Accuracy of silicone impressions and stone models using two laboratory scanners: a 3D evaluation

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Submitted November 1, 2021; Accepted April 6, 2022.
ABSTRACT

Purpose: To evaluate the in vitro accuracy of impressions obtained with two silicone and corresponding stone models using two laboratory scanners. Material and Methods: A master model with synthetic resin teeth with two single-unit crown preparations was created and scanned using a 12-MP scanner. Five conventional impressions of the physical model were prepared with different silicone impression systems (Zhermack and Coltene) using the double-mix technique and poured with gypsum. The impressions and stone models obtained were scanned by two extraoral scanning systems (Identica T500 Medit and S600 ARTI Zirkonzahn). All best-fit superimpositions of the teeth areas were conducted between the master model and the scans of the impressions and models obtained with the two scanners. A $P < .05$ significance level was considered. Results: The Identica T500 Medit scanner showed an accuracy of 102.34 (89.67, 115.01) µm for Coltene silicone and 79.51 (67.82, 91.21) µm for Zhermack silicone, while the S600 ARTI Zirkonzhan scanner presented 110.79 (98.24, 123.33) µm and 91.91 (81.29, 102.54) µm, respectively, with significant differences between scanners for Zhermack silicone ($P = .008$) and for the corresponding stone models ($P = .002$). Zhermack silicone presented overall discrepancies lower than Coltene silicone, with statistically significant differences in both scanners analyzed ($P < .001; P = .017$). However, the discrepancies found were within clinically acceptable values. With the Zirkonzahn scanner, discrepancies found in the Zhermack impressions were lower than in the corresponding stone models ($P < .001$). Conclusion: The direct digitalization of silicone impressions by laboratory scanners presented comparable results to conventional techniques with stone models. Int J Prosthodont 2022. doi: 10.11607/ijp.8074

INTRODUCTION

The use of CAD/CAM (computer-aided design and computer-aided manufacturing) technology introduced innovative changes in Dentistry, allowing faster and predictable prosthetic rehabilitation.¹ The first description of the use CAD/CAM in Dentistry dates from 1971.² ³ Later, several manufacturers developed laboratory and intra-oral scanners, being CAD/CAM a currently well-accepted technology.² ³ The conventional workflow entails several laboratory steps using different materials that may lead to accumulating distortions and could affect the outcome.⁴ ⁵ A digital workflow allows the removal
of some operational steps, reducing time and material costs, including impression storage, gypsum pouring, and model articulation. Currently, the gold-standard technique in oral rehabilitation is physical impression using a tray and an elastomeric impression material and digitalization of the resulting stone models using laboratory scanners; being this technique considered the benchmark of comparison with different techniques.

Nowadays, according to manufacturers, last-generation scanners, due to the most recent light sourcing techniques, also allow digitalization of dental impressions with elastomeric materials, avoiding the need to create the solid stone model. This method would allow omitting the gypsum pouring step, thus eliminating potential errors and distortions caused by the procedure and reducing time and laboratory costs.

Among the factors that could influence dental laboratory digitalization, two stand out the most: the scanner’s accuracy in obtaining the three-dimensional (3D) points and the quality of the software’s 3D-structure reconstruction. The ISO-5725 standard defined accuracy as based on precision and trueness. Precision relates to the measurements’ reproducibility, while trueness corresponds to the deviation from the measurements’ true value.

Nevertheless, scientific evidence on this subject is scarce and insufficient to assess the whole potential of this new methodology. Several authors have reported data on the comparison between intraoral and extraoral digitalization, but only a few studies analyzed the differences between the digitization of silicone impressions and stone models in order to assess the influence of gypsum pouring. Some of these studies applied a conventional two-dimensional measurement instead of a three-dimensional superimposing method, while others evaluated single abutments or small casts instead of scans of the full arch. To overcome some of these limitations, the current study was designed.

Therefore, this in vitro study aims to: i) assess the accuracy of dental impressions digitalization obtained from two different elastomers using two laboratory scanners; and ii) assess the influence of the gypsum model creation step in the discrepancies obtained compared to the master model. The null hypotheses are the following: H₀₁, the two extraoral scanners show the same 3D discrepancies regarding the master model; H₀₂, the two elastomers show the same 3D discrepancies regarding the master model; and H₀₃, the scans of the impressions and corresponding models show the same 3D discrepancies regarding the master model.
MATERIAL AND METHODS

A model was created with synthetic-resin teeth (A-3, Frasaco®, Germany) with two full-crown dental preparations in teeth 36 and 45 (Figure 1A). The model was scanned using a reference 12-megapixel scanner (Gom® Atos Compact Scan 12M), saved as an STL file, and considered the master model (Figure 1B).

The workflow is represented in Figure 2 with five conventional impressions of the model (Frasaco®, Tettnang, Germany) produced per group with a standard metal tray (Asa Dental®, Marlia LU, Italy) using two elastomers from different brands: Group 1) Light Body Type III, Heavy Body Type I, Hydrorise Implant, Zhermack®, Rovigo, Italy; Group 2) Affinis Light Body ISO-4823 Type III, Heavy Body ISO-4823 Type I, Coltene®, Altstätten, Switzerland. A silicone adhesive (Coltene®, Altstätten, Switzerland) was applied before making the impressions in each group with a one-step impression technique. One operator (M.S.) performed the impressions using a device to standardize the tray’s position and the amount of impression material between the tray and model (Figure 3). The manufacturers’ instructions were followed regarding the material’s setting time and handling, but the waiting time was set to compensate for the temperature difference between the environment and the oral cavity’s mean temperature. After polymerization, the impressions were removed from the Frasaco® model and stored at 23ºC for 8 hours. Then, the leaked impression material was cut with a scalpel according to the ISO-11607. Before laboratory digitalization, the impressions were sprayed with a uniform minimum thickness coating of TiO2 particles according to the ISO-12836. The operator performed the powdering of the master cast before the start of the first digital impression: the layer of dust had to be removed carefully with an air blast after having accomplished a series of five impressions.

The impressions were digitalized with two laboratory scanners: a blue-LED scanner (Identica T500 Medit®, Seoul, Korea) with two high-resolution 2-megapixel cameras, and according to the manufacturer up to 7-µm accuracy; and a structured-light optical scanner (S600 ARTI Zirkonzhan®, Gais, Italy) with two high-resolution 3-megapixel cameras and up to 10-µm accuracy according to the manufacturer. After digitalization, the impressions were cleaned with an air blasted and poured with Elite Rock type 4 gypsum (REF: C410334 Zhermack®, Italy) at a ratio of 100 g of powder per 20 mL of water. The stone models obtained were digitalized with the same scanners in a controlled environment, at
20±1°C temperature and 50±20% relative humidity. After digitalization eight digital models study groups were obtained (Table 1).

The STL files obtained were evaluated with a 3D analysis software (Geomagic Control X, 3D Systems) by previously described methodology, being successively superimposed on the standard STL, using the dental surfaces as reference for the superimposition and best-fit alignment.20-22 The STL files of the impressions and corresponding stone models obtained with the different impression materials and extraoral scanners were analyzed. Virtual sagittal planes relative to the master model were created in the model to standardize the 3D analysis locations, guaranteeing the successive assessment of the same areas among all STL files (Figure 4).

In this study, accuracy was defined as the volumetric discrepancy between the master model and the virtual models, measured as the root mean square (RMS) at the different defined locations. Nineteen locations were defined to compare the master model with the other digital models in each group (Figure 5). For each location, the 3D Compare tool was used to determine the differences between the STL files within an area of interest of at least 1 mm² of the RMS. Three measurements were made per area, and their mean was estimated for the statistical analysis, as described by Marques et al.20 Two independent operators conducted all measurements and the interoperator variability was evaluated through the intraclass correlation coefficient (ICC), according to Fleiss classification.23 For a global volumetric analysis, a color map was created with negative values in blue and positive values in red, varying between -1000 and +1000 μm, considering a clinical tolerance range between -100 and +100 μm, highlighted in green (Figure 6).20

The data obtained are presented as median and IQR values and mean ± confidence interval (CI) at 95% of the RMS in μm for the different locations. RMS’s normality of distribution was tested by the Shapiro-Wilk test and the equality of variance by the Levene test. Since the data was not normally distributed, the nonparametric Mann-Whitney U and Kruskal-Wallis tests were used to compare the RMS between groups in different locations (α=.05). For multiple comparisons, the P value was adjusted based on the Bonferroni correction method. Kappa tests were conducted to compare the different groups according to the discrepancies’ location. Results were considered statistically significant at \( P<.05 \). Statistical analysis was conducted using the software SPSS 25.0 (SPSS Inc., Chicago, Illinois).
RESULTS

Results were calculated from 19 locations defined in the master model. Three measurements were obtained from each location, and the corresponding mean RMS value estimated. A total of 4560 measurements were obtained. The interoperator ICC was 0.96±0.01, which indicate excellent reliability as the value is greater than 0.9. ICC estimates and their 95% confident intervals were calculated based on a single rater, using a consistency definition and 2-way mixed effects model.

The mean RMS values ranged between 79.51 and 110.79 µm when comparing the master model with the different groups of impressions, and between 89.82 and 131.30 µm when comparing it with the different groups of stone models (Table 2).

The Mann-Whitney U test showed statistically significant differences between the STL files obtained with Identica T500 Medit® and the S600 ARTI Zirkonzhan® scanners in the Zhermack® silicone impressions’ - groups MIZ 79.51[67.82;91.21] µm vs. ZIZ 91.91[81.29;102.54] µm - (P=.008) and stone models’ groups - groups MMZ 89.82[77.12;102.51] µm vs. ZMZ 131.30[112.14;150.47] µm - (P=.002) with best results presented on Medit scanner. The Coltene® silicone did not present differences in either the impressions’ - groups MIC 102.34[89.67;115.01] µm vs. ZIC 110.79[98.24;123.33] µm - (P=.161) or the stone models’ groups - groups MMC 99.62[86.89;112.35] µm vs. ZMC 114.97[100.45;129.49] µm - (P=.215) although the lower discrepancies were detected on the Medit scanner (Table 2).

When comparing the two studied silicones (groups MIC vs. MIZ and ZIC vs. ZIZ), the Zhermack® silicone presented better accuracy than the Coltene® silicone, with statistically significant differences in both the Medit® (Mann-Whitney U, P<.001) and Zirkonzhan® scanners (Mann-Whitney U, P=.017). The stone models (groups MMC vs. MMZ and ZMC vs. ZMZ) had no statistically significant differences among them in both scanners (Table 2).

The silicone impressions’ and the corresponding stone models’ results were also compared by Mann-Whitney U tests. No statistically significant differences were found between the impressions produced with Coltene® silicone and the corresponding stone models in the scans obtained with both the Medit® (groups MIC vs. MMC) (P=.943) and the Zirkonzhan® scanners (groups ZIC vs. ZMC) (P=.146). The Zhermack® silicone presented higher accuracy than the corresponding stone models.
although only presented statistically significant differences when compared with the Zirkonzhan® scanner (groups MIZ vs. MMZ) \((P<.001)\) (Table 2).

According to the literature, 100 \(\mu\)m is the threshold value for prosthodontically acceptable discrepancies.\(^\text{24}\) When grouping all points measured as above or below 100 \(\mu\)m (Table 3), the Kappa concordance test detected that, considering the discrepancies’ location, there was a substantial agreement \((\kappa=0.77)\) between scanners, an almost perfect agreement \((\kappa=0.88)\) between polyvinyl siloxanes, and an almost perfect agreement \((\kappa=0.83)\) when comparing dental impressions and stone models.

Mann-Whitney tests were conducted regarding the discrepancies’ location in the teeth in the dental arch (Table 4). The points corresponding to the premolars presented statistically significantly better accuracy than those corresponding to the molars \((P<.001)\). Regarding dental surfaces, occlusal surfaces showed the higher accuracy, followed by lingual surfaces, and buccal surfaces presented the worst results (Kruskal-Wallis test; \(P<.001)\).

**DISCUSSION**

This in vitro study detected statistically significant differences between the studied laboratory scanners, the impression materials and between the digitized silicone impressions and corresponding stone models with the Zhermack® material, thus rejecting the first two null hypotheses and partially rejecting the third proposed null hypothesis.

To assess the accuracy between the STL files a 3D analysis software (Geomagic X) was used by using the best-fit superimposition of models which could be considered as a predictable method. Additionally, the reference STL model for comparison purposes was digitized by a 12-megapixel high-precision industrial scanner, being considered as one of the most reliable references for comparison.\(^\text{12,24}\)

Two operators performed the superimposition methodology, and the obtained ICC was 0.96, corresponding to excellent reliability, corroborating the reproducibility of the method used. Several authors have considered that dental restorations presenting marginal fit values ranging up to 100-120 \(\mu\)m are clinically acceptable since higher values could lead to biological and mechanical issues.\(^\text{5,24,25}\)

The literature indicates that intraoral scans offer lower accuracy in complete arches when compared to conventional polyvinyl siloxane impressions.\(^\text{15,26}\) Contrary to intraoral scanners, where precision decreases as the area increases, extraoral scanners’ precision remains high regardless of the
extension of the dental arch to scan. In 2018, an in-vivo study reported that intraoral scanners offer higher accuracy than extraoral scanners. Nonetheless, in that study, extraoral readings were performed in stone models, which could have negatively influenced the results since the casting process promotes more risk factors. Other studies report that scanners are all alike or that extraoral scanners offer better results than intraoral scanners. Currently, there is no consensus as to which scanner, intraoral or extraoral, offers better accuracy.

Different laboratory scanners are available: white-light, LASER, and blue-LED scanners. Structured white-light scanners offer quick scanning but low repeatability, and errors in narrow, deep areas are frequent. LASER scanners have a low scanning speed. In turn, blue-LED scanners offer high repeatability and few errors, a short wavelength, and, consequently, high precision. A study by Emir et al. concluded that blue-light scanners (21.7 µm – 19.2 µm) had higher precision than LASER scanners (28.2 µm – 29.2 µm) and white-light scanners (32.9 µm – 24.4 µm). However, the different technologies do not seem to affect the general reliability of extraoral scanners. The comparison between the scanners tested in our study revealed that the blue-LED scanner (Identica T500 Medit®) had better results than the white-light scanner (S600 ARTI Zirkonzhan®) with significant differences in the Zhermack silicone groups (groups MIZ vs. ZIZ) and with the corresponding stone models (groups MMZ vs. ZMZ). Both scanners with silicones studied showed discrepancies within the acceptable limits. These results are in agreement with the high precision of the blue-LED scanners reported in the literature.

This study compared the digitalization of impressions produced with two elastomeric material systems from different manufacturers using the double-mix technique. The double-mix technique was used in this study which, according to Sason et al., is more precise than the double-impression technique. Considering the discrepancies’ location, the obtained results revealed an almost perfect concordance between both materials. However, the Zhermack® silicone presented lower overall RMS discrepancies than Coltene® silicone with statistically significant differences in both scanners.

When comparing models’ scans with impressions’ scans, Yus et al. reported higher discrepancies after milling monolithic zirconia crowns in impressions’ scans. Another study comparing the structures produced after dental impressions digitalization and stone models concluded that the scans of models presented more precise values than the scans of impressions, although both attained an acceptable clinical level. A 2015 study suggested a potential clinical advantage of scanning...
impressions with a blue-LED scanner compared to scanning stone models after observing statistically significant differences in some dental preparations. However, that study’s assessments were made in 2D and not 3D as in the present study. Some of the reasons given by the authors for that result were the concavity, diameter, and length of the impression’s pillar, and the color of the impression material, which could affect the digitalization process. A study by Jeon et al. showed differences in the scans of the impressions of different abutment teeth types. This difference is attributed to crown preparations with a narrow and deep shape. In our study, the obtained stone models presented different discrepancies when compared with the respective silicone direct digitalization with significant discrepancies in the Zhermack® silicone group. This fact could be caused by different reasons such as gypsum expansion or specific location scanner imprecisions.

A study by Bohner et al. indicated that the greatest discrepancies are expected to occur in the cervical and occlusal regions. Yus et al. reported that the greatest deviations occur in the interproximal areas when comparing scans of impressions with scans of stone models. In our study, the higher discrepancies were detected in the buccal surfaces and the most posterior regions of the arch, while the smallest discrepancies were detected in the occlusal surfaces. Although definitive explanations could not be advanced, these discrepancies might be related to specific location scanner imprecisions with interference in the position of the margin, which could lead to an overcontoured crown that will have to be corrected in the solid model. Extraoral scanners are more precise in digitizing smooth surfaces than areas with cutting edges or undermined areas.

One of this study’s limitations is the potential influence of the antireflective spray. In fact, despite being recommended by manufacturers, the application of a titanium oxide spray to minimize reflectiveness may cause discrepancies in the values obtained, leading to errors of up to 40 µm. In this study, the powdering was performed by the same operator in every impression and model studied according to the ISO-12836 to compensate for the elastomers’ reflectiveness. There is no scientific evidence to avoid using antireflective sprays in silicone impressions.

Using the RMS error to assess accuracy does not allow to determine the displacement’s direction. However, a qualitative analysis based on the volumetric maps with the corresponding color codes allows the comprehension of the type of distortion observed.

In clinical conditions, the patient’s dental arches have different sizes and shapes. Using acrylic models with standard teeth does not fully simulate the true dental arches since different geometries may
affect the scanner’s accuracy. Nonetheless, omitting intraoral factors such as saliva and the patient’s movement avoids confounding factors that could overestimate the differences obtained. Lastly, the choice of only one type of dental preparation represents a limitation of our study, and interesting results could be obtained if vertical preparations or preparations for partial indirect restorations have been also tested. This choice was driven by the fact that full-crown preparations are the most commonly used in similar studies, which would enable a straightforward comparison with the available published data.

**CONCLUSION**

Considering the limitations of this in-vitro study, we conclude that the digitalization of silicone impressions and stone models is directly dependent on the silicone material and the type of laboratory scanners. However, the detected accuracy met the clinical acceptable guidelines. The direct digitalization of silicone impressions seems a predictable technique with similar accuracy and a better cost-benefit ratio.

Therefore, the extraoral scanning of impressions showed to be a valid approach that offers additional advantages due to reduced time and laboratory costs by omitting stages with similar accuracy.

**ACKNOWLEDGEMENTS**

The authors would like to gratefully thank Digitech and S3D for their help in model scannings.
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FIGURES

Figure 1 - Synthetic resin model (A) and corresponding STL file (B) - master model

Figure 2 - Stages of the digital workflow

Figure 3 - Device used to standardize the impressions
Figure 4 – Virtual sagittal planes

Figure 5 - Standardized locations for comparison between STL files, defined as the intersection of two planes (one from the teeth’ zeniths to the occlusal border and the other from the mesial aspect to the distal aspect). Teeth 41, 34, and 47 - midpoint of the buccal aspect (Ib, Pb, and Mb), lingual aspect (Il, Pl, and Ml), and occlusal border (Io, Po, and Mo); Teeth 45 and 36 - midpoint in the buccal finish line (Pcb and Mcb), lingual finish line (Pcl and Mcl), mesial finish line (Pcm and Mcm), and distal finish line (Pcd and Mcd), and center of the occlusal aspect (Pco and Mco).

Figure 6 - Representation of the color map between the master model and the extraoral scans for each group. A – MIC; B – MIZ; C – MMC; D – MMZ; E – ZIC; F – ZIZ; G – ZMC; H – ZMZ. Nominal max/min ±100 μm (green). Critical max/min ±1000 μm (dark red and dark blue)
### Table 1 - Definition of the study groups

<table>
<thead>
<tr>
<th>Scanner</th>
<th>Material</th>
<th>Model</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medit Zhermack</td>
<td>Coltene</td>
<td>Impressions</td>
<td>MIC</td>
</tr>
<tr>
<td></td>
<td>Zhermack</td>
<td>Stone Models</td>
<td>MMC</td>
</tr>
<tr>
<td>Zirkonzhan</td>
<td>Coltene</td>
<td>Impressions</td>
<td>ZIC</td>
</tr>
<tr>
<td></td>
<td>Zhermack</td>
<td>Stone Models</td>
<td>ZMZ</td>
</tr>
</tbody>
</table>

### Table 2 – Accuracy assessment between each group and the master model

<table>
<thead>
<tr>
<th>Scanner</th>
<th>Material</th>
<th>Group (N=190)</th>
<th>Accuracy (RMS ± 95% CI) in µm</th>
<th>Statistical differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medit</td>
<td>Coltene silicone</td>
<td>MIC</td>
<td>102.34 [89.67; 115.01]</td>
<td>72.38, 75.05, 72.06</td>
</tr>
<tr>
<td></td>
<td>Zhermack silicone</td>
<td>MIZ</td>
<td>79.51 [67.82; 91.21]</td>
<td>52.77, a, b, c</td>
</tr>
<tr>
<td></td>
<td>Coltene stone model</td>
<td>MMC</td>
<td>99.62 [86.89; 112.35]</td>
<td>70.02, 85.28</td>
</tr>
<tr>
<td></td>
<td>Zhermack stone model</td>
<td>MMZ</td>
<td>89.82 [77.12; 102.51]</td>
<td>67.92, 75.80, a, b, c</td>
</tr>
<tr>
<td>Zirkonzhan</td>
<td>Coltene silicone</td>
<td>ZIC</td>
<td>110.79 [98.24; 123.33]</td>
<td>86.48, e</td>
</tr>
<tr>
<td></td>
<td>Zhermack silicone</td>
<td>ZIZ</td>
<td>91.91 [81.29; 102.54]</td>
<td>71.72, 82.70, c, e</td>
</tr>
</tbody>
</table>

RMS=root mean square; CI=confidence interval; IQR=interquartile range; a: p<.001, Mann-Whitney U; b: p=.008, Mann-Whitney U; c: p=.002, Mann-Whitney U; d: p=.017, Mann-Whitney U

### Table 3 – Accuracy assessment for each reference point. Results are shown as RMS ± 95% CI.

<table>
<thead>
<tr>
<th>Reference Point</th>
<th>MEDIT SCANNER</th>
<th>ZIRKONZAHN SCANNER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coltene silicone</td>
<td>Zhermack silicone</td>
</tr>
<tr>
<td>Ib</td>
<td>110.61 [87.23; 133.99]</td>
<td>70.74 [56.88; 84.98]</td>
</tr>
<tr>
<td>Io</td>
<td>63.42 [51.09; 75.75]</td>
<td>70.27 [59.06; 81.48]</td>
</tr>
<tr>
<td>II</td>
<td>39.56 [28.78; 51.54]</td>
<td>23.30 [18.77; 27.83]</td>
</tr>
<tr>
<td>Pb</td>
<td>46.44 [28.56; 64.32]</td>
<td>21.50 [16.23; 26.77]</td>
</tr>
<tr>
<td>Po</td>
<td>44.95 [39.36; 50.54]</td>
<td>44.93 [38.67; 51.20]</td>
</tr>
</tbody>
</table>

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Kappa concordance tests between scanners, polyvinylsiloxanes and dental impressions vs stone models

Values >100 μm are highlighted in gray.

RMS=root mean square; CI=confidence interval

Table 4 – Accuracy assessment for each reference tooth surface and tooth

<table>
<thead>
<tr>
<th>Location</th>
<th>Points</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>RMS ± 95% CI (μm)</td>
</tr>
<tr>
<td>Oclusal surfaces</td>
<td>Io, Po, Mo, Pco, Mco</td>
<td>68.34 [61.64; 75.04]</td>
</tr>
<tr>
<td>Buccal surfaces</td>
<td>Ib, Pb, Mb, Pcb, Mcb</td>
<td>190.23 [158.72; 183.74]</td>
</tr>
<tr>
<td>Lingual surfaces</td>
<td>II, Pl, Mi, Pcl, Mcl</td>
<td>92.29 [85.30; 99.27]</td>
</tr>
<tr>
<td>Premolars</td>
<td>Pb, Pl, Po, Pcb, Pco, Pcl, Pcm, Pcd</td>
<td>72.18 [67.19; 77.17]</td>
</tr>
<tr>
<td>Molars</td>
<td>Mb, Mi, Mo, Mcb, Mcl</td>
<td>140.54 [131.67; 149.41]</td>
</tr>
</tbody>
</table>
Mann-Whitney tests were conducted regarding the discrepancies’ location (Occlusal, buccal or lingual surfaces and between Premolars and Molars)

RMS=root mean square; CI=confidence interval; IQR=interquartile range; a: p<.001, Kruskal-Wallis; b: p<.001, Mann-Whitney U

Ib, Pb, and Mb – midpoint of the buccal aspect of teeth 41, 34, and 47, respectively; Il, Pl, and Ml – midpoint of the lingual aspect of teeth 41, 34, and 47, respectively; Io, Po, and Mo – midpoint of the occlusal border of teeth 41, 34, and 47, respectively; Pcb and Mcb – midpoint in the buccal finish line of teeth 45 and 36, respectively; Pcl and Mcl – midpoint of the lingual finish line of teeth 45 and 36, respectively; Pcm and Mcm – midpoint of the mesial finish line of teeth 45 and 36, respectively; Pcd and Mcd – midpoint of the distal finish line of teeth 45 and 36, respectively; and Pco and Mco – center of the occlusal aspect of teeth 45 and 36, respectively.