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ORIGINAL RESEARCH ARTICLE

# Does the traditional or digital dental model measurement method affect the results?: A validation study

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## Abstract

The aim of this study is to evaluate the accuracy, reliability and reproducibility of measurements made on digital models obtained using OrthoAnalyzer (3Shape, Copenhagen, Denmark) and Materialize 3-matic (MIMICS ®, Leuven, Belgium) software by comparing them with measurements made on dental plaster models. The teeth of 50 individuals were measured and plaster models were obtained. In addition, digital images were obtained from the patients with Trios intraoral scanner. A total of 30 linear measurements were made using OrthoAnalyzer and Materialize 3-matic software, including the mesiodistal width of the teeth, arch perimeter, intercanine and intermolar distances. All measurements were made by two different examiners. For the first and second measurements of the first examiner, intraexaminer reliability was calculated using intra-class correlation coefficients (ICCs), two-way mixed model, consistency type. The largest mean difference between Materialize 3-matic and caliper measurements was -0.136 mm in maxillary right first premolar and maxillary left lateral incisor. The smallest mean difference was -0.0029 mm in the mandibular left lateral incisor. In transverse measurements, the largest mean difference was found in the upper intercanine distance of 0.117 mm, and the smallest mean difference was -0.0086 mm in the upper intermolar distance. The largest mean difference between OrthoAnalyzer and caliper measurements was 0.107 mm in the maxillary right lateral incisor, and the smallest mean difference was -0.0049 mm in the maxillary left lateral incisor. Linear distance measurements with three-dimensional digital models are a valid, reliable and reproducible method compared to plaster models.

**Key words**: 3D scanner; digital models; reliability

## Introduction

For a successful orthodontic treatment, it is very important to make a detailed planning and model analysis. The literature states that dental model analysis should be performed before treatment for all patients who will undergo orthodontic treatment [1]. Thus, the existing malocclusion can be accurately evaluated to achieve an ideal occlusal closure. The traditional method in dental model analysis is to take the measurements of the patient's teeth and to obtain plaster models from these measurements. Dental analyses on the plaster model are made using a compass or caliper. With the developments in computer technology, it has become possible to make orthodontic diagnoses and treatment planning using digital models. Routine measurements can be made digitally for orthodontic diagnosis, overjet, overbite, tooth dimensions, arch lengths, and transversal distance measurements. In dental model analysis for these measurements, plaster models have been accepted as the gold standard for many years [2].

However, plaster models have many disadvantages. Among these issues are that models can be lost, broken, deformed over time, and require physical storage space [2]. To overcome these disadvantages, three-dimensional digital models have been developed in recent decades. Digital orthodontic models have such advantages as archiving and accessibility, no risk of breakage or wear, easy throughput transfer between physicians, and obtaining diagnostic information equal to or better than plaster models. Furthermore, it is easier to make changes on the digital model throughput than on the plaster model, and it is possible to enlarge digital models and create precise cross-sectional images [2,3].

Digital models can be obtained by direct or indirect methods.



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Indirect methods get going with taking dental impressions, and then digital models can be obtained by imaging the plaster models with laser scanning or computed tomography. In the direct method, an intraoral scanner is used to directly scan the patient's mouth. This method eliminates the risk of aspiration of the impression material. It also makes modeling easier for patients with a gag reflex or cleft lip-palate[4].

After the introduction of the computer-aided design/computer-aided manufacturing (CAD/CAM) system to the field of dentistry in 1989, several intraoral scanning devices have taken their place in the market[5]. Today, many intraoral scanners are used in orthodontics, such as iTero (Align Technologies), Trios (3Shape), True Definition (3M ESPE), CEREC Omnicam (Sirona), CS 3600 (Carestream Dental), and Materialise 3-Matic (Mimics)[6].

All conventional measurements can be made on digital models and can achieve the accuracy needed for various dental analyses[7]. Accuracy and reproductibility of measurements of teeth in the dental arch are affected by many factors such as the tilt, rotation, anatomical variation of the teeth, and the variability of the examiners[8]. Therefore, the accuracy, reliability, and reproducibility of different measuring devices and applied techniques should be evaluated.

In the literature, there are studies evaluating the accuracy and reliability of digital models using various methods[3,9–16]. Most of the existing studies have used different browsers and different software programs[15,17].

It should not be assumed that all software that measures orthodontic models will produce the same level of clinically acceptable results. For this reason, it would be useful to evaluate the comparison of measurements made between different software programs. To the best of our knowledge, for example, no study in the literature compares the Materialise 3–Matic (Mimics, Leuven, Belgium) with other software. In the study we had planned to do manual measurements on traditional plaster models taken from patients with a digital caliper were compared with digital model measurements made with two different programs, namely OrthoAnalyzer (3Shape, Copenhagen, Denmark) and Materialise 3-Matic (Mimics, Leuven, Belgium). Thus, three measurements were made, evaluating the accuracy, reliability, and repeatability of these measurements. Our study also aimed to compare the measurements obtained with each other.

## Material and Methods

Ethical approval was obtained for our research by the health research authority in October 2022 (reference: 2022/6). Power analysis was used to calculate the sample size, and to do this the research of Naidu[1] was taken as a basis. The results—alpha error=0.05, beta error=0.20, effect size 0.7—suggested that at least 20 participants would be sufficient. In the end, 50 volunteer participants aged between 18 and 24 were included in our study.

These were the inclusion criteria:

- All permanent teeth from the right first molar to the left first molar were in the mouth and had erupted.
- Interproximal caries, conservative or prosthetic restorations, and occlusal abrasions that may affect tooth widths were absent.
- Also absent were developmental or structural deformities, such as macrodontia or microdontia in the teeth.
- Finally, there was an absence of periodontal problems that may affect the localization of the approximal contact surfaces.
- The orthodontic treatment of the voluntary participant had just been completed.

Models were created using two different methods. In the first method, plaster models were obtained by taking measurements of the 50 participants with alginate. In the second method, 3D digital models were created using the Trios (3Shape, Copenhagen, Denmark) intraoral scanning device. The created digital models were also loaded into the Materialise 3-Matic (Mimics, Leuven, Belgium) program in stereolithography (STL) format. ( Figure1 and Figure2 )

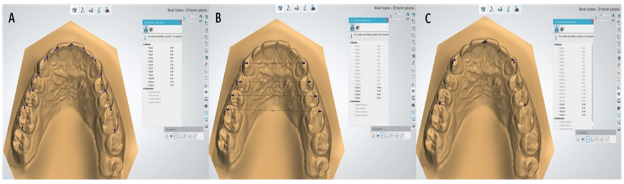


**Figure 1.** OrthoAnalyzer measurements. A. Tooth width measurements. B. Transversal measurements. C. Arch perimeter measurements

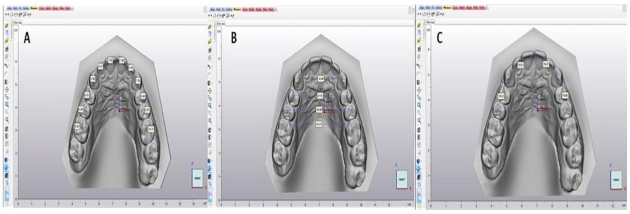


**Figure 2.** Materialise 3-matic program measurements. A. Tooth width measurements. B. Transversal measurements. C. Arch perimeter measurements

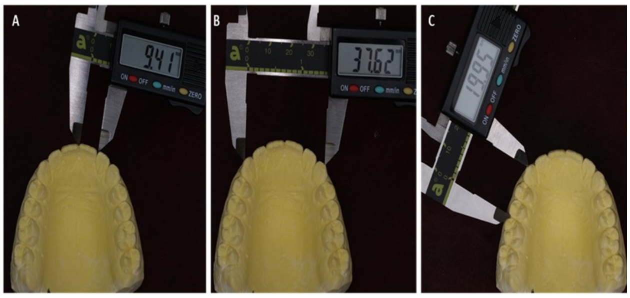


**Figure 3.** Caliper measurements. A. Tooth width measurements. B. Transversal measurements. C. Arch perimeter measurements

A digital caliper (Mitutoyo, Tokyo, Japan) was used to measure on the plaster models. The tips of the caliper are sharpened for easier placement in the interproximal areas of the teeth. All measurements on digital models were made using both the OrthoAnalyzer and the Materialise 3-Matic version 15.0 software programs. The zooming, rotating, and panning features of both programs were fully exploited so that the teeth could be properly displayed. ( Figure 3 )

All measurements were made in both arches, and all incisors, canines, premolars, and first molars were included in the measurements. Measurements made on plaster and digital models were mesiodistal tooth widths, arch circumference, intermolar distance, and intercanine distance. The definitions of these measurements are given in Table 1.

The measurements were carried out by two experienced examiners working independently of each other. The primary examiner measured all models in duplicate using all three measurement methods. Measurements were made two weeks apart. The secondary examiner measured once using all three measurement methods. All examiners were blinded to the identity of the models by assigning a random number to the models for all of the measurements.

In this study, accuracy was accepted as the degree of compatibility of the values measured in the digital system with the caliper measurements. Measurements made with caliper on the plaster

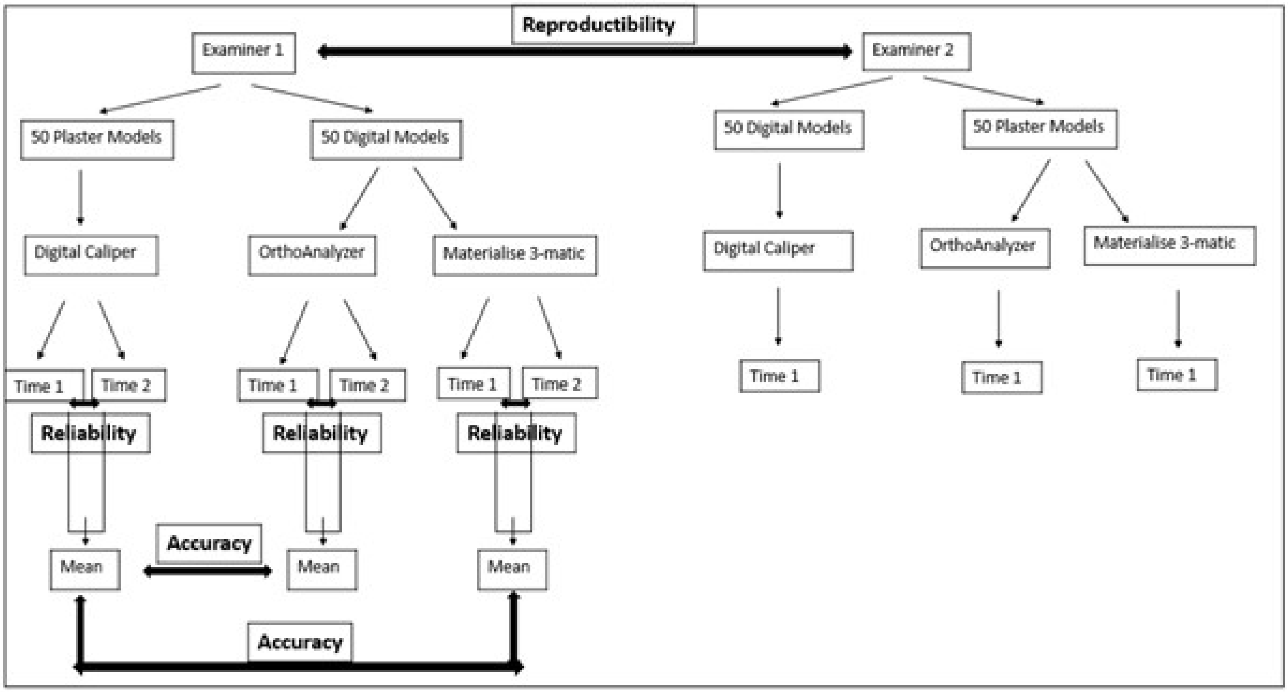


**Figure 4.** Schematic illustration showing how the measurements of 2 examiners were used for the various investigations.

**Table 1.** Measurement Definitions

| Measurement | Definition |
|---|---|
| Mesiodistal tooth width | It was defined as the maximum mesiodistal diameter of each crown made parallel to the occlusal and labial/buccal surfaces of the teeth. |
| Intercanine distance | It was defined as the transverse distance between the crown tips of the right and left permanent canines. |
| Intermolar distance | It was defined as the transverse distance between the mesiobuccal tubercle tips of the right and left permanent first molars. |
| Arch perimeter | Arc length was measured with the segment arc approximation. It was defined as the sum of the linear distance from the mesial of the permanent first molar to the apex of the canine tubercle and the linear distance from the apex of the canine to the point of contact of the incisors of the central teeth in the right and left hemispheres. |

model were taken as real values. Reliability was determined as the degree to which the measurements were reproducible at different times under the same conditions. Reproducibility is the degree of closeness between independent results obtained by measuring the same models with the same method by different examiners. It refers to the ability of a measurement technique to be accurately reproduced by another examiner [1]. The methodology of the study is shown in Figure 4.

## Statistical Analysis

All measurements were recorded in Excel, Version 2010 (Microsoft, Redmond, WA, USA). Statistical analyses were performed using IBM SPSS V21.0 software (IBM, Armonk, NY, USA) and Jamovi Version 2.2.5 (open-source statistical software).

Intra-/ and interexaminer reliability were calculated for total tooth widths, upper intercanine distance, upper intermolar distance, upper arch dimension, lower intercanine distance, lower intermolar distance, and lower arch dimension.

Intraclass correlation coefficients (ICCs) for the first and second trial measurements of the primary examiner were calculated to determine the intraexaminer reliability using a two-way mixed-model, consistency type.

By taking the average of the measurements of the primary examiner, the interexaminer reliability of the measurements between the primary examiner and the secondary examiner was calculated using a two-way random-model, absolute-agreement type.

The average of the first and second measurement taken from the primary examiner for each technique was used in statistical analysis. Descriptive statistics were calculated as mean and standard deviation (SD) for caliper and digital methods. The normality of throughput distribution was evaluated using histograms, normality curves, and the Kolmogorov–Smirnov test. The homogeneity of variance was determined using Levene's test.

For comparison of measurements using the caliper method with measurements using the digital method, a paired sample t test was used for parametrically distributed throughput, and the Wilcoxon signed-rank test was used for nonparametrically distributed throughput. In all cases, p-values of $<0.05$ were accepted as statistically significant.

By averaging the first and second measurements taken by the primary examiner for each technique, Bland–Altman analysis 1 was used to compare the techniques (caliper and OrthoAnalyzer; caliper and Materialise 3-matic) in terms of total tooth widths, upper intercanine distance, upper intermolar distance, upper arch dimension, lower intercanine distance, lower intermolar distance, and lower arch dimension. The mean difference between caliper and digital techniques, the standard deviations of differences, and the limits of agreement were examined.

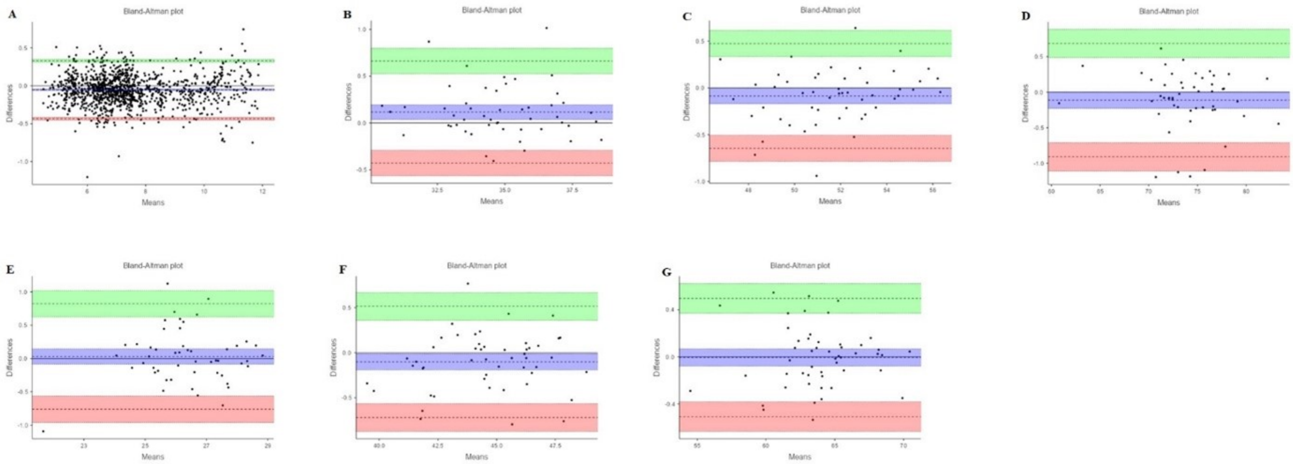

**Figure 5.** The Bland–Altman plot of the consistency of the caliper and Materialise 3-matic. The X-axis represents the means of the caliper and Materialise 3-matic. The Y-axis represents the differences between the caliper and Materialise 3-matic. The solid line in the purple area indicates zero bias. The dashed line in the purple area indicates the estimate of bias. The dashed line in the green area indicates the upper limit of agreement (Mean of difference+(1.96*standard deviation of difference)). The dashed line in the green area indicates the upper limit of agreement (Mean of difference+(1.96*standard deviation of difference)). The dotted lines next to the bias and the dotted lines next to the limits of agreement depict 95% confidence intervals. Differences and means were represented as one point for each patient. A: Total tooth width, B: Upper intercanine distance, C: Upper intermolar distance, D: Upper arch dimension, E: Lower intercanine distance, F: Lower intermolar distance, G: Lower arch dimension

## Results

ICC values less than 0.5 are indicative of poor reliability, values between 0.5 and 0.75 indicate moderate reliability, values between 0.75 and 0.9 indicate good reliability, and values greater than 0.9 indicate excellent reliability. Intra¬ and inter¬ rater reliability was found to be excellent for all measurements in each method (ICC $\geq$ .959)[18].

Table 2 shows the differences between the manual and digital measurements of each tooth. There were statistically significant differences between the caliper and Materialise 3-matic in all maxillary tooth width measurements except 24 ($P<0.05$), and between the caliper and OrthoAnalyzer in teeth 14, 12, 24, 25, 26, and 34 ($P<0.05$). The largest mean difference between caliper and Materialise 3-matic was -0.136 mm at the maxillary right first premolar and the maxillary left lateral, and the smallest mean difference was -0.0029 mm at the mandibular right canine.

There were statistically significant differences between the caliper and OrthoAnalyzer in teeth 14, 12, 24, 25, 26, and 34 ($P<0.05$). The largest mean difference between the caliper and OrthoAnalyzer was 0.107 mm at the maxillary right lateral, and the smallest mean difference was 0.0084 mm at the right canine. Table 3 shows the differences between the caliper and Materialise 3-matic for total tooth width, and the lower and upper arch measurements. There were statistically significant differences between the caliper and the Materialise 3-matic method in terms of total tooth width, upper intercanine distance, upper intermolar distance, and lower intermolar distance ($P<0.05$). The largest mean difference was 0.117 mm at the upper intercanine distance, and the smallest mean difference was -0.0059 mm at the lower arch dimension. The Bland–Altman plots are visualized inFigure 5.

Table 4 shows the differences between the caliper and OrthoAnalyzer for total tooth width and lower and upper arch measurements. There were no statistically significant differences between the caliper and the OrthoAnalyzer method in total tooth width and lower and upper arch measurements ($P>0.05$). The largest mean difference was 0.0651 mm at the upper intercanine distance, and the smallest mean difference was -0.0001 mm at the lower intercanine distance. The Bland-Altman plots are visualized in Figure 6.

## Discussion

As far as is known, this study compares the digital model measurements made with the Materialise 3-matic and OrthoAnalyzer software programs and the measurements made with a digital caliper on the plaster model. It is also the first study to evaluate the accuracy, reliability, and reproducibility of these measurements. The obtained results show that the measurements made with both the OrthoAnalyzer software program and the Materialise 3-matic software program are valid, reliable, and reproducible.

Interexaminer variability may lead to different results in measurements made with caliper on the plaster model or digitally on the computer[16]. In the measurements made on the plaster model, different examiners can place the caliper tips at different points on the model. In digital models, the measurements made by different examiners may vary according to the position of the two points selected with the mouse on the computer screen. Therefore, it is important to evaluate the inter-measurement accuracy of two different examiners. Due to the difficulty in determining the correct widths of teeth in a crowded mouth, participants who had just finished orthodontic treatment and had no crowding were included in this study to minimize measurement errors that could be made by different examiners.

In many studies, plaster models were accepted as the gold standard, while the accuracy of digital models was evaluated with various measurements. Fleming et al. reported 0.01–0.3 mm average difference in the mesio-distal dimensions of teeth in their review[2,19–21]. It has been reported in the literature that deviations of less than 0.3 mm in tooth dimensions are clinically acceptable[1,8,19]. In our study, the highest statistically significant difference between the caliper and the Materialise 3-matic measurements was -0.13 mm, and this difference was found in teeth 14 and 22 (Table 2). It was determined that the highest difference between the caliper and the OrthoAnalyzer measurements belonged to tooth number 12 and that said difference was 0.10 mm (Table 2). According to the orthodontic literature, it was concluded that although these differences in our study were statistically significant, they were not clinically significant.

Other parameters evaluated in this study are intercanine and intermolar distance measurements. The differences between the groups in transversal measurements in our study are given in Table 3 and Table 4. Significant findings in these tables range from -0.005 to 0.117 mm. In the literature, it has been reported that the mean

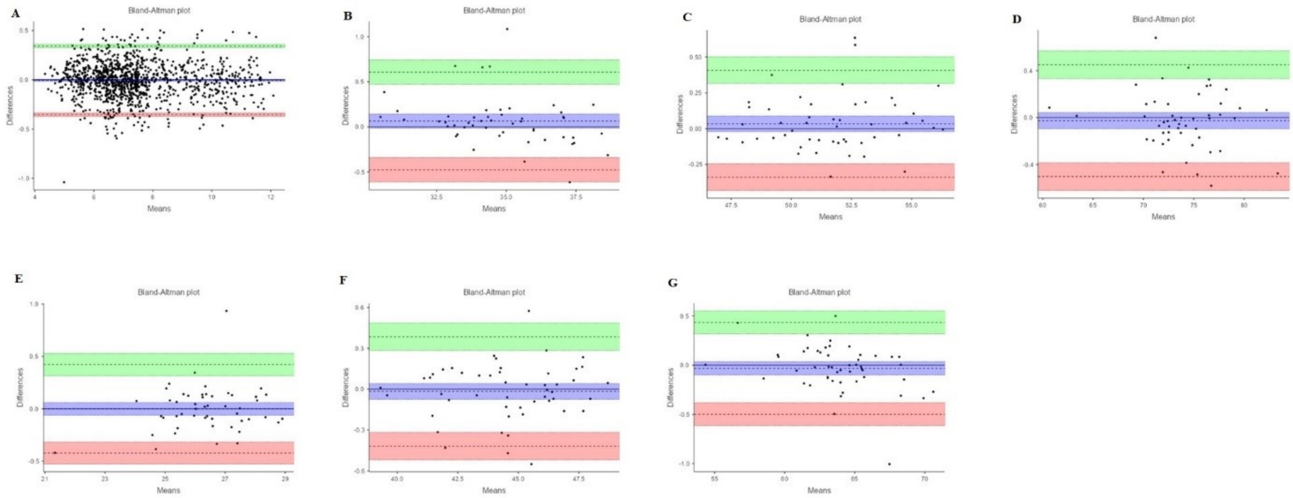

**Figure 6.** The Bland–Altman plot of the consistency of the caliper and OrthoAnalyzer. The X-axis represents the means of the caliper and OrthoAnalyzer. The Y-axis represents the differences between the caliper and OrthoAnalyzer. The solid line in the purple area indicates zero bias. The dashed line in the purple area indicates the estimate of bias. The dashed line in the green area indicates the upper limit of agreement (Mean of difference+(1.96*standard deviation of difference)). The dashed line in the green area indicates the upper limit of agreement (Mean of difference+(1.96*standard deviation of difference)). The dotted lines next to the bias and the dotted lines next to the limits of agreement depict 95% confidence intervals. Differences and means were represented as one point for each patient. A: Total tooth width, B: Upper intercanine distance, C: Upper intermolar distance, D: Upper arch dimension, E: Lower intercanine distance, F: Lower intermolar distance, G: Lower arch dimension

differences in studies evaluating the maxillary and mandibular intercanine and intermolar distances are between 0.04 and 0.4 mm. The transversal findings in our study are in this range, so the values found in our study being in this range, they are clinically insignificant[19]. Therefore, the differences in the comparisons between groups were found to be statistically significant but not clinically significant. All these findings in Table 2, Table 3 and Table 4 show the accuracy of the measurements made with the OrthoAnalyzer and Materialise 3-matic programs.

In this study, the reliability and reproducibility of these two programs were also investigated. Reliability refers to the consistency of a measured value. In the literature, an ICC value below 0.5 has been reported as having low reliability, between 0.5 and 0.75 as moderate-to-good reliability, and above 0.75 as excellent reliability[18]. In our study, this scale was used to evaluate reliability. It was found that the ICC values between the first and second measurements for all parameters in the maxilla and mandibula in Table 5 were quite high in all groups. ICC values above 0.90 in all groups in both jaws show that measurements made manually with a digital caliper or digitally with the OrthoAnalyzer or the Materialise 3-matic program are highly reliable and repeatable.

In our study, when the accuracy of the digital model and plaster model groups were evaluated, there were statistically significant differences in some parameters, but these differences were not clinically significant. It has been found that scanning using an intraoral scanner is not affected by ambient conditions such as blood, saliva, or humidity, and it has also been found that the accuracy of both digital

## Conclusion

In conclusion, the students with higher dental education levels scored higher in self-reported oral health behavior. There were differences between Turkish dental students and other students from different countries when the findings were compared with the literature. The presence of students' education as well as changes in curricula may be causing these differences. For this reason, such studies can be carried out on a university basis to make the oral and dental health behavior of dental students positive and to improve the oral health of the community and the insufficient points in the curriculum can be strengthened.

## Author Contributions

Concept: N.K.,Z.Y.,M.G. Design: N.K. Supervision: N.K. Data collection and/or processing: N.K., Z.Y. Data analysis and/or interpretation: N.K.,Z.Y.,M.G.,K.Ç. Literature search: N.K.,Z.Y.,M.G.,K.Ç. Writing: N.K.,Z.Y.,M.G.,K.Ç. Critical review: N.K., M.G. Submission and revision: N.K.,Z.Y.,M.G.,K.Ç. Project management: N.K.,Z.Y.,M.G.,K.Ç. Funding acquisition: N.K.,Z.Y.,M.G.,K.Ç.

## Conflict of Interest

The authors declare no conflict of interest.

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**Table 3.** Comparison of the tooth widths, lower and upper arch measurements (mm) between the caliper and Materialise 3-matic

| Caliper Mean-SD | Materialise 3-matic Mean-SD | p | Mean difference (Bias) | 95% CI of the Mean difference Lower | 95% CI of the Mean difference Upper | 95% CI of the ULA ULA | 95% CI of the ULA Lower | 95% CI of the ULA Upper | 95% CI of the LLA LLA | 95% CI of the LLA Lower | 95% CI of the LLA Upper |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.41 ± 1.62 | 7.46 ± 1.62 | **0.001**β | -0.0528 | -0.0638 | -0.0417 | 0.3292 | 0.3103 | 0.348 | -0.4347 | -0.4536 | -0.4158 |
| 34.86 ± 1.95 | 34.74 ± 1.97 | **0.005** α | 0.117 | 0.0377 | 0.196 | 0.662 | 0.5257 | 0.798 | -0.428 | -0.5642 | -0.292 |
| 51.69 ± 2.41 | 51.77 ± 2.34 | **0.037** α | -0.0866 | -0.168 | -0.0054 | 0.4734 | 0.334 | 0.61313 | -0.6466 | -0.786 | -0.50692 |
| 73.93 ± 3.89 | 74.04 ± 3.93 | 0.058 α | -0.111 | -0.227 | 0.0041 | 0.686 | 0.487 | 0.88465 | -0.909 | -1.108 | -0.70987 |
| 26.38 ± 1.39 | 26.34 ± 1.36 | 0.593 α | 0.0308 | -0.0842 | 0.146 | 0.8237 | 0.6259 | 1.021 | -0.7621 | -0.9598 | -0.564 |
| 44.54 ± 2.28 | 44.64 ± 2.24 | **0.025** α | -0.103 | -0.192 | -0.0136 | 0.513 | 0.36 | 0.6672 | -0.719 | -0.873 | -0.5656 |
| 63.83 ± 3.06 | 63.84 ± 3.06 | 0.871 α | -0.0059 | -0.0787 | 0.0669 | 0.49631 | 0.371 | 0.6216 | -0.50811 | -0.6334 | -0.3828 |

**Table 2.** Comparison of the tooth width measurements (mm) between the Caliper and digital models

| | Caliper Mean-SD | Materialise 3-matic Mean-SD | OrthoAnalyzer Mean-SD | Caliper - Materialise 3-matic p | Caliper - OrthoAnalyzer p | Difference Caliper - Materialise 3-matic Mean difference (Bias) | Difference Caliper - Materialise 3-matic 95% CI of the Mean difference Lower | Difference Caliper - Materialise 3-matic 95% CI of the Mean difference Upper | Difference Caliper -OrthoAnalyzer Mean difference (Bias) | Difference Caliper -OrthoAnalyzer 95% CI of the Mean difference Lower | Difference Caliper -OrthoAnalyzer 95% CI of the Mean difference Upper |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 (n=50) | 9.82 ± 0.59 | 9.89 ± 0.55 | 9.86 ± 0.62 | **<.001** α | 0.187 α | -0.0691 | -0.105 | -0.033 | -0.0373 | -0.0934 | 0.0188 |
| 15 (n=50) | 6.65 ± 0.51 | 6.73 ± 0.51 | 6.68 ± 0.5 | **<.001** α | 0.215 α | -0.0825 | -0.1123 | -0.0527 | -0.0326 | -0.0848 | 0.0196 |
| 14 (n=50) | 6.98 ± 0.47 | 7.12 ± 0.47 | 7.05 ± 0.47 | **<.001** α | **0.005** α | -0.136 | -0.1733 | -0.0996 | -0.0691 | -0.117 | -0.0214 |
| 13 (n=50) | 7.76 ± 0.52 | 7.87 ± 0.56 | 7.76 ± 0.53 | **<.001** α | 0.778 α | -0.103 | -0.1415 | -0.0645 | 0.0084 | -0.0511 | 0.0679 |
| 12 (n=50) | 6.71 ± 0.69 | 6.81 ± 0.68 | 6.6 ± 0.67 | **<.001** α | **0.001** α | -0.103 | -0.1383 | -0.0677 | 0.107 | 0.0457 | 0.169 |
| 11 (n=50) | 8.63 ± 0.55 | 8.69 ± 0.6 | 8.6 ± 0.57 | **0.001** α | 0.258 α | -0.0652 | -0.104 | -0.0269 | 0.0301 | -0.0227 | 0.0829 |
| 21 (n=50) | 8.57 ± 0.61 | 8.64 ± 0.63 | 8.53 ± 0.58 | **<.001** α | 0.160 α | -0.0622 | -0.0952 | -0.0292 | 0.0405 | -0.0165 | 0.0975 |
| 22 (n=50) | 6.53 ± 0.67 | 6.67 ± 0.66 | 6.54 ± 0.69 | **<.001** α | 0.854 α | -0.136 | -0.1786 | -0.0924 | -0.0049 | -0.058 | 0.0482 |
| 23 (n=50) | 7.6 ± 0.47 | 7.65 ± 0.47 | 7.61 ± 0.43 | **0.028** α | 0.532 α | -0.0493 | -0.093 | -0.00562 | -0.0151 | -0.0633 | 0.0331 |
| 24 (n=50) | 6.92 ± 0.38 | 6.95 ± 0.38 | 6.97 ± 0.37 | 0.364 β | **0.018** β | -0.0342 | -0.0853 | 0.0169 | -0.0573 | -0.107 | -0.00734 |
| 25 (n=50) | 6.42 ± 0.62 | 6.53 ± 0.63 | 6.48 ± 0.67 | **<.001** α | **0.018** α | -0.103 | -0.155 | -0.051 | -0.0581 | -0.106 | -0.0105 |
| 26 (n=50) | 9.7 ± 0.56 | 9.77 ± 0.55 | 9.78 ± 0.58 | **0.022** α | **0.002** α | -0.0696 | -0.129 | -0.0105 | -0.0742 | -0.12 | -0.0287 |
| 36 (n=50) | 10.83 ± 0.73 | 10.8 ± 0.66 | 10.81 ± 0.73 | 0.507 α | 0.466 α | 0.0238 | -0.0477 | 0.0953 | 0.016 | -0.0277 | 0.0597 |
| 35 (n=50) | 7.13 ± 0.51 | 7.14 ± 0.53 | 7.14 ± 0.53 | 0.830 α | 0.647 α | -0.0063 | -0.0651 | 0.0525 | -0.0107 | -0.0573 | 0.0359 |
| 34 (n=50) | 7.16 ± 0.46 | 7.13 ± 0.49 | 7.11 ± 0.44 | 0.282 β | **0.007** β | 0.0294 | -0.0323 | 0.0911 | 0.0471 | 0.00283 | 0.0686 |
| 33 (n=50) | 6.68 ± 0.61 | 6.68 ± 0.59 | 6.66 ± 0.61 | 0.931 α | 0.229 α | -0.0029 | -0.0697 | 0.0639 | 0.0259 | -0.0168 | 0.0686 |
| 32 (n=50) | 5.91 ± 0.41 | 5.95 ± 0.37 | 5.89 ± 0.44 | 0.289 α | 0.496 α | -0.0381 | -0.109 | 0.0333 | 0.0171 | -0.033 | 0.0672 |
| 31 (n=50) | 5.37 ± 0.43 | 5.37 ± 0.37 | 5.35 ± 0.43 | 0.876 α | 0.413 α | 0.0049 | -0.0579 | 0.0677 | 0.0192 | -0.0275 | 0.0659 |
| 41 (n=50) | 5.32 ± 0.43 | 5.34 ± 0.44 | 5.32 ± 0.43 | 0.333 α | 0.756 α | -0.0248 | -0.0758 | 0.0262 | -0.0086 | -0.0638 | 0.0466 |
| 42 (n=50) | 5.79 ± 0.41 | 5.84 ± 0.43 | 5.76 ± 0.4 | 0.055 α | 0.130 α | -0.0485 | -0.0982 | 0.00118 | 0.0285 | -0.00866 | 0.0657 |
| 43 (n=50) | 6.5 ± 0.49 | 6.52 ± 0.49 | 6.52 ± 0.5 | 0.384 α | 0.385 α | -0.0212 | -0.0697 | 0.0273 | -0.0179 | -0.0589 | 0.0231 |
| 44 (n=50) | 7.02 ± 0.47 | 7.05 ± 0.47 | 7.04 ± 0.51 | 0.206 β | 0.432 β | -0.0329 | -0.0841 | 0.0183 | -0.0154 | -0.0554 | 0.0246 |
| 45 (n=50) | 7 ± 0.6 | 7.06 ± 0.6 | 7.04 ± 0.61 | 0.119 α | 0.128 α | -0.0578 | -0.131 | 0.0153 | -0.0397 | -0.0912 | 0.0118 |
| 46 (n=50) | 10.82 ± 0.59 | 10.9 ± 0.56 | 10.83 ± 0.59 | 0.092 α | 0.508 α | -0.0787 | -0.171 | 0.0134 | -0.0161 | -0.0646 | 0.0324 |

**Table 4.** Comparison of the tooth widths, lower and upper arch measurements (mm) between the caliper and OrthoAnalyzer

| | | | | 95% CI of the Mean difference | | 95% CI of the ULA | | | 95% CI of the LLA | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Caliper Mean-SD** | **OrthoAnalyzerMean-SD** | **p** | **Mean difference (Bias)** | **Lower** | **Upper** | **ULA** | **Lower** | **Upper** | **LLA** | **Lower** | **Upper** |
| 7.41 ± 1.62 | 7.41 ± 1.62 | 0.684 β | -0.00487 | -0.0149 | 0.00516 | 0.34251 | 0.3253 | 0.35967 | -0.35226 | -0.3694 | -0.3351 |
| 34.86 ± 1.95 | 34.79 ± 2.03 | 0.102 α | 0.0651 | -0.0134 | 0.144 | 0.6068 | 0.4716 | 0.742 | -0.4766 | -0.6117 | -0.341 |
| 51.69 ± 2.41 | 51.65 ± 2.39 | 0.205 α | 0.0346 | -0.0195 | 0.0887 | 0.4079 | 0.3148 | 0.501 | -0.3387 | -0.4318 | -0.2456 |
| 73.93 ± 3.89 | 73.96 ± 3.92 | 0.456 α | -0.0258 | -0.0948 | 0.0432 | 0.4503 | 0.3316 | 0.5691 | -0.5019 | -0.6207 | -0.3832 |
| 26.38 ± 1.39 | 26.38 ± 1.36 | 0.997 α | -0.0001 | -0.0614 | 0.0612 | 0.422 | 0.317 | 0.5278 | -0.423 | -0.528 | -0.3172 |
| 44.54 ± 2.28 | 44.56 ± 2.26 | 0.578 α | -0.0162 | -0.0744 | 0.042 | 0.3849 | 0.2849 | 0.485 | -0.4173 | -0.5174 | -0.3173 |
| 63.83 ± 3.06 | 63.86 ± 3.15 | 0.354 α | -0.0315 | -0.0992 | 0.0362 | 0.4353 | 0.3189 | 0.5518 | -0.4983 | -0.6148 | -0.3819 |

**Table 5.** Intraexaminer and interexaminer ICC

| | Intraexaminer | | | Interexaminer | | |
|---|---|---|---|---|---|---|
| | **Caliper ICC (95% CI)** | **Trios ICC (95% CI)** | **Materialise 3-matic ICC (95% CI)** | **Caliper ICC (95% CI)** | **Trios ICC (95% CI)** | **Materialise 3-matic ICC (95% CI)** |
| Total tooth width | 0.992 (0.991 - 0.993) | 0.996 (0.995 - 0.996) | 0.989 (0.985 - 0.991) | 0.983 (0.974 - 0.988) | 0.988 (0.986 - 0.99) | 0.990 (0.988 - 0.992) |
| Upper intercanine distance | 0.989 (0.981 - 0.994) | 0.985 (0.973 - 0.992) | 0.983 (0.971 - 0.990) | 0.984 (0.972 - 0.991) | 0.991 (0.985 - 0.995) | 0.982 (0.956 - 0.992) |
| Upper intermolar distance | 0.994 (0.989 - 0.996) | 0.999 (0.999 - 1.000) | 0.989 (0.981 - 0.994) | 0.990 (0.983 - 0.995) | 0.988 (0.978 - 0.993) | 0.988 (0.979 - 0.993) |
| Upper arch dimension | 0.997 (0.995 - 0.998) | 0.999 (0.998 - 0.999) | 0.996 (0.992 - 0.998) | 0.996 (0.993 - 0.998) | 0.998 (0.996 - 0.999) | 0.994 (0.989 - 0.996) |
| Lower intercanine distance | 0.982 (0.969 - 0.990) | 0.976 (0.958 - 0.986) | 0.985 (0.974 - 0.992) | 0.959 (0.928 - 0.976) | 0.966 (0.941 - 0.981) | 0.973 (0.951 - 0.985) |
| Lower intermolar distance | 0.993 (0.988 - 0.996) | 0.996 (0.993 - 0.998) | 0.980 (0.965 - 0.989) | 0.990 (0.982 - 0.994) | 0.993 (0.986 - 0.996) | 0.977 (0.949 - 0.989) |
| Lower arch dimension | 0.996 (0.993 - 0.998) | 0.995 (0.991 - 0.997) | 0.997 (0.995 - 0.998) | 0.992 (0.985 - 0.995) | 0.993 (0.988 - 0.996) | 0.994 (0.989 - 0.996) |

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