Effect of the presence of orthodontic brackets on intraoral scans

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ABSTRACT

Objectives: The need for intraoral scanning in the presence of brackets has increased for monitoring tooth movement during orthodontic treatment. The purpose of this study was to evaluate the effect of orthodontic brackets bonded to tooth surfaces on intraoral scans.

Materials and Methods: Intraoral scans were performed in 30 patients using both iTero and Trios scanners before and after bonding of the brackets. The two sets of intraoral scans of each patient and intraoral scans with and without brackets were superimposed using a best-fit algorithm, and three-dimensional (3D) surface analysis was performed. In each superimposition, discrepancies in the 3D axes and arch-width measurements in the incisor and molar regions were compared. In addition, the range of distortion around the brackets was evaluated on the cross sections of each superimposition.

Results: The overall discrepancies between the intraoral scans with and without brackets were within 0.30 mm. The arch-width discrepancies in the molar region were greater than those in the incisor region, but the differences were not statistically significant ($P = .972$ for iTero; $P = .960$ for Trios). The cross sections of the superimposed intraoral scans with and without brackets showed that the deviations were within 0.40 mm in the horizontal section and within 0.35 mm in the vertical section around the brackets.

Conclusions: The results of this study indicate that the accuracy of intraoral scans, even in the presence of brackets, is clinically acceptable, and the regions beyond 0.50 mm around the brackets should be used for superimposition on images without brackets. (*Angle Orthod.* 0000;00:000–000.)

KEY WORDS: Intraoral scan; Orthodontic brackets; Accuracy; Image noise

INTRODUCTION

Successful orthodontic treatment depends not only on initial diagnosis but also on accurate assessment of treatment progress. Clinicians often make impressions of patients' dentitions for analyzing the occlusion and for monitoring and evaluating tooth movement during orthodontic treatment. With recent developments in intraoral scanners, intraoral scanning has been widely applied in dentistry as an alternative to conventional impression making, and its validity and reliability have been reported in previous studies.[1–3] However, previous studies analyzed the intraoral scans of the intact dentition without any oral appliances or attachments, and no studies have reported the accuracy of intraoral scans in the presence of orthodontic brackets.

Clinicians often perform intraoral scanning of the patients' dentition with braces for analyzing the occlusion during orthodontic treatment. Thus, the need for direct scanning of the dentitions of orthodontic patients with braces in the middle phase of treatment is greater than that need in the pre- and posttreatment phases. Additionally, many studies[4–7] have attempted to replace the dental part of maxillofacial computed tomography (CT) image with an image that represents the teeth in more detail. When integrating or superimposing intraoral scans and cone-beam CT (CBCT) images, accurate registrations of both images are essential for an accurate integrated image. When integrating intraoral scans of the teeth with brackets and CBCT images, brackets can cause registration errors. The purpose of this study was to evaluate the effects of orthodontic brackets bonded to tooth surfaces on intraoral scans.

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MATERIALS AND METHODS

This study was approved by the Institutional Review Board of the Chonnam National University Dental Hospital. The sample size was determined using the G-power program (version 3.1.9.2; Heinrich-Heine-University, Düsseldorf, Germany), at the significance level of 0.05 and the power of 0.8 in the paired *t*-test, based on a previous study.[8] Thirty patients categorized as Grades 1, 2, and 3 on the Index of Orthodontic Treatment Need[9] were enrolled in this study. Individuals with severe crowding, particularly in the mandibular arch (those with Little's Irregularity Index of greater than 6 mm),[10] and any dentofacial deformity, such as cleft lip/palate or craniofacial syndrome, were excluded. All patients provided informed consent. The inclusion criteria were (1) fully erupted permanent dentition from the first molar to the contralateral first molar in both jaws and (2) no metal or gold crowns or bridges.

Intraoral Scanning Using iTero and Trios Scanners

Intraoral scanning with both iTero (Align Technology, San Jose, Calif) and Trios (3Shape, Copenhagen, Denmark) scanners was performed before and after bonding of the brackets by a single investigator (SJK), according to the manufacturers' recommendations. Standard metal brackets with 0.018-inch slots (Tomy Incorporated, Tokyo, Japan) were used in all patients, and the same investigator performed this process. Before initiating the procedure of scanning, calibration and pre-heating of the scanner were accomplished. The teeth were slightly dried using compressed air. All scanned data from the iTero scanner were transferred to Align Technology, where they were reprocessed to be available for download in a stereolithography (STL) file format. The scanned data obtained by Trios were transferred to the OrthoAnalyzer™ (3Shape) software program, where they were reprocessed as STL files.

The intraoral scans obtained from both scanners were superimposed; the images from iTero without brackets were overlapped with the images from Trios without brackets, and the images from iTero with brackets were overlapped with the images from Trios with brackets. Surface differences determined from the scans without brackets and those determined from the scans with brackets were compared. A reverse engineering software program (Rapidform, 3D Systems, Rock Hill, SC) was used to superimpose the two categories of scanned images. First, the initial registration was completed by selecting three points on corresponding images obtained by the two scanners in each category (brackets vs without brackets), after which the program's automatic "fine registration" function was employed to finalize the matches. The three points considered during initial registration were the mesiobuccal cusp tips of the right and left second molars and the mesiolabioincisal point angle of the right central incisor of both arches. The initial registration established a tentative initial alignment, using whichever fine registration could be performed. The software utilized the iterative closest point algorithm for fine registration. Since the presence of adjacent soft tissues could increase the range of error, these areas were deleted along the gingival margin to allow the superimposition of the clinical crowns. Using the "shell/shell deviation" function of the program, the average surface differences between the iTero and Trios scans without brackets and the iTero and Trios scans with brackets were compared at all points on the surfaces. Absolute values were used as measurements in this study. In addition, the differences between the two categories of images were evaluated using color-mapping methods.

In order to determine the effect of brackets bonded to tooth surfaces on image noise, the iTero scans with and without brackets and the Trios scans with and without brackets were superimposed. For each superimposition, three-dimensional (3D) linear measurements were obtained in the incisor and molar regions to analyze the discrepancies between each superimposition. After initial registration, regional registration was performed by selecting the incisal edge and lingual side of the teeth to finalize the registration (Figure 1). Four reference points (the mesiolabioincisal point angles of the right and left central incisors and the mesiolingual cusp tips of the right and left first molars) were selected, and distances between the points on the superimposed scans with and without brackets were compared. The distances between the points were regarded as displacement in the superimposition of iTero scans with and without brackets and in the superimposition of the Trios scans with and without brackets, and the relative distance between each superimposition was calculated. In addition, the means and standard deviations were computed for each in the *x*-, *y*-, and *z*-axes to determine the direction of the discrepancy that contributed to the overall degree of discrepancy.

The intercanine and intermolar widths were also measured in the scans with and without brackets. The intercanine width was measured between the incisal tips of the right and left canines. The intermolar widths were measured at two sites: between the mesiobuccal cusp tips of the right and left first molars and between the mesiolingual cusp tips of the right and left first molars. For the evaluation of distortion around brackets, the scans with and without brackets were superimposed. Using the "create the plane" function in the program, the superimposed images were cross-

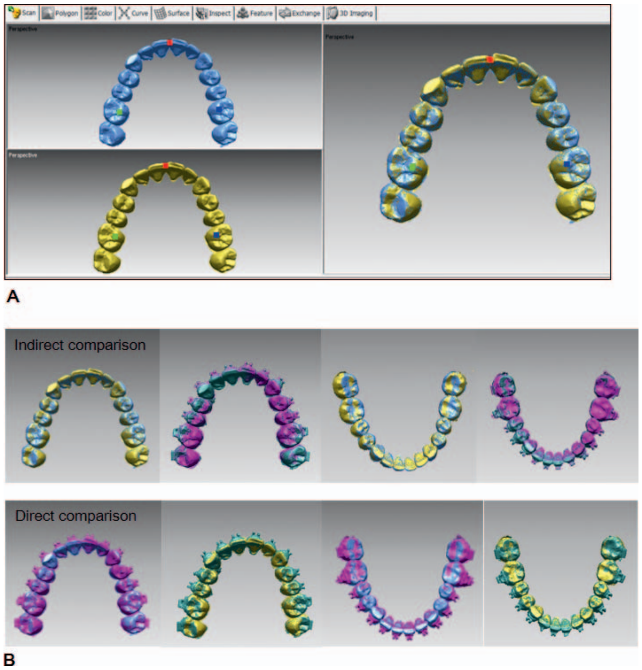

Figure 1. Two methods, direct and indirect comparison, used for comparing two intraoral scans with and without brackets. (A) Initial registration of the two scans achieved by designating the same three points. Registration completed by the "fine registration" function of the software program. (B) Registration of the two intraoral scans without brackets and of the two intraoral scans with brackets from iTero and Trios scanners for the indirect comparisons; registration of the intraoral scans with and without brackets in the iTero and Trios scanners for the direct comparisons.

sectioned vertically and horizontally in the first molar region. A vertical cross-sectional plane was obtained using three reference points: central fossa and midpoints of the buccal and lingual surfaces of the first molars. A horizontal plane was obtained using the center point of the bracket slot on the buccal surface and midpoints of the lingual and proximal surfaces. The scan distortions were measured as the maximum distance between the deviated points on the scanned images and on the actual brackets.

Statistical Analysis

The paired *t*-test was used to determine the differences in shell/shell deviations between the two intraoral scanners, to compare the differences in the discrepancies between the incisor and molar regions, and to determine the differences in discrepancies in linear measurements between the intraoral scans with and without brackets. One-way analysis of variance was used to analyze the differences in 3D discrepancies between the incisor and molar regions and to analyze the differences in discrepancies in linear measurements. Statistical analyses were performed at a 5% level of significance with the SPSS statistics software (version 23.0, IBM, Armonk, NY).

RESULTS

The comparisons of shell/shell deviations, according to the presence of brackets, are shown in Table 1. Shell/shell deviation between iTero and Trios scans performed without brackets was 0.09 mm, whereas the value between iTero and Trios scans performed with brackets was 0.11 mm. However, there was no statistically significant difference between the two values ($P = .920$) (Table 1). Discrepancies between the intraoral scans with and without brackets showed that overall discrepancies in the scans obtained by iTero ranged from 0.22 mm to 0.30 mm, and those obtained by Trios ranged from 0.20 mm to 0.29 mm. The discrepancies in the first molars were larger (range: 0.27–0.30 mm) than those in the central incisors (range: 0.20–0.25 mm). The discrepancies between the intraoral scans with and without brackets were within 0.30 mm, and they were not statistically significant ($P = .539$ for iTero; $P = .546$ for Trios) (Table 2). Table 3 shows the differences in linear measurements between the intraoral scans with and without brackets. The differences in intercanine width and intermolar width ranged from 0.04 mm to 0.07 mm and 0.22 mm to 0.25 mm, respectively. These differences were not statistically significant ($P = .972$ for iTero; $P = .960$ for Trios) (Table 3). In addition, the cross sections of superimposed images of the intraoral scans with and without brackets showed that the deviations were within 0.40 $\pm$ 0.15 mm in the horizontal section and 0.35 $\pm$ 0.11 mm in the vertical section around the brackets (Figure 2).

DISCUSSION

Advances in 3D imaging technology have enabled acquisition and analysis of digitally obtained facial and dental images for diagnosis, treatment planning, and

Table 1. Comparison of Shell/Shell Deviation According to Presence of Brackets[a]

	iTero/Trios				iTero-br/Trios-br				
	Min	Max	Median	Mean ± SD	Min	Max	Median	Mean ± SD	*P*-Value
Shell/shell deviation	0.07	0.19	0.04	0.09 ± 0.10	0.10	0.19	0.01	0.11 ± 0.16	.920

[a] iTero/Trios indicates superimposition of intraoral scans without brackets, whereas iTero-br/Trios-br indicates superimposition of intraoral scans with brackets. Min indicates minimum value; Max, maximum value; and SD, standard deviation. *P*-value was obtained from paired *t*-test.

Table 2. Comparison of Discrepancy in Incisor and Molar Regions According to Presence of Brackets and its Interscanner Comparison[a]

	iTero/iTero-br				Trios/Trios-br				Difference[b] (*P*-Value)
	Min	Max	Median	Mean ± SD	Min	Max	Median	Mean ± SD	
Central incisor mesiolabial point angle, right	0.09	0.66	0.19	0.22 ± 0.13	0.01	0.59	0.20	0.20 ± 0.12	.721
Central incisor mesiolabial point angle, left	0.08	0.95	0.23	0.25 ± 0.17	0.08	0.72	0.18	0.23 ± 0.14	.697
First molar mesiolingual cusp, right	0.10	1.11	0.28	0.30 ± 0.15	0.07	0.78	0.28	0.29 ± 0.16	.352
First molar mesiolingual cusp, left	0.01	0.91	0.25	0.28 ± 0.17	0.08	0.80	0.25	0.27 ± 0.15	.517
Difference[c] (*P*-value)				.539				.546	

[a] iTero/iTero-br indicates superimposition of intraoral scans with and without brackets obtained from iTero scanner. Trios/Trios-br indicates superimposition of intraoral scans with and without brackets obtained from Trios scanner. Min indicates minimum value; Max, maximum value; and SD, standard deviation.

[b] The result of paired *t*-test.

[c] The result of analysis of variance.

posttreatment assessment.[11,12] In clinical settings, intraoral scanners are widely used to acquire dental images, as they are convenient for both clinicians and patients and eliminate the necessity of fabrication and the resultant storage of gypsum models. A systematic review[1,2] of the accuracy of intraoral scans reported that inter- and intra-arch measurements from intraoral scans were more reliable and accurate in comparison to those from conventional impressions. Another systematic review[3] in prosthodontics reported that dental restorations fabricated using digital impressions exhibited similar marginal fit to those fabricated using conventional impressions.

One in vitro study[13] evaluated the effects of brackets on the measurements of enamel thickness on radiographs. In that study, the presence of brackets significantly affected interproximal enamel measurements. A similar clinical situation is encountered by clinicians during intraoral scanning of patients with brackets. There are more chances to take an impression of patients in the active treatment phase. Thus, in the current in vivo study, intraoral scans of teeth with brackets were assessed to determine the influence of brackets on the accuracy of dental images acquired using intraoral scanners. The principal strength of this study was its in vivo nature. Although previous studies[14,15] evaluated the effect of brackets bonded to tooth surfaces on the accuracy of intraoral scans, no in vivo study has investigated the accuracy of full-mouth scans in the presence of brackets. Previous studies[14,15] were in vitro studies using dental models and obtained the discrepancy between models with and without brackets by means of 3D comparison. This discrepancy failed to quantify the displacement of the intraoral scans with brackets and simply computed surface distances between thousands of surface points.

Shell/shell deviation does not represent the discrepancy in corresponding surfaces between the images with and without brackets. Therefore, in this study indirect comparison was used for the value of shell/shell deviation. In the indirect comparison, the images without brackets from iTero and Trios scanners were superimposed and the shell/shell deviation was computed. Thereafter, the values of shell/shell deviations obtained from the superimposition of the two images with brackets from the iTero and Trios scanners were compared.

Although shell/shell deviations did not show significant differences in the presence or absence of brackets, slightly higher discrepancies were evident in the presence of brackets. These differences could be attributed to image displacement caused by the scattered reflection of light rays by the metal brackets in the mouth during scanning with the iTero and Trios scanners, as both operate according to the principle of light emission. This finding was in agreement with the results reported by Nabha et al.[16] CBCT scans of teeth with amalgam restorations resulted in the distortion of

Table 3. Discrepancy of Linear Measurements Between With/Without Brackets in Each Intraoral Scanner and its Interscanner Comparison[a]

	iTero/iTero-br				Trios/Trios-br				Difference[b] (*P*-Value)
Linear Measurements	Min	Max	Median	Mean ± SD	Min	Max	Median	Mean ± SD	
Intercanine width	−0.54	0.71	0.05	0.07 ± 0.27	−0.69	0.63	0.07	0.04 ± 0.25	.523
Intermolar width between mesiobuccal cusps	0.01	0.50	0.22	0.23 ± 0.15	0.00	0.51	0.21	0.22 ± 0.11	.424
Intermolar width between mesiolingual cusps	−0.20	0.56	0.23	0.25 ± 0.18	0.00	0.52	0.22	0.22 ± 0.11	.573
Difference[c] (*P*-value)				.972				.960	

[a] iTero/iTero-br indicates superimposition of intraoral scans with and without brackets obtained from iTero scanner. Trios/Trios-br indicates superimposition of intraoral scans with and without brackets obtained from Trios scanner. (–) indicates larger value of intraoral scans without brackets than intraoral scans with brackets; Min, minimum value; Max, maximum value; and SD, standard deviation.

[b] The result of paired *t*-test.

[c] The result of analysis of variance.

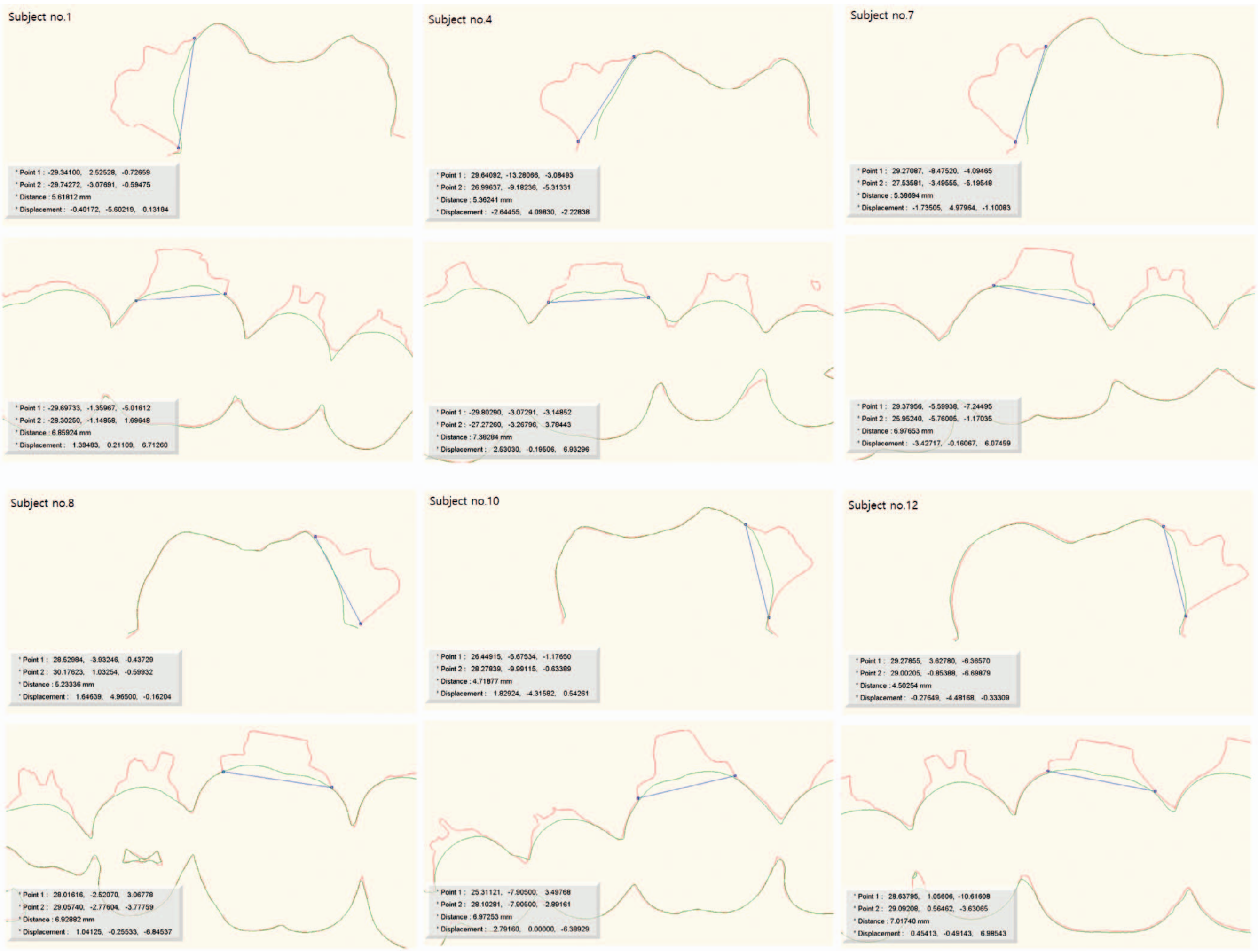

Figure 2. Cross sections showing the discrepancies between the intraoral scans with and without brackets.

the images obtained. However, since the difference between shell/shell deviations in the presence and absence of brackets was only 0.02 mm, this deviation did not appear to be clinically significant for orthodontic diagnosis and treatment planning.

During the superimposition of the images with and without brackets, the discrepancies were 0.22 mm to 0.30 mm for iTero and 0.20 mm to 0.29 mm for Trios. In a previous in vitro study,[14] the discrepancies of the images due to the presence of the metal brackets were 0.006 mm to 0.028 mm for average values and 0.97 mm to 1.26 mm for maximum values. In the current study, maximum values of 0.66 mm to 1.11 mm were found for iTero and values of 0.59 mm to 0.80 mm for Trios. Lower values observed for the Trios scanner could be due to the difference in the methods of image acquisition employed by the two scanners. Although both the iTero and Trios scanners are laser scanners operating on the confocal principle, the iTero scanner irradiates the object being scanned with over 100,000 parallel red-laser beams and acquires 3D data by measuring the reflected distance. Additionally, the iTero scanner acquires data from the buccal, lingual, occlusal, mesial, and distal aspects of each tooth separately and then matches the data to produce the image.[17] In contrast, the Trios scanner matches data by recording a video based on a real-time rendering mode. Telecentricity of Trios is superior to that of iTero. This minimizes any chances of error, since it matches the data while auto-adjusting the distance between the object being scanned and the light source by moving the focal plane and acquires accurate images with the same ratio, regardless of the distance of the light source to produce images with fewer errors.[17]

Overall, a greater difference was found in the posterior teeth than in the anterior teeth. Jung et al.[14] compared intercanine and intermolar widths with and without brackets. In their study, the deviations of maximum and minimum values in maxillary intercanine and intermolar widths were 0.20 mm and 0.16 mm, respectively, for iTero, whereas those in mandibular intercanine and intermolar widths were 0.14 mm and 0.36 mm, respectively, for Trios. Their results were similar to those of the current study in that the deviation was greater in the molar area than the incisor area. This difference could be evident as a result of the characteristics of intraoral scanners, whereby device accessibility to the posterior teeth is poorer than that to the anterior teeth. This could have resulted in the greater degree of error while simultaneously allowing for the acquisition of more accurate images of the posterior teeth than of the anterior teeth. With respect to the posterior teeth, the buccal surfaces, where the metal brackets were located, were expected to show a greater difference in the transverse dimension than the lingual aspect; however, no such difference was evident. It could be concluded that the presence or absence of brackets did not affect the overall dimensions of the teeth at the level of the occlusal surface.

The average vertical and horizontal image distortions near the brackets were 0.40 $\pm$ 0.15 mm and 0.35 $\pm$ 0.11 mm, respectively. Noh et al.[18] compared the errors when images obtained from laser-scanned dental models were superimposed on the CBCT images. They found fewer errors when both buccal and lingual surfaces were used for superimposition than when lingual surfaces were used alone. This indicated that accuracy increased with the widening of the superimposed region. Based on the results of the current study, the image distortion (image noise) was limited to within 0.50 mm around the brackets. These results suggested that only regions beyond 0.50 mm from the bracket should be used for the superimposition of intraoral scans in pretreatment, midtreatment, and posttreatment phases.

Currently, no absolute reference value exists with which to determine the utility of 3D dental images in clinical orthodontic diagnosis. However, based on the results obtained by Hiroki et al.,[19] it was concluded that an orthodontic diagnostic model is clinically useful if its accuracy is approximately 0.30 mm, while Schirmer and Wiltshire[20] suggested that a measurement error of $<$0.20 mm between the actual model and the scanned images can be permitted. The current study showed that errors in all 3D images in the presence or absence of brackets were within 0.30 mm. Thus, 3D images with brackets can be used clinically, based on the criteria suggested by recent studies.

When superimposing dental images obtained from initial examination on images obtained in the presence of brackets, regions beyond 0.50 mm from the bracket should be included in the superimposed region. The results showed that accurate and clinically valuable images can be acquired using an intraoral scanner even in the presence of brackets on the teeth, indicating that dental image acquisition can be used effectively and easily for orthodontic diagnosis and midtreatment assessment. In addition, these results showed that diagnosis and treatment assessment could be performed with greater ease in clinical settings by eliminating the additional processes associated with plaster model fabrication and storage. In this study, intraoral scanning was not repeated for determining intraexaminer reliability due to the in vivo nature of the study. Since intraoral scanning was performed before and after bonding of the brackets, it was impossible to repeat the intraoral scanning in the same patient. Considering that intraoral scanning procedures were previously shown[21,22] to exhibit a learning curve, the results obtained later in the study might be better than those associated with scans performed in the beginning of the study.

CONCLUSIONS

- The overall discrepancies between intraoral scans with and without brackets were within 0.30 mm, and the distortion of images occurred within 0.50 mm around brackets.
- The results of this study indicate that the accuracy of intraoral scans with brackets is clinically acceptable in orthodontics, and regions beyond 0.50 mm around brackets should be used for the superimposition on images without brackets.

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