press technique. J Prosthet Dent 2014;112:249-56.
19. Ali AO. Accuracy of digital impressions achieved from five different digital impression systems. Dentistry 2015;5:1.
20. Renne W, Ludlow M, Fryml J, Schurch Z, Mennito A, Kessler R, *et al*. Evaluation of the accuracy of 7 digital scanners: An *in vitro* analysis based on 3-dimensional comparisons. J Prosthet Dent 2017;118:36-42.
21. Hack GD, Patzelt S. Evaluation of the accuracy of six intraoral scanning devices: An *in-vitro* investigation. ADA Prof Prod Rev 2015;10:1-5.
22. Rudolph H, Salmen H, Moldan M, Kuhn K, Sichwardt V, Wöstmann B, *et al*. Accuracy of intraoral and extraoral digital data acquisition for dental restorations. J Appl Oral Sci 2016;24:85-94.
23. Persson M, Andersson M, Bergman B. The accuracy of a high-precision digitizer for CAD/CAM of crowns. J Prosthet Dent 1995;74:223-9.

24. DeLong R, Heinzen M, Hodges JS, Ko CC, Douglas WH. Accuracy of a system for creating 3D computer models of dental arches. J Dent Res 2003;82:438-42.
25. Del Corso M, Abà G, Vazquez L, Dargaud J, Dohan Ehrenfest DM. Optical three-dimensional scanning acquisition of the position of osseointegrated implants: An *in vitro* study to determine method accuracy and operational feasibility. Clin Implant Dent Relat Res 2009;11:214-21.