THE JOURNAL OF PROSTHETIC DENTISTRY

CLINICAL RESEARCH

Clinical assessment of scanning deviations of four intraoral scanner systems following the cut-out and rescan procedures with dental dam isolation

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ABSTRACT

Statement of problem. The effect of errors in the cut-out and rescan procedure with dental dam isolation in restorative dentistry might be crucial for the clinical success of indirect restorations, but investigations are lacking.

Purpose. The purpose of this clinical study was to assess the scanning deviations of 4 intraoral scanners (IOSs) after the cut-out and rescan procedure with dental dam isolation and to compare 2 different computer software programs in the assessment of the deviations.

Material and methods. Twenty initial scans (prescans) were collected from 20 participants using 4 dental IOSs (TRIOS 3; 3Shape A/S, Cerec Primescan; Dentsply Sirona, iTero Element 5D; Align, iTero Lumina; Align). The 3-dimensional data were obtained from the right side of the mandible between the canine and the second molar area and recorded in standard tessellation language (STL) format. Then, the second premolar was cut on the screen of each IOS using the cutting tool in its software program, within 1 mm of the adjacent teeth. The dental dam was applied, and the same quadrant was rescanned by each IOS for each participant to allow the software program to overlap the 2 scans and fill in the cut-out area. The superimposition scan was recorded in STL format as the rescan data. The trueness of each scanner was assessed by overlapping the prescan and rescan data with Geomagic ControlX (3D Systems) and Oracheck (Dentsply Sirona) software programs to assess the root mean square (RMS) errors and the mean distance (MD) deviations, respectively. The deviations were assessed individually for the first premolar, second premolar, and first molar. Two-way ANOVA and Robust ANOVA with the median method were used for the statistical analyses ($\alpha<.05$).

Results. The overall RMS errors ranged between 60 and 90 µm, and the overall MD deviations ranged between 80 and 200 µm. All scanners presented beyond 60 µm of RMS errors with significant differences between them for the overall comparisons (P=.001). The iTero Lumina presented the lowest RMS error (60 ±20), followed by iTero Element 5D (70 ±20), Primescan (70 ±30), and TRIOS 3 (80 ±30) (P=.001). Regardless of the scanner type, the second premolar had significantly the highest RMS error (90 ±30) (P<.001). Regarding the overall data, a very low agreement was observed between MD deviations and RMS errors (Cronbach alpha=.047).

Conclusions. The cut-out and rescan procedure with dental dam isolation may cause RMS errors ranging from 60 to 90 µm, which were below the clinically acceptable limits. The deviation occurred mainly in the cut-out area, while the adjacent teeth were less affected. The level of deviation may vary depending on the selected IOS. The Oracheck may not be a good replacement for the Geomagic ControlX regarding the assessment of the deviations between the 2 scans. (J Prosthet Dent xxxx;xxx:xxx-xxx)

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.
The authors did not have any commercial interest in any of the materials used in this study.
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Clinical Implications

The cut-out and rescan procedure with dental dam isolation in restorative dentistry might affect an indirect restoration's clinical success. The outcomes may guide clinicians in the decision and planning of the cut-out and rescan technique to obtain an accurate restoration fit on the prepared cavities.

New dental procedures and techniques tend to make restorative or prosthetic procedures more straightforward and clinically effective, with the developments in intraoral scanners (IOSs) and restoration manufacturing technologies.[1–5] The cut-out and rescan procedure[6] is one of these additions, a common application for indirect restorative treatments that has been used mostly to recapture an unscanned or mis-scanned intraoral digital 3-dimensional (3D) image.[6,7] The cut-out and rescan procedure has recently been used in combination with dental dam isolation, especially for single-visit indirect restorations.[8,9] This procedure can provide the superimposition of the prescan and rescan data of a participant to provide a definitive virtual 3D image, including the dental dam isolation, and also to match it with the participant's individual occlusal records.[9] The dental dam has been used for its positive effects in increasing the quality and longevity of indirect restorations[10–12] because it improves humidity control and provides effective gingival displacement, which enhances visualization during the cementation of indirect restorations[13] and the detection of secondary caries lesions.[14] Additionally, more accessibility and more precise scanning ability around deep marginal areas can be achieved without requiring a displacement cord or hemostatic agents.[15–17] However, the longevity of indirect restorations produced by IOSs is contingent upon variables that include the scanning pattern,[18] operator experience,[19] quality of ambient light,[20] tip size,[21] scanning technologies,[22] and calibration of the scanner.[23,24] Furthermore, the accuracy of IOSs is affected by the surface morphology, which influences the reflected light[23,25] and the color of the scanned area.[6,26] Likewise, some researchers recently claimed that the cut-out and rescan procedure may adversely affect scan accuracy.[6,7,27]

Studies evaluating the effect of the cut-out and rescan technique are sparse, with only a few in vitro studies and case reports[7,27–34] and a few clinical studies.[6,8,9,20,35] Clinical research evaluating the impact of this procedure with the dental dam isolation is lacking.[9] This clinical study aimed to assess the scanning deviations of 4 IOSs following the cut-out and rescan procedure with dental dam isolation. Also, 2 different computer software programs were compared regarding the assessment. The research hypotheses were that significant scanning deviations would be observed after the cut-out and rescan procedure with the dental dam isolation, that the level of deviation would vary among the IOSs for the RMS error after the cut-out and rescan procedure with the dental dam isolation, and that the obtained RMS errors of the Geomagic ControlX software program and Md deviations of the Oracheck software program would have positive and high agreement.

MATERIAL AND METHODS

This clinical study was conducted with the approval of the ethics committee of a public university (approval number: 09.2024/1000). It was also registered in the U.S. National Library of Medicine (ClinicalTrials.gov Identifier: NCT06689384). A software analysis (G*Power, v. 3.1.9.6; Heinrich-Heine-Universität Düsseldorf) indicated that a minimum sample size of 7 participants and 14 scans in each of 4 groups was necessary for the study for an effect size of f=0.926 at a confidence level (1-α) of 0.05 and desired power (1-β) of 0.95. Because of the noninvasive research design, the number of participants was increased to 20 with 40 scans by using 4 IOSs (in total, 160 scans). Healthy participants who attended the restorative dentistry clinic in Marmara University Dentistry Faculty with restorative demands on the right mandibular premolar or molar teeth were evaluated. Among these, 20 participants between the ages of 18 and 55 without periodontal disease or contraindications to dental dam application were included. Those with missing teeth, a fixed prosthesis, or restorations that could affect scanning in the same quadrant were excluded.[36] All selected participants read, approved, and signed a consent form. Mandibular right quadrant intraoral digital scans (prescan and rescan) were obtained following the scanning protocols of the manufacturers by 4 restorative dentists (B.K., A.A.Ş., C.C.S., B.D.K.) with similar clinical experience of more than 5 years. The scanning speed, pattern, and effectiveness of the dentists had been calibrated with a pilot study.[9,17] The initial prescans were collected from 20 participants before the dental dam isolation procedure using 4 IOS groups (TRIOS 3; 3Shape A/S, Cerec Primescan; Dentsply Sirona, iTero Element 5D; Align, iTero Lumina; Align). The 3D data were obtained from the mandibular right quadrant between the canine to second molar and saved in standard tessellation language (STL) format. The same scanning strategy was followed for all the scanners that embraced every IOS's specific scanning technique under standardized ambient light conditions. The prescan was initiated from the occlusal surface of the second molar and continued to the canine. Then, it continued toward the buccal surfaces of the canine and the second molar. It was finalized on the lingual surface from the second molar to the canine. The IOS type was randomly changed

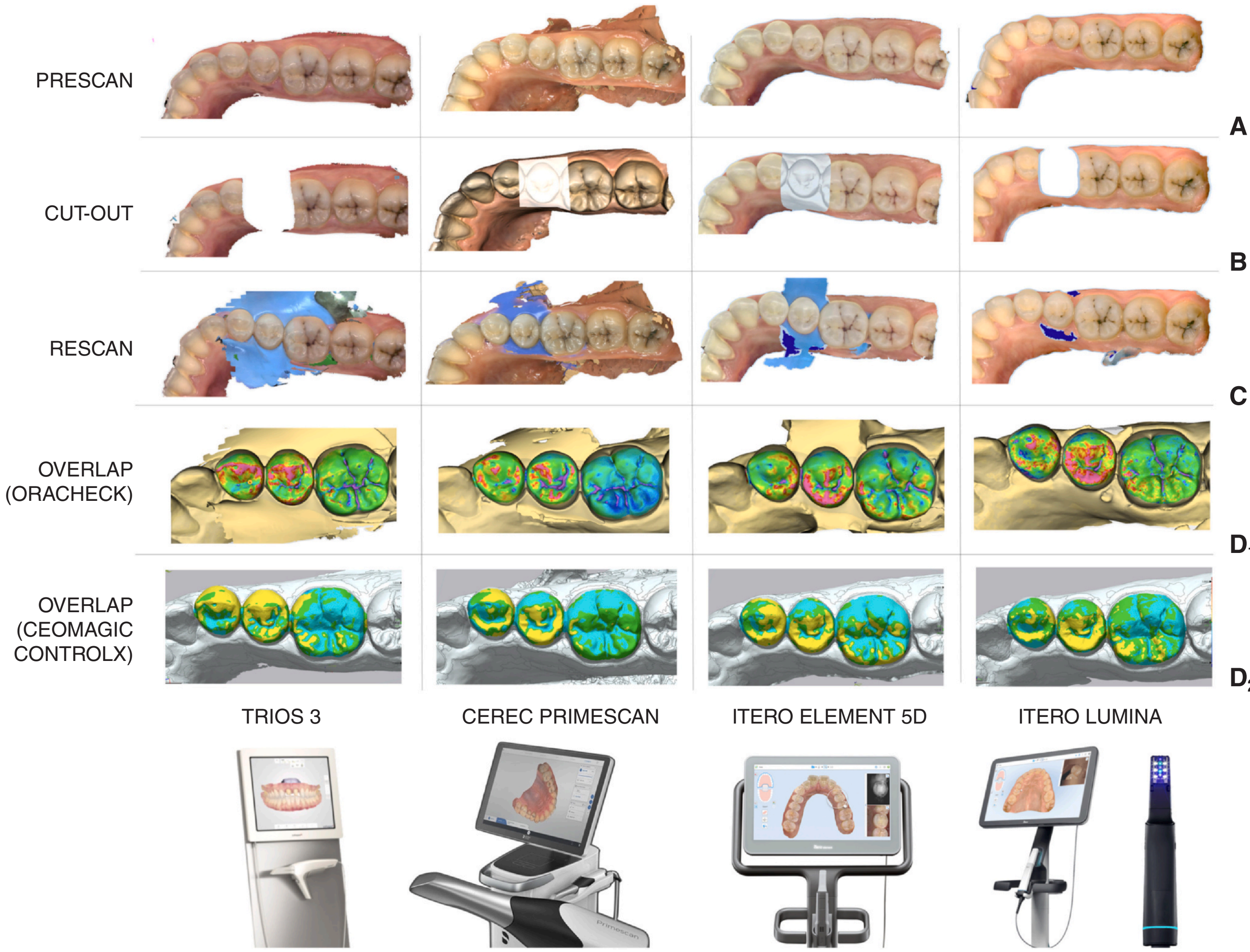

Figure 1. Distribution of scanner groups and study workflow. A, Prescan procedure. B, Cut-out procedure. C, Rescan procedure. D_1, Overlap procedure using Oracheck software program. D_2, Overlap procedure using Geomagic ControlX software program.

for each participant to minimize the bias (Fig. 1A). Each operator used 1 of the 4 IOSs for each participant, and they switched to another IOS randomly before scanning a new participant. Every operator used the 4 IOSs in a row before using the same IOS again.

After completing the prescans of the quadrant, the second premolar area on the screen of each IOS was cut out with the crop tool of the respective software program (considering that the second premolar was the one to be prepared and restored in a clinical scenario). Because of the differences of the IOS's integrated software programs in arranging the cut-out area, the cut-out procedure was performed within 1 mm mesially and distally of the adjacent teeth for each IOS for standardization (Fig. 1B). The 1-mm distance was ensured by measuring the distance with the ruler tool in each IOS's software program and by visually calibrating it among the 3D images. After the cut-out procedure, a single operator (A.A.Ş.) isolated the teeth in the mandibular right quadrant from canine to second molar clinically using a dental dam (Medium; NicTone). A premolar retention clamp (Black Line; Hu-Friedy Group) was placed on the second molar tooth, and a retentive piece of dental dam sheet was placed between the lateral incisor and canine. Then, the cut-out area was rescanned using each IOS and its software program by starting from the occlusal surface of the second molar toward the first premolar. Each IOS's software program digitally matched the rescan data with the prescan data and filled in the cut-out area. The dental dam was not changed during the scanning with other IOSs, and the scanning conditions remained similar. After the superimposition, the rescan was continued with the buccal and lingual surfaces (Fig. 1C). The rescan data were saved in STL format for each IOS per participant.

The trueness of the IOSs was quantitatively evaluated by assessing the deviations between the prescan and rescan data in STL file format after overlapping them in 2 different 3D analysis programs (Fig. 1D). The first premolar, second premolar, and first molar were

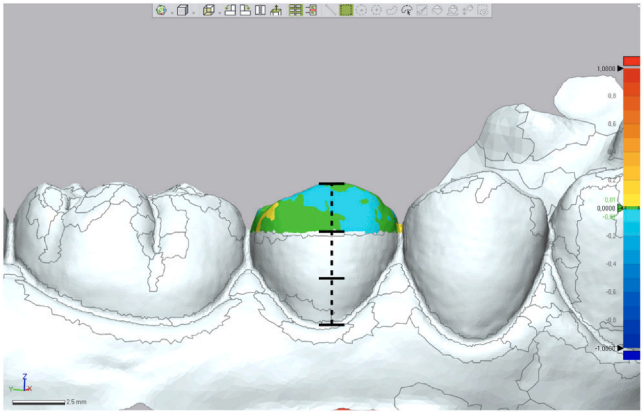

Figure 2. Selection of occlusal one-third of tooth from buccal view, including entire occlusal surface in 3 dimensions.

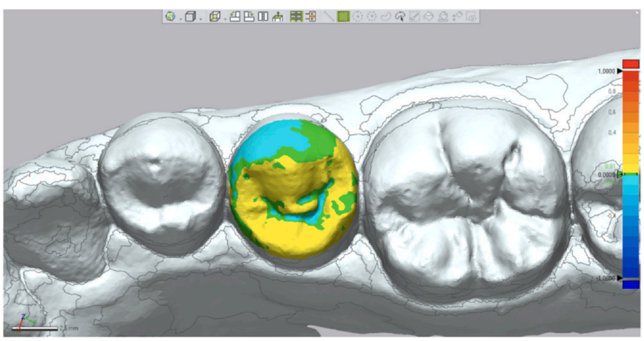

Figure 3. Selective analysis of root mean square error for second premolar after superimposition using Geomagic ControlX software program.

selectively assessed one by one in each integrated software program by a single operator (C.C.S.). The occlusal one-third of the tooth's crown length (including the entire occlusal surface) was selected in the overlapped 3D images of each software program for the assessments (Fig. 2). The root mean square (RMS) error (in µm) was calculated quantitatively in each IOS for each tooth using a software program (Geomagic ControlX; 3D Systems) based on the following equation: $RMS = \sqrt{\frac{\sum_{i=1}^{n}(x_{1,i} - x_{2,i})^2}{n}}$, where $X_{1,i}$ represents the reference data, $X_{2,i}$ represents the scan data, and n denotes the total number of measurement points recorded in each analysis (Fig. 3). The deviation in mean distance (MD) (in µm) was also calculated in each IOS per tooth by a software program (Oracheck; Dentsply Sirona) (Fig. 4). The MD deviations were obtained from the manually selected points on the occlusal surface of each superimposed tooth (premolars and first molar) by using the cursor tool. The software program automatically displayed the closest occlusal surfaces in pink color and the farthest occlusal surfaces in purple color between the overlapped scans (Fig. 4). For each tooth, the operator

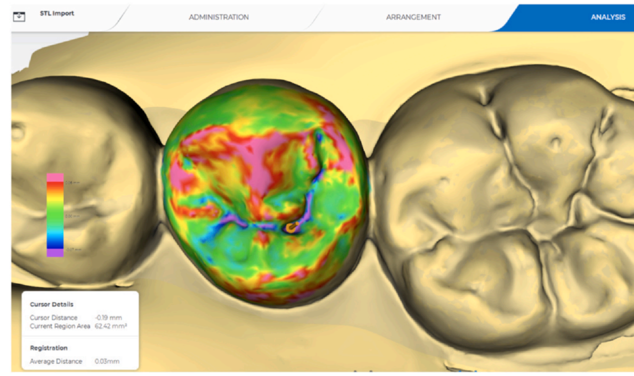

Figure 4. Selective analysis of MD deviation for second premolar after superimposition using Oracheck software program. MD, mean distance.

selected the 3 closest and 3 farthest superimpositions from each color by locating the cursor, and related cursor distance deviations were generated simultaneously. The obtained deviations in millimeters (mm) were then transformed into micrometers (µm).

Data were analyzed using statistical software programs (IBM SPSS Statistics, v23; IBM Corp, Jamovi V 2.6; The Jamovi Project) software programs. The conformity of the data was examined with the Shapiro-Wilk test. Intra-observer agreement was analyzed using the intraclass correlation coefficient. Descriptive statistics were presented, and multiple comparisons for the parametric data of RMS error were performed using the 2-way ANOVA and presented as mean ±standard deviation. Multiple comparisons for the nonparametric data of MD deviations were performed using the Robust ANOVA with Median method and presented as median (minimum-maximum). Cronbach alpha was used to analyze the agreement between the 2 software programs (α=.05).

RESULTS

Very strong and positive correlations were observed among the 3 assessments made by the same observer for both the RMS error and MD deviation values regarding each IOS (P<.001 for each scanner) (Table 1). Tooth number and IOS type were considered effective factors for the RMS assessments (P<.001 and P=.001, respectively), but the tooth-IOS interaction was statistically similar (P=.967) (Table 2). All IOSs presented an RMS error beyond an average value of 60 µm (Table 3). iTero Lumina presented the lowest RMS error (60 ±20 µm) among the IOSs, while TRIOS 3 (80 ±30 µm) and Primescan (70 ±30 µm) presented the highest (P=.001). Regardless of the IOS type, the second premolar presented significantly the highest RMS error (90 ±30 µm), followed by the first molar (70 ±20 µm) and the first

Table 1. Intra-observer agreement for RMS error and MD deviation assessments

	ICC (%95 CI)	*P*
RMS error assessment		
TRIOS 3	0.999 (0.999-0.999)	<.001
Primescan	0.999 (0.999-0.999)	<.001
iTero Lumina	0.999 (0.999-0.999)	<.001
iTero Element 5D	0.999 (0.999-0.999)	<.001
MD deviation assessment		
TRIOS 3	0.8 (0.72-0.86)	<.001
Primescan	0.73 (0.64-0.81)	<.001
iTero Lumina	0.62 (0.5-0.72)	<.001
iTero Element 5D	0.92 (0.89-0.95)	<.001

CI, confidence interval; ICC, intraclass correlation coefficient; MD, mean distance; RMS, root mean square.

Table 2. Comparison of variables regarding RMS error

	Test Statistics	*P***
Tooth	21.313	<.001
Scanner	5.281	.001
Tooth×Scanner	0.324	.967

RMS, root mean square.
* Two-way ANOVA.

premolar (60 ±20 μm), respectively. No significant differences were observed for the IOS and tooth number interactions (*P*=.967).

Tooth number and IOS type were considered effective factors for the MD assessments (*P*=.003 and *P*=.006, respectively), but the tooth-IOS interaction was not considered effective (Table 4). All IOSs presented MD deviations of more than a median value of 130 μm, with significant differences among them for the overall comparisons (*P*=.006) (Table 5). The TRIOS 3 [200 (30-820) μm] presented significantly the highest MD deviation, followed by the Primescan [150 (10-2290) μm], iTero Lumina [130 (10-940) μm], and iTero Element 5D [130 (20-1680) μm], with no difference between them. Regardless of the IOS type, the second premolar presented significantly the highest MD deviation [160 (60-940) μm], followed by the first premolar [110 (30-2290) μm] and the first molar [110 (20-500) μm], with no difference between them. Regarding the overall data, a very low agreement was observed between the MD deviations and RMS errors (Cronbach alpha=.047).

Table 4. Comparison of variables regarding MD deviation

	Test Statistics	*P**
Tooth	4.59	.003
Scanner	5.16	.006
Tooth×Scanner	4.97	.548

MD, mean distance.
* Robust ANOVA with median method.

DISCUSSION

The research hypothesis that significant scanning deviations would be observed after the cut-out and rescan procedure with the dental dam isolation was accepted because the cut-out and rescan procedure with the dental dam isolation caused significant scanning deviations for all IOSs tested. The research hypothesis that the level of deviation would vary among the IOSs for the RMS error after the cut-out and rescan procedure with dental dam isolation was accepted because of the observed significant RMS error differences among the IOSs. However, the research hypothesis that the obtained RMS errors of the Geomagic ControlX software program and the Md deviations of the Oracheck software program would have a positive and high agreement was rejected because the Geomagic ControlX and the Oracheck outcomes had a very low agreement.

Different software programs have been used to calculate volumetric deviations by overlapping STL files,[7,9,34] but the majority of studies have assessed the scanning deviations of IOSs using the Geomagic ControlX and the RMS error.[21–23,31,32] Consistent with the results of the present study, many previous studies revealed that the cut-out and rescan technique can reduce the scanning trueness in the IOSs.[7,14,17,31–33,36] When the scanning deviation increases, the fit and occlusal/proximal contacts of a restoration might be potentially affected.[9,35] The overall RMS errors within the IOSs ranged between 60 and 90 μm in the present study (Table 3). These deviations were higher than the reported deviations of Gómez-Polo et al,[7] ranging between 15 and 26 μm, but close to the deviations of Guo et al,[32] ranging between 65 and 78 μm. However, these studies used typodont jaws through the complete arch scans, comparing the results with an extraoral scanner.

Table 3. Comparison of scanners regarding RMS error (μm)

	Intraoral Scanner				
Tooth	TRIOS 3	Primescan	iTero Lumina	iTero Element 5D	Overall
First premolar	60 ±20	60 ±20	60 ±10	60 ±20	60 ±20^{B}
Second premolar	90 ±30	80 ±40	80 ±30	90 ±30	90 ±30^{A}
First molar	70 ±20	70 ±30	60 ±20	60 ±20	70 ±20^{BC}
Overall	80 ±30^{Y}	70 ±30^{Y}	60 ±20^{X}	70 ±20^{XY}	70 ±20

Average ±standard deviation. No significant differences with the same letters in row. No significant differences between the same letters in column. Deviations presented as root mean square error values in μm.
RMS, root mean square.

Table 5. Comparison of scanners regarding MD deviations (μm)

	Intraoral Scanner				
Tooth	TRIOS 3	Primescan	iTero Lumina	iTero Element 5D	Overall
First premolar	130 (60-300)	90 (30-2290)	100 (50-190)	110 (60-570)	110 (30-2290)^{A}
Second premolar	190 (80-330)	160 (60-680)	140 (60-940)	130 (70-320)	160 (60-940)^{B}
First molar	170 (60-420)	80 (20-500)	100 (40-280)	110 (40-330)	110 (20-500)^{A}
Overall	200 (30-820)^{X}	150 (10-2290)^{Y}	130 (10-940)^{Y}	130 (20-1680)^{Y}	150 (10-2290)

Median (min-max); No significant differences with the same letters in the row. No significant differences between the same letters in the column. Deviations presented as mean distance deviations in μm.

Moreover, a dental dam was not used in these studies. The IOSs in this study exhibited RMS errors beyond 60 μm and MD deviations beyond 130 μm for the overall tooth assessments (Tables 3, 5). According to previous research focusing mainly on the MD deviations, deviations even above 130 μm were considered within the clinically acceptable trueness limits of the IOSs.[10,11,28,29] Hickel et al[37] published clinical criteria for the evaluation of indirect restoration and considered marginal gap(s) or ditching up to 250 μm clinically satisfactory. Additionally, other studies reported that the resin-based cement material's thickness ranged from 20 to 200 μm and that the mean internal adaptation of milled ceramic crowns ranged from 220 to 295 μm.[15,26] Therefore, both the RMS errors and the MD deviations obtained in this study were considered within the clinically acceptable limits.

The accuracy during the cut-out and rescan procedure decreased with the increasing number of teeth in the rescanned areas.[35] The teeth were individually overlapped and assessed in this study to overcome the fact that a larger selected cut-out area can lead to an average superimposition by moving the dental geometries to compensate for the deviation.[4,9] Therefore, the quantity of out-of-reference surfaces was minimized to ensure optimal alignments. However, MD deviations in this study even reached 200 μm (Table 5), which was much higher than the overall RMS error range. Therefore, the obtained exact deviation values from the Geomagic ControlX and Oracheck software programs were far from a good match (Tables 3, 5). This inconsistency was also confirmed with the very low agreement between the RMS error and the MD deviation outcomes. The Oracheck was able to provide an average distance deviation for the entire scan superimposition data; however, it could not provide an average distance deviation for the manually selected occlusal surface of each tooth, unlike the Geomagic ControlX. This might be because of its algorithm, which was not designed to detect deviations after rescanning with the dental dam. Instead of obtaining an average value of the entire occlusal surface, the distance deviations of the manually selected points on the superimposed occlusal surfaces of each tooth were obtained in this study (Fig. 4). Even though the 3 closest and 3 farthest occlusal surfaces were selected to minimize the bias, this alternative method was operator-dependent and led to doubt regarding the reliability of the collected MD results.[9] This manual selection in the Oracheck software program was more difficult and probably less precise than Geomagic ControlX's artificial intelligence-based best-fit alignment feature.[4,9] Yet, up to 200 μm of MD deviations was still considered within the clinically acceptable trueness limits.[10,11,28,29]

Guo et al[32] assessed the trueness of the TRIOS 3, Medit i500, and Omnicam after a repeated number of cut-out and rescan procedures and reported significant deviations for in vitro test conditions. Even though TRIOS 3 presented the lowest RMS error, they did not compare it with more recently introduced IOSs like those in the present study.[32] Ali et al[31] reported that the cut-out and rescan procedure affected in vitro scanning accuracy depending on the mesh hole size and that trueness was more affected than precision. Gómez-Polo et al[7] also performed a complete arc rescanning to evaluate the effect of the mesh holes and reported that rescanning decreased the accuracy of the IOS. Consistent with their findings, the highest deviation in the present study was observed for the main and largest cut-out area, which was the tooth to be prepared and restored. The highest RMS error (90 μm) and also the highest MD deviation (160 μm) were both observed for the second premolar (Tables 3, 5), whereas both the RMS errors and MD deviations for the adjacent premolar and molar were considered lower. A comparison between the jaws could not be made because only the mandibular arch was investigated.[14] Passos et al[30] reported that Primescan presented lower trueness and precision when using the cut-out and rescan procedure compared with the Omnicam. Likewise, in the present study, the RMS errors for the Primescan were higher than for the iTero Lumina and also higher than for the iTero Element 5D regarding the MD deviations (Tables 3, 5, respectively). This result supported the Primescan manufacturer's statement that its algorithm did not support the cut-out and rescan procedure and that rescanning the entire arc was recommended. It was also previously revealed that the partial cut-out procedure might cause lower RMS values than the complete rescan procedure.[32] Therefore, even though Reich et al[33] observed no significant differences in trueness in the IOSs (Primescan, TRIOS, and Omnicam) after the cut-out and rescan procedure, they performed complete arc scans on typodont jaws as in many other studies.[7,21,22] Clinical evidence for the restorative cut-out and rescan procedure is limited,[6,20,30] and only a few studies used dental dam isolation.[8,27,30] In a clinical report, Jurado et al[8] reported that using Primescan with the cut-out and rescan procedure under the dental dam isolation was feasible only if prescan data were obtained. Espona et al[34] conducted a clinical study using only Primescan and reported no differences in trueness with and without using the cut-out and rescan procedure under dental dam isolation. They also reported an average deviation of 40 µm for the Primescan, which was lower than the findings of the present study. However, the assessments were made through the onlay restorations, and the Primescan was the only IOS used. Another gap in the literature is clinical information on iTero Lumina. It presented promising clinical results in the present study, with the best scanning consistency, together with the subsequent Element 5D. The lower deviation than the other IOSs might be because of the larger tip size, which can reduce scanning deviation.[20] Moreover, Lumina has the greatest reported scanning depth of field (25 mm), even greater than that of Primescan (20 mm), and it used a new technology called multidirect capture rather than the conventional confocal imaging.[12] Although the depth of field (DOF) value of TRIOS 3 and Element 5D are similar,[12,13] the lesser scanning deviation of Element 5D might be because of the parallel confocal imaging technology, which captures points and then generates a stitch reconstruction to make precise digital prints.[13] The TRIOS 3 captures single images stitched together in a 3D mesh.[16] Moreover, the software program of the Lumina had only the orthodontic mode (lower scanning resolution) in this study, thus lacking the restorative mode features (higher scanning resolution). However, the scanning resolution was previously considered not effective in terms of scanning trueness.[23] Even though the scanning pattern can influence the trueness,[21,24] this was not a variable in the present study.

Limitations of this clinical study included that it was conducted on healthy volunteers without tooth preparation that might have provided additional recognition areas for the Geomagic ControlX and OraCheck during overlapping and that the scanning procedures were only performed in the mandibular arch.[32] The cut-out procedure was mainly applied to the second premolar by manually erasing the area. However, the location and dimension of the cut-out area and the operator factors may influence the outcomes.[6] The cut-out could not be done in the same way for all the IOS-integrated software programs. Even though the differences in the cut-out type and dimension might have led to distortions during the superimposition procedure, this study compared the ability of the selected IOS systems with the integrated software programs.[9] Also, rescanning the entire region from the canine to the second molar might have increased misalignment errors during the superimposition. Moreover, multiple cut-out areas in the same arc were not evaluated.[14] An earlier version of the TRIOS system (3Shape A/S) was compared with relatively up-to-date scanning systems, which might have influenced the outcomes. The ambient lighting conditions and different dental dam sheet colors should be investigated.[9,20]

CONCLUSIONS

Based on the findings of this clinical study, the following conclusions were drawn:

1. Intraoral scanning after the cut-out and rescan procedure with dental dam isolation may cause RMS errors ranging from 60 to 90 µm, which was below the clinically acceptable limit in terms of indirect restorations.
2. The deviation occurred mainly in the cut-out area, which was the tooth to be prepared and restored, while the adjacent teeth were less affected.
3. The level of deviation may vary depending on the selected IOS. The Oracheck software program may not be a good replacement for the Geomagic ControlX software program for the clinical assessment of scanning deviations after the cut-out and rescan procedure with dental dam isolation.

PATIENT CONSENT

Each participant involved in this clinical study read an informed consent form informing the risks, benefits, and potential consequences of the clinical intervention. They approved and signed the form to participate in this clinical research.

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Bora Korkut: Conceptualization, Methodology, Resources, Writing – original draft, Project administration, Visualization. **Ayşe Aslı Şenol:** Methodology, Investigation. **Cevdet Can Saygılı:** Formal analysis, Data curation, Software. **Bengü Doğu Kaya:** Methodology, Visualization. **Marco Gresnigt:** Writing - review & editing, Validation. **Mutlu Özcan:** Supervision, Writing - review & editing, Validation.

https://doi.org/10.1016/j.prosdent.2025.12.021