Comparative analysis on reproducibility among 5 intraoral scanners: sectional analysis according to restoration type and preparation outline form

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PURPOSE. The trueness and precision of acquired images of intraoral digital scanners could be influenced by restoration type, preparation outline form, scanning technology and the application of power. The aim of this study is to perform the comparative evaluation of the 3-dimensional reproducibility of intraoral scanners (IOSs). **MATERIALS AND METHODS.** The phantom containing five prepared teeth was scanned by the reference scanner (Dental Wings) and 5 test IOSs (E4D dentist, Fastscan, iTero, Trios and Zfx Intrascan). The acquired images of the scanner groups were compared with the image from the reference scanner (trueness) and within each scanner groups (precision). Statistical analysis was performed using independent two-samples t-test and analysis of variance (α=.05). **RESULTS.** The average deviations of trueness and precision of Fastscan, iTero and Trios were significantly lower than the other scanners. According to the restoration type, significantly higher trueness was observed in crown and inlay than in bridge. However, no significant difference was observed among four sites of preparation outline form. If compared by the characteristics of IOS, high trueness was observed in the group adopting the active triangulation and using powder. However, there was no significant difference between the still image acquisition and video acquisition groups. **CONCLUSION.** Except for two intraoral scanners, Fastscan, iTero and Trios displayed comparable levels of trueness and precision values in tested phantom model. Difference in trueness was observed depending on the restoration type, the preparation outline form and characteristics of IOS, which should be taken into consideration when the intraoral scanning data are utilized. ***[J Adv Prosthodont 2016;8:354-62]***

KEYWORDS: Intraoral scanner; Digital impression; Reproducibility of intraoral scanner; Trueness; Precision

INTRODUCTION

With the recent acceleration of the application of digital technology in the dental medicine, various intraoral scanners (IOSs) that can acquire intraoral images without using the impression material have been introduced in addition to the existing CAD/CAM system.[1]

According to Nedelcu *et al.* and Schaefer *et al.*,[2,3] IOS can be classified into the still image acquisition and video acquisition methods according to the image recombination. Of the IOS distributed currently in use, CEREC AC Bluecam, E4D dentist and iTero (first generation) adopted the former method while the latter is adopted by E4D NEVO, Fastscan, Lava COS, Trios and Zfx Intrascan. Due to its nature that the scanner itself has to move in the narrow oral cavity as compared with the desktop scanner, there are various scanning technologies. For instance, E4D is operated by optical coherence tomography. Also, active triangulation is applied for CEREC AC Bluecam, Fastscan and Lava COS while confocal microscopic technology is adopted in iTero, Trios and Zfx Intrascan. The depth of field depends

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on these scanning technologies and has an influence on the learning curve of the device. The powder is used to enhance scanner's recognition rate and shorten scan time by reducing reflection on the tooth surface with various materials. CEREC AC Bluecam, Fastscan and Lava COS always require powder. On the other hand, E4D dentist does not require powder in most cases and iTero, PlanScan, Trios and Zfx Intrascan do not require the application of reflective agent.[4] The literatures comparing the accuracy of IOSs largely concerned two subjects; the measurement of the internal gap of fabricated crowns and the measurement of the deviations after superposition of two images. There are various studies on these. In particular, the former internal gap study includes Seelbach *et al.*'s studyon the single crown and Schaefer *et al.*'s on the partial crown while the latter image superposition study includes Nedelcu *et al.*'s study on simplified and standardized scan body, Ender *et al.*'s on full arch, and Patzelt *et al.*'s on edentulous jaws.[2,3,5-10] Papaspyridakos and Wismeijer reported the investigation on the accuracy of digital implant impressions with IOS.[11-13] In the study on the measurement of the gap of crowns, there is a limitation in determining the performance of the scanner itself due to the uncontrollable factors occurring in the fabrication of crowns while the image superposition study suggests neither the relationship with the actual crown nor the data for the specific important sites such as margins since this is a mere comparison of images. If the data on each section of the cavity form according to various restorations are measured and compared, it will be possible to compare the 3-dimensional reproduction capability of digital IOSs that expresses the crucial parts of the abutment affecting the fits of crowns.

The aim of this study is to perform the comparative evaluation of the 3-dimensional reproducibility of several intraoral scanners (IOS) by the restoration type. For this purpose, each intraoral scanner's precision and trueness were investigated by superposing 3-dimensioanl images and measuring the deviation at the main sites of the abutment in each section. Additionally, the differences depending on the scanning technology and characteristics of the scanner were compared and analyzed. The primary null hypothesis was that the 3-dimensional reproducibility of intraoral scanners did not differ by the restoration type and preparation location. The secondary null hypothesis was that the trueness of 3-dimensional images were not influenced by the scanning technology and characteristics of the scanners.

MATERIALS AND METHODS

In this study, a phantom model containing prefabricated abutment teeth was prepared. Right maxillary incisor and canine were selected as abutment teeth for a 3-unit fixed dental prosthesis. Right maxillary second molar was designated as an abutment for MO inlay, and the right mandibular second molar as that for a crown. Artificial tooth with an ideal shape were arranged at the left dentition for the occlusal stability during the digital buccal bite registration (Fig. 1). In order to obtain standardized preparations and to avoid an arbitrary preparation by a practitioner, the abutment teeth that had been prepared in precision processing by the manufacturer (A50H-set Prepared teeth assortment; Nissin) were used. To keep the reflectivity similar to the natural tooth, the metal tooth was not used. The setscrews which fixate the individual teeth were tightened firmly and cyanoacrylate cement was applied to prevent unwanted screw loosening. The tooth on the phantom was not removed or added and no external force was applied during the experiment. All the experiments were carried out at 23 ± 1°C and 50 ± 5% relative humidity.

In order to obtain the reference STL file, a desktop scanner (7 Series; Dental Wings Inc.) with the trueness of 15 µm was used. This scanner uses a laser light source with 5 axes of freedom, and thus is favorable for reproduction of an undercut or complicated shapes. Also, it has a high scanning capacity (140 × 140 × 100 mm), which enables scanning of a full arch restoration. 5 types of IOSs were used in this study: iTero (1st generation; ALIGN TECHNOLOGY, INC.), E4D dentist (initial version; E4D Technologies), Zfx Intrascan (Zfx GmhH), Trios (2^{nd} generation; 3shape A/S) and Fastscan (IOS Technologies, Inc.). These were classified by the scanning technology such as Fastscan with the active triangulation, iTero, Trios and Zfx Intrascan with the confocal microscopy technology, and E4D dentist with the optical coherence tomography (Table 1).

Fig. 1. Dental models with various preparation designs. Right maxillary incisor and canine (#11, 13); 3-unit fixed dental prosthesis, right maxillary second molar (#17); MO inlay, and right mandibular second molar (#47); crown.

Table 1. Characteristics of intraoral scanners

System	Manufacturer	Scanner technology	Light source	Acquisition	Necessity of coating
E4D dentist (initial version)	D4D Technologies	Optical coherence tomography	Laser	Still imaging	None but occasionally
Fastscan	IOS Technologies	Active triangulation and Scheimpflug principle	Laser	Still imaging	Yes
iTero (1st generation)	Align Technologies	Parallel confocal microscopy	Red laser	Still imaging	None
Trios (2nd generation)	3shape A/S	Confocal microscopy	Not disclosed	Video	None
Zfx Intrascan	ZFX GmbH	Confocal microscopy and Moiree effect detection	Laser	Video	None

A phantom containing prepared teeth was scanned using 5 different IOSs, and the respective test group was scanned 4 times. Scanning was performed according to the instruction of each manufacturer. In iTero and E4D groups, scanning was guided according to software instructions and abutment scan was finished first, followed by remaining teeth scanning. When scanning with Zfx Intrascan and Trios, occlusal sweep was done first and was followed by buccal and lingual sweeps in case of upper arch. Buccal and lingual sweeps were changed for lower arch scan. In case of Fastscan, posterior sections on both sides and anterior section were scanned separately and stitched together afterwards. Since Fastscan required the use of spray, its scan was performed at the last turn. 4 pairs of 3D data were acquired for each IOS. Data were obtained directly from the scanner of Fastscan and Zfx Intrascan while files were obtained from the manufacturer of E4D dentist, iTero and Trios.

According to ISO 12836, the deviation of measurements between the reference model and the intraoral scan model was termed the "trueness" of impression technique, and the deviation of measurements between digital models of the same intraoral scanner was "precision" of impression technique.

For the image superposition, a reverse engineering program (Rapidform; INUS Technology Inc.) was used. The reference STL file and intraoral scan STL files were superposed. Superposition was performed as follows: three points A, B and C were spotted on images, and while matching these, the two data were moved closer to each other, then, automerging was performed by computation using a command 'fine' (Fig. 2A). After superposition, the tooth model was divided in the mesiodistal, buccolingual, and right and left diagonal directions into a total of 8 sections. For the trueness investigation, the distance between the reference data and intraoral scan data were measured at 4 points (marginal, axial, line-angle, occlusal) on each section (Fig. 2B). In case of precision measurement, the distance between two intraoral scans within the same group at the aforementioned points on each section. For the mesiodistal and buccolingual comparison, mesial, diatal, buccal, and lingual sections were investigated and diagonal sections were excluded in the measurement.

The inlay was measured likewise. After superposition, section was created in the mesiodistal and buccolingual direction of the tooth model, and the distance between the two data were measured at the corresponding 4 points in

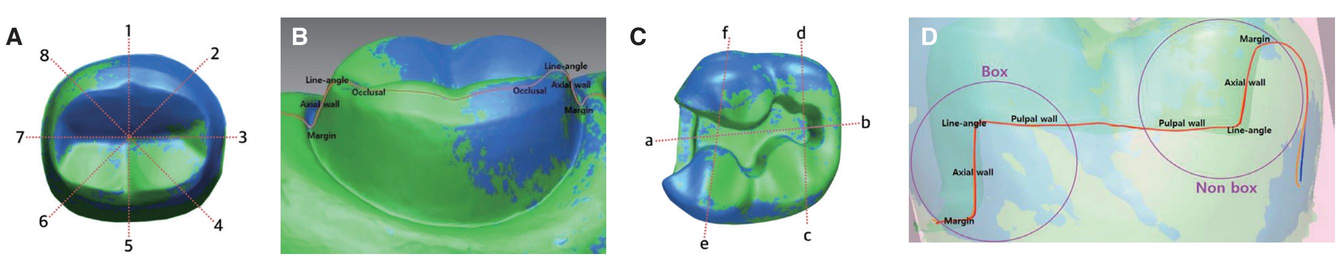

Fig. 2. Illustration of the sectioning of the superposed datasets and selected sites from preparation ouline form. (A) section lines of crown and bridge groups (sections 1, 3, 5, and 7 were investigated for the mesiodistal and buccolingual comparison). (B) measured sites for crown and bridge groups. (C) section line of inlay group (sections a and b were inspected for the box and non-box comparision). (D) sites from preparation outline form for inlay group.

these sections. For the comparison of box and non-box regions, sections in the mesiodistal directions were investigated (Fig. 2C and Fig. 2D).

The difference in trueness and precision of intraoral scanners, and trueness according to preparation design, preparation site, and scanning technology were verified by analysis of variance (ANOVA). When the difference was significant, Tukey HSD test was used in multiple comparisons. In addition, independent two-samples t-test was used to compare the trueness according to image acquisition and necessity of coating. Data were analyzed using a statistical program IBM SPSS version 18.0 (IBM Corporation). The significance level was set at $P = .05$.

RESULTS

Each scanner had a different resolution, leading to the difference in the details of the model, and the number of polygones were in the order of iTero (42,687), Trios (28,280), Fastscan (20,210), E4D dentist (17,607), and Zfx intrascan (10,432) (Fig. 3). Scanners used in this study showed the deviations in trueness and precision of 70.1 µm and 58.9 µm on average, respectively. The average deviations in trueness and precision of Fastscan, iTero and Trios were in the range of 40 to 60 µm and 10 to 30 µm, respectively, while those of Zfx Intrascan and E4D dentist were in the range of 80 to 120 µm and 90 to 140 µm, respectively, which were significantly higher than the other three scanners (Table 2 and Fig. 4). In comparison by the restoration type, significantly higher trueness was observed in crown and inlay than in bridge irrespective of intraoral scanners. While no significant difference in overall mean trueness was observed among margin, axial wall, line-angle, and occlusal site, the trueness at line-angle was higher than those at the others in E4D dentist group. In comparison by the section, the mesiodistal direction showed significantly higher devia-

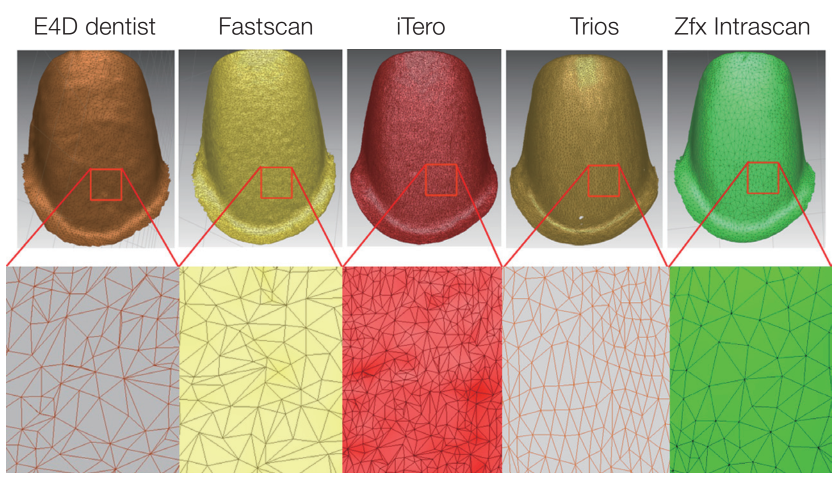

Fig. 3. Number of polygons for selected maxillary incisor for the comparison of the each IOS's resolution.

Table 2. Trueness and precision of each intraoral scanner

Scanner	Trueness	Precision
	Mean value ± SD (µm)	Mean value ± SD (µm)
E4D dentist	114.2 ± 80.7[a]	97.6 ± 109.2[b]
Fastscan	45.2 ± 29.8[c]	26.0 ± 24.4[c]
iTero	52.1 ± 38.8[c]	25.8 ± 22.5[c]
Trios	49.7 ± 36.6[c]	13.0 ± 12.1[d]
Zfx Intrascan	89.4 ± 64.2[b]	132.3 ± 124.4[a]
Overall mean	70.1 ± 60.0	58.9 ± 89.2
Dental wings (reference scanner)	Not determined (≤ 15 manufacturer)	35.3 ± 42.4
F	132.3**	339.7**
P value	.000	.000

Multiple comparison: a > b > c, $P < .01$: **, $P < .05$: *

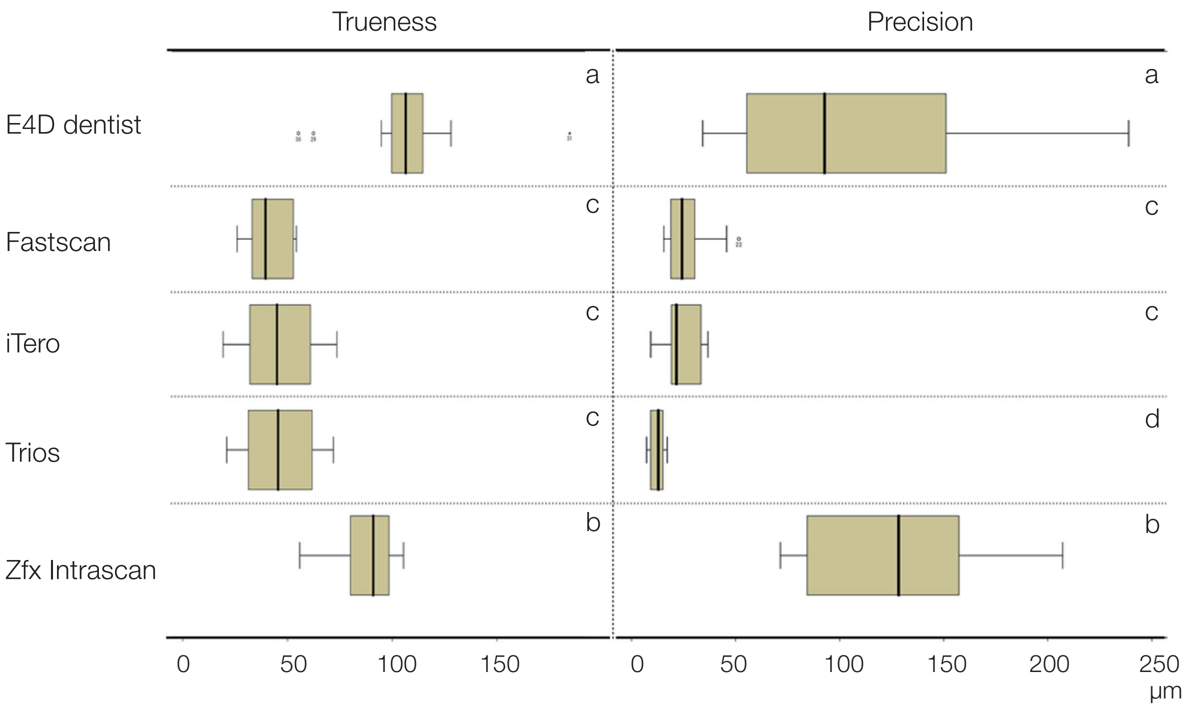

Fig. 4. Illustration of absolute mean trueness and precision values of intraoral scanners. Same letters denote significant differences in between the groups at the 5% significance level.

tion than the buccolingual direction. Also, while the trueness is lower in the box overall, there was no significant difference in the trueness between the box and the non-box with Fastscan and iTero (Table 3 and Table 4). Trueness was observed to be in the increasing order of Fastscan with the active triangulation, iTero, Trios and Zfx Intrascan with the parallel confocal technology, and E4D dentist with the optical coherence tomography. In addition, the group using powder displayed lower trueness which means higher accuracy. On the other hand, no significant difference in trueness was observed between the still image acquisition and the video acquisition groups (Table 5).

DISCUSSION

The trueness and precision of IOS are among the most fundamental evaluation elements for the clinical application of the digital impression method. Although the evaluation method via image superposition has a fundamental error and limitation in the selection and superposition of random points on the program, and does not necessarily suggest the relationship with the actual restoration, it can still play an important role in the comparative evaluation of each IOS. In this *in vitro* study, the first null hypothesis was rejected because in general, the intraoral scanner had lower trueness

Table 3. Trueness according to the preparation design

Scanner	Crown	Inlay	Bridge	F	*P* value
E4D dentist	95.7 ± 67.4[b]	95.2 ± 62.6[b]	130.6 ± 89.0[a]	11.8**	.000
Fastscan	39.0 ± 26.6[b]	32.9 ± 19.3[b]	52.8 ± 32.3[a]	21.9**	.000
iTero	38.1 ± 21.4[b]	35.3 ± 25.5[b]	65.3 ± 44.5[a]	36.9**	.000
Trios	28.2 ± 19.3[b]	50.8 ± 42.2[a]	60.0 ± 36.5[a]	37.2**	.000
Zfx Intrascan	70.3 ± 50.3[b]	94.5 ± 57.2[a]	97.1 ± 70.8[a]	8.0**	.000
Overall mean	54.3 ± 48.4[b]	61.7 ± 52.5[b]	81.2 ± 65.5[a]	50.6**	.000

Multiple comparison: a > b, *P* < .01: **, *P* < .05: *

Table 4. Trueness according to the preparation site and in the inlay box

Scanner	Margin	Axial wall	Line-angle	Occlusal	*P* value	Mesio distal	Bucco lingual	*P* value	Box	Non-box	*P* value
E4D dentist	112.7 ± 82.4[b]	102.6 ± 69.8[b]	146.8 ± 97.6[a]	95.9 ± 62.6[b]	.000**	148.5 ± 97.5[a]	91.7 ± 60.7[b]	.000**	104.2 ± 59.5[a]	50.8 ± 23.7[b]	.002**
Fastscan	45.1 ± 28.5	49.1 ± 35.6	44.7 ± 28.7	42.2 ± 26.2	.361	57.4 ± 41.7[a]	39.0 ± 19.9[b]	.000**	39.3 ± 26.4	38.1 ± 23.1	.892
iTero	54.5 ± 44.0	57.8 ± 31.8	46.1 ± 34.1	52.6 ± 44.6	.136	70.5 ± 53.5[a]	48.0 ± 27.2[b]	.000**	31.0 ± 14.7	30.7 ± 12.5	.964
Trios	54.5 ± 38.4	47.4 ± 31.5	47.2 ± 36.8	48.9 ± 39.7	.388	61.3 ± 46.3[a]	40.0 ± 22.9[b]	.000**	54.1 ± 34.6[a]	13.1 ± 7.8[b]	.000**
Zfx Intrascan	93.1 ± 72.7	87.8 ± 62.4	84.6 ± 62.8	90.0 ± 59.9	.781	93.1 ± 66.9	79.6 ± 59.4	.141	104.3 ± 54.4[a]	65.9 ± 25.6[b]	.016*
Overall mean	72.0 ± 62.7	69.0 ± 53.7	73.9 ± 69.9	65.9 ± 53.2	.116	86.2 ± 72.4[a]	59.7 ± 47.3[b]	.000**	66.6 ± 51.5[a]	39.7 ± 26.4[b]	.000**

Multiple comparison: a > b, *P* <.01: **, *P* < .05: *

Table 5. Trueness according to the characteristics of IOS

Characteristics	Image acquisition		*P* value	Necessity of coating		*P* value	Scanning technology			*P* value
	Still image	Video		Coating	None		Confocal microscopy	Active triangulation	Optical coherence tomography	
Mean Trueness	70.5 ± 62.7	69.5 ± 55.9	.732	45.2 ± 29.8[b]	76.3 ± 64.0[a]	.000**	63.7 ± 51.5[b]	45.2 ± 29.8[c]	114.2 ± 80.7[a]	.000**

Multiple comparison: a > b > c, *P* < .01: **, *P* <.05: *

in the inlay box, and it is considered that this was potentially caused by the limitation in the scan depth of IOS and the adjacent teeth undercut that hampered the image acquisition. For the trueness depending on the scanning technology and characteristics of scanners, the second null hypothesis was rejected because the acquired image displayed deviations in trueness by the scanning technology and characteristics of scanners.

A desktop scanner, Dental Wings 3D scanner, was used as a reference scanner as in previous studies,[14-17] and the reason that an IOS was not selected as a reference scanner was that the accumulation of errors caused by sudden actions during scanning due to the high degree of freedom could lead to the bending of the model. A trueness of up to 15 μm was reported on the reference scanner for a single measurement case of the plaster model,[18] and it was shown that the internal and marginal gaps of the crown on the experimental model fabricated using this scanner were up to the range of 23.45 to 42.43 μm.[19] In this study, the precision of this reference scanner was measured, which was 35.3 ± 13.9 μm.

There have been many studies which evaluated the performance of intraoral scanners by measuring fit of restoration or superimposing scan data. Seelbach *et al.* fabricated a single crown using CEREC, iTero and Lava COS, and measured the internal gap and marginal fit, which were 29 to 88 μm and 30 to 41 μm, respectively, in agreement with the values measured on the crown fabricated by the conventional method.[5] In a study of van der Meer *et al.* using the implant scan body, the distance errors between the scan bodies measured by CEREC, iTero and Lava COS were 79.6 to 81.6 μm um, 61.1 to 70.5 μm and 14.6 to 23.5 μm, respectively.[13] Mehl *et al.* analyzed the accuracy by superposing the model data acquired from a desktop scanner and CEREC AC Bluecam, and reported that the deviation was 19.2 μm for a single tooth and 35 μm for a quadrant.[20] Kim *et al.* scanned a polyurethane model fabricated by milling process using scan data of iTero and a traditional plaster model with a desktop scanner, and compared the data.[21] They reported that the deviation was 23.9 ± 17.6 μm for a single tooth and the model fabricated using IOS showed a significantly higher deviation than the traditionally fabricated model, which, however, was clinically acceptable.

Ender *et al.* reported that a deviation of 58.6 µm was observed in the comparison of accuracy in the full arch models between CEREC AC system and a reference scanner, and a deviation of 32.4 µm was observed in the analysis of precision by comparing between the CEREC data.[22] They concluded that this had a significantly lower accuracy than the traditional method. In their further study, it was reported that the deviations in accuracy and precision for CEREC Bluecam, iTero, Lava COS and Omnicam were up to 29.4 to 44.9 µm um and 19.5 to 63.0 µm, respectively,[8] which leads to a conclusion that these IOSs could be applied to full mouth scan cases within the limitations of *in-vitro* study. Patzelt *et al.* also reported studies on the accuracy of full arch scan and fully edentulous jaw digitization.[9,10] As the intraoral scanner is a handheld device, the image stitching error from the uneven and abrupt movement of scanner wand might cause the deformation of scan data. These studies have a great significance because they were focused on the deformation of entire arch. This study was conducted to investigate another characteristic of intraoral scanner. The depth of field is related to not only the difficulty of scanning but also the accuracy of scan data. Learning curve of intraoral scanners with narrow depth of field is very long because the operator has to keep distance from patient's teeth while watching computer display. When the maximum range that intraoral scanner can reach is short, the image acquisition could not be possible at the long tooth with deep preparation enclosed by tall adjacent teeth. In this study, the accuracy of various intraoral scanners was evaluated at the microscopic level of the abutment teeth by sectioning and picking up the anatomic structures which might be critical for the adaptation of restorations.

In studies that compared the accuracy of IOSs, Nedelcu *et al.* analyzed the accuracy and precision of 4 IOSs by the superposition method based on a desktop scanner as a reference, showing that the accuracy and precision of CEREC were better than those of E4D dentist.[2] They suggested that this was because E4D dentist did not have sufficient transition area that was relatively clearly defined, and much noise appeared on the surface. In this study, iTero displayed better results compared to E4D dentist and Zfx Intrascan, which was in agreement with previous studies.

Schaefer *et al.* reported that marginal discrepancy of a partial crown (MOD inlay) fabricated using iTero was up to 90 µm, while An *et al.* analyzed the marginal fits of zirconia coping fabricated using iTero by a replica technique, which was shown to be up to 103.05 µm for a single tooth.[3,23] Also, Keul *et al.* performed experiments similarly and reported that the marginal opening of 4-unit zirconia framework was up to 127.23 µm.[24] In our study, an abutment scanned by iTero displayed higher deviations in the increasing order of the inlay, crown and bridge, and this trend is consistent with preceding studies. Also, in general, the trueness of IOS was lower in the fixed dental prosthesis, which can be attributed to the errors in the image acquisition and stitching processes due to the presence of the glossy pontic space with less surface characteristics.

Brawek *et al.* measured the fits of the crown fabricated using Lava COS and CEREC AC, and showed that the internal gap was larger than the marginal gap.[25] They suggested that this larger internal gap could be attributed to the fact that there was a lower limit in the size of the milling tool for processing of the interior of the restoration, and thus the software relief had to be made to process the angled corner of the interior of the restoration, which was compounded by the errors in replica technique.[26] In this study, the deviations between the marginal and internal gaps did not show any significant difference unlike previous studies, which can be attributed to the difference in the experimental method since this study only compared the abutment forms observed on the scan data. Also, in comparison of sections, the trueness in the mesiodistal section was lower than in the buccolingual section, and it is considered that this was because multiple scans were necessary at the mesiodistal site due to the undercut by adjacent teeth, and subsequently the amount of data to be stitched was larger.

There are various factors that affect the reproducibility of an IOS, including the scanning technology, data processing algorithm, whether or not to use powder and image acquisition method. Active triangulation is a traditional scanning technology and has been frequently applied in the desktop scanner, which offers the highest trueness if the condition is right. In comparison, the parallel confocal technology does not require a certain distance for focusing, and thus images can be acquired regardless of whether the scanner tip is attached to the teeth when the oral cavity is scanned. On the other hand, the optical coherence tomography has a high resolution that can create an image of the micromorphology of the abutment by combining the optical interference phenomenon and the confocal microscopy technology. In this study, the deviations in trueness and precision increased in the order of Fastscan with the active triangulation technology, iTero, Trios and Zfx Intrascan with the parallel confocal technology, and E4D dentist with the optical coherence tomography technology. In a study of Nedelcu *et al.* on CEREC, E4D dentist, iTero and Lava COS, the better result was obtained in the order of the active triangulation, confocal microscopy and optical coherence tomography, consistent with this study.[2] However, Ender *et al.* and Seelbach *et al.* studied using CEREC, iTero and Lava COS, and reported no notable difference between the active triangulation and parallel confocal scanners,[5,7] while Schaefer *et al.* suggested that the confocal microscopy displayed higher accuracy than the active triangulation.[3] These latter studies are in disagreement with our study, and thus yet another different result may be expected in the actual clinical setting, which warrants further studies on this matter.

In studies of Ender *et al.* and Seelbach *et al.*, similar accuracy was observed regardless of the use of powder while Schaefer *et al.* observed a significant higher accuracy in the powder free group.[3,5,7] In contrast, Nedelcu *et al.* suggested that the group using powder showed higher accuracy, in consistent with our study.[2] In addition, they prepared an experimental group with excessive spray coating, and investigated its impact on the accuracy, which yielded no significant difference. Rupf *et al.* reported that 4.6×10^6 of fine and ultrafine particles were accumulated per minute on average under conventional dental suction if scanning spray was applied, and recommended high volume evacuation for the prevention of the exposure to fine or ultrafine particles.[27] Although the use of powder can increase the scanning speed and the ease of scan, inconvenience to patients may be caused during the application and removal process of powder, and the powder remaining in the oral cavity may exert a harmful effect on the body.

Schaefer *et al.* and Nedelcu *et al.* classified IOSs largely into video acquisition and still image acquisition types depending on the scanning method,[2,3] and Ender *et al.* analyzed the accuracy of Bluecam and Lava COS by superposing images from these scanners with those of the reference scanner, which showed that there was no significant difference in the deviations between the video acquisition and still image acquisition methods.[6] Their further study on CEREC Bluecam, CEREC Omnicam, iTero and Lava COS showed similar results.[7,8] Also, the studies of Schaefer *et al.* and Seelbach *et al.* did not show any significant difference in the accuracy between the video acquisition and still image acquisition types.[3,5] Likewise, in this study, a significant difference in trueness between the two scanning methods was not observed. However, the video acquisition method has a clear advantage that scanning is convenient and images can be monitored during scanning.

A limitation of this study is that the data on the restoration itself fabricated using IOSs could not be provided. Also, as actual scanning conditions were not taken into consideration in this study, the lower trueness is expected in the actual clinical setting than in this study due to the level of patient's compliance, the skill of a practitioner, the presence of saliva during scanning, reflectivity of the tooth and the intraoral structure. Therefore, it is considered that further study using the final restoration in the clinical setting is necessary.

CONCLUSION

Except for 2 intraoral scanners, Fastscan, iTero and Trios displayed comparable levels of trueness and precision values in tested phantom model. The difference in trueness was observed depending on the restoration type, the preparation out line form, the scanning technology and the application of power.

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