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Comparison of Accuracy of Alginate Impression and Intraoral Scanner in Model with and without Orthodontic Brackets

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Abstract: Surgical splints are widely used in orthognathic surgery. The fitting of a surgical splint affects the success of the surgery. Stereolithography (STL), the method used to achieve accurate and reliable input files, is important for the manufacturing process of the surgical splint. Nowadays, data acquisition can be performed with the aid of an intraoral scanner (IOS) or impression materials. This in vitro study aimed to compare the trueness and precision of IOS (TRIOS3®, 3Shape, Copenhagen, Denmark) and alginate impression (Kromopan®, Lascod, Florence, Italy) in a full-arch dental model with/without orthodontic brackets. Custom complete arch models were fabricated with a refractive index similar to that of tooth structure. A TRIOS3® intraoral scanner (3Shape, Copenhagen, Denmark) and an alginate impression were used to duplicate the custom model without orthodontic brackets for complete arch scenarios (both upper and lower arches), *n* = 5. Subsequently, orthodontic brackets (Ormco®, Glendora, CA, USA) were attached to the custom model and the TRIOS® intraoral scanner and alginate impression were used again. Analysis was performed using 3-dimensional (3D) metrology software (GOM inspect®, GOM GmbH, Braunschweig, Germany) to measure surface deviations between the STL files from the custom model to evaluate and compare their trueness and precision. All data were entered into Microsoft Excel and then transferred to SPSS (Statistical Package for the Social Sciences). The average surface deviations were compared between the TRIOS3® intraoral scanner and the alginate impression using a repeated measures ANOVA (Analysis of Variance) with adjustment for multiple comparisons using Bonferroni's correction. There were no significant differences in trueness and precision between TRIOS3® and alginate impression in full arch models with and without orthodontic brackets. Moreover, the accuracy of all groups was less than 100 microns, which was acceptable. Further in vivo studies are required to confirm these results.

Keywords: intraoral scanner; TRIOS; alginate impression; orthodontic brackets; accuracy; digital; surface deviation

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1. Introduction

In orthognathic surgery, surgical splints have been widely used to position the jaws. Therefore, their fitting plays an important role in the success of the treatments. The more accurate they are, the better the predicted outcomes. In fabrication methods, alginate impressions were mandatory during the last few decades. The conventional impression procedure has been challenging for patients with gag reflexes, causing feelings of discomfort and being time-consuming [1]. Nowadays, an optical record of dental arches can be acquired with the aid of an intraoral scanner (IOS). This allows a patient's oral cavity morphology to be captured comfortably [2]. Using digital model systems, the disadvantages of plaster models, such as storage and data query problems, can be overcome [3]. Moreover, IOS can be utilized in several fields of dentistry such as restorative dentistry, prosthodontics, orthodontics, implantology, and oral surgery.

The accuracy of IOS and alginate impression play an important role in the success of the treatment. According to ISO 5725, the definition of accuracy can be divided into two aspects, "trueness" and "precision". "Trueness" describes the closeness of agreement with the actual dimensions of the reference object, while "precision" refers to the closeness of agreement between individual measurements [4–6]. The accuracy of alginate impressions is affected by manipulation guidelines, water temperature [7], environment, and water-to-powder ratio. Therefore, clinicians must control these factors strictly to obtain accurate models. On the other hand, the accuracy of IOS is affected by the length of the scanning area, clinician's skills, IOS brands, and capturing area of IOS tips [8–13]. Recently, Ji-Man Park et al. [14] reported that the existence of orthodontic brackets and their positions also affected the accuracy of IOS. For some IOS systems, the powder had to be poured onto the models or the patient's teeth to reduce the reflection of the metal before scanning. Nevertheless, inaccuracy was found in both IOS and alginate impression for the whole arch [15].

Nowadays, the relative degree of accuracy between alginate impressions and the IOS method remains controversial. Liczmanski et al. [16] reported that intraoral scans were more detailed and less error-prone compared to alginate impressions. On the other hand, Ender et al. [10] reported that the accuracy of IOS and alginate impressions in a full arch model without orthodontic brackets were not different. Moreover, the accuracy of each method has not been widely studied in patients with orthodontic brackets. The aims of this study were to evaluate the accuracy of IOS (TRIOS3®) and alginate impressions in models with and without orthodontic brackets and to compare the accuracies of IOS and alginate impressions in models without orthodontic brackets, IOS and alginate impressions in models with orthodontic brackets, IOS in models with and without orthodontic brackets, and alginate impressions in models with and without orthodontic brackets.

2. Methodology

The overview of the research is shown in Figure 1. This study consisted of six steps.

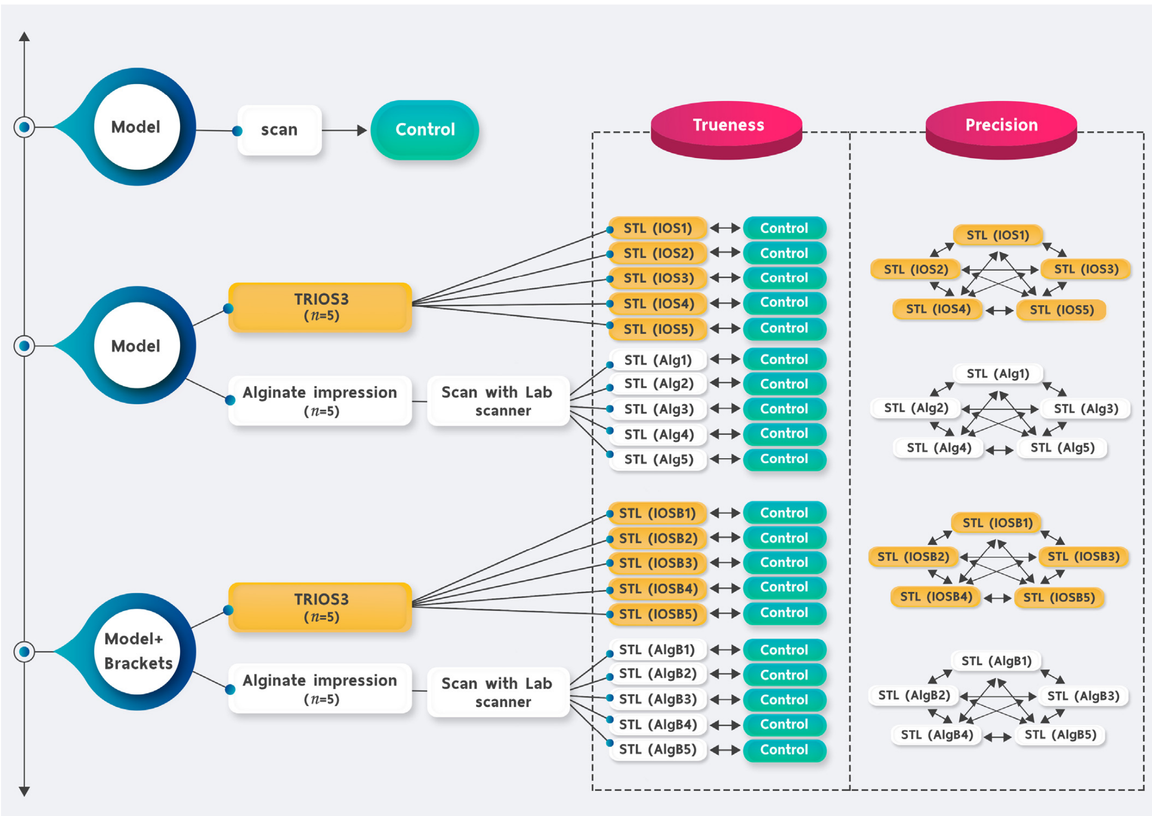

Figure 1. The flow chart shows experimental details.

2.1. Fabrication of Dental Model

Customized upper and lower dental models were fabricated from epoxy resin with no gaps between the teeth. All teeth were well aligned with no fractures. Reference points were marked at all canines and first molar teeth at 3 mm below incisal or occlusal of teeth. Subsequently, the models were scanned using a laboratory scanner (3Shape D900L®, 3Shape, Copenhagen, Denmark) to create STL files as a reference and 3D printed indirect bracket bonding trays with Ortho analyzer software (Figure 2).

Figure 2. Pictures of customized dental models: (**A**) models without orthodontic brackets; upper arch and lower arch models, (**B**) models with orthodontic brackets; upper arch and lower arch models.

2.2. Alginate Impression

The impressions were performed by applying alginate, an irreversible hydrocolloid substrate (Kromopan®, Lascod, Florence, Italy), and number 12 perforated metal trays to the customized dental models. According to the manufacturer's recommendations, 100 g of alginate powder was mixed with 60 mL water at room temperature (25 ± 2 °C) using a vacuum alginate mixer for 30 s before applying it to the perforated tray. The tray was then pressurized into the customized model for 2 min and removed. The tray was snapped out of the model and the imprints were explored; imprints with air bubbles, distortion, non-homogeneous, and irregular forms were excluded. Imprints were rinsed and blown dry for 15 s with air from a triple syringe, after which the impressions were poured with dental stone plaster (Kromotypo®, Lascod, Florence, Italy) within 30 min of separating the impression from the original model. To form the plaster, 300 g dental stone plaster powder was mixed with 87 mL water using a vacuum mixer for 30 s before each imprint was poured. To prevent air bubble formation in the model, a vibrator was used to assist the pouring process. The plaster model was extracted and trimmed from the impression after 60 min. Excess material was trimmed and the process was repeated until a complete set of stone plaster pieces of five pieces in each group had been fabricated. The plaster models were placed in the open air at room temperature for 24 h to dry the plaster casts completely. Finally, the created plaster stones were digitalized and stored as STL files using a 3Shape D900L® dental lab scanner, a non-contact optical scanner with accuracy of 7 µm (ISO 12836), used as a control in this study.

2.3. Scanning with TRIOS3 Intraoral Scanner (3Shape, Copenhagen, Denmark)

The original model was scanned using a TRIOS3® intraoral scanner (3Shape, Copenhagen, Denmark) (n = 5). The files were saved as STL files. The scanning method followed the manufacturer's recommendation.

2.4. Attachment of Orthodontic Brackets

The orthodontic brackets were bonded to the model using 3D printed indirect bracket bonding trays between the first molars of each side. Both the upper and lower arches were fixed with orthodontic brackets (Figure 3).

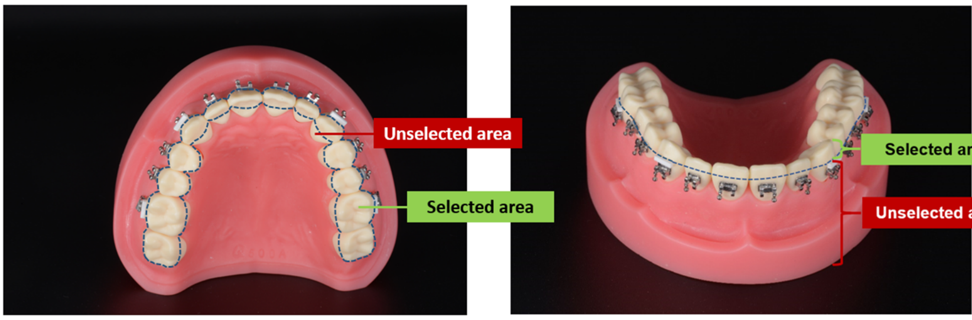

Figure 3. Picture of the customized dental model shows selected and unselected areas.

2.5. Measurements

The STL file was opened with meshmixure® program (Autodesk Inc., San Rafael, CA, USA) in order to crop the file above the reference points and then transfer the modified STL files to GOM inspect program® (GOM inspect, Braunschweig, Germany) using a best-fit algorithm for superimposition. Comparison between groups was done as shown in Figure 4. The absolute surface deviation was calculated by the program and expressed as mean and standard deviation (SD).

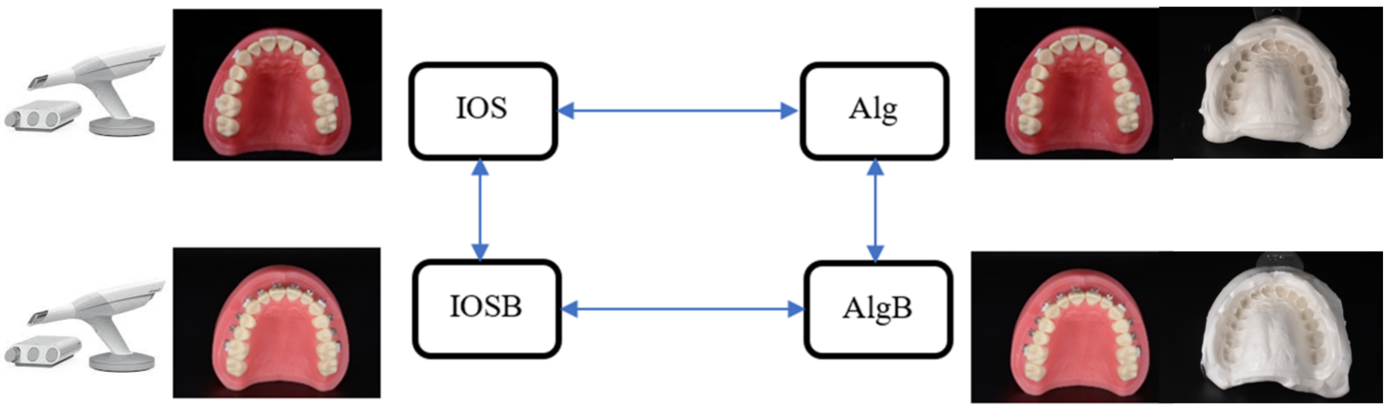

Figure 4. The chart shows a comparison between the groups. IOS = intraoral scanner (TRIOS3®) in model without orthodontic brackets, IOSB = intraoral scanner (TRIOS3®) in model with orthodontic brackets, Alg = alginate impression in model without orthodontic brackets, AlgB = alginate impression in model with orthodontic brackets.

2.6. Sample Size Calculation

The sample size calculation was calculated with the help of a statistician as follows.

$$n = \frac{\left(Z_{\frac{\alpha}{2}} + Z_{\beta}\right)^2 \left(sd_1{}^2 + sd_2{}^2\right)}{\left(\overline{X}_1 - \overline{X}_2\right)^2} = \frac{(1.96+0.84)^2\left((0.102)^2+(0.0725)^2\right)}{(62.5499-62.3255)^2} = 2.4382$$

$$Z_{\frac{\alpha}{2}} = 1.96,\ Z_{\beta} = 0.84$$

According to the study done by Tomita et al. [17], $n = 3$ pieces per group can be used. In this research, we used 5 pieces per group ($n = 5$).

2.7. Statistical Analysis

Descriptive statistics were calculated using Microsoft Excel 365 and SPSS (Statistical Package for the Social Sciences) version 25 (IBM Company, Chicago, IL, USA). Data were analyzed using a repeated measure ANOVA with adjustment for multiple comparisons using Bonferroni's method to evaluate significant differences. The level of significance was set at $p < 0.05$. Comparison between groups is shown in Figure 4.

3. Results

3.1. Trueness

The average trueness of the upper model without orthodontic brackets from the TRIOS3® intraoral scanner was 86.80 ± 3.11 microns. The maximum surface deviation was 85 microns, and the minimum surface deviation was 101 microns. The average trueness of the upper model without orthodontic brackets from the alginate impression was 89.60 ± 3.97 microns with a maximum surface deviation of 88 microns and a minimum surface deviation of 96 microns. The average trueness of the upper model with orthodontic brackets from the TRIOS3® was 90.80 ± 1.64 microns. The maximum and minimum surface deviations were 72 and 94 microns, respectively. The average trueness of the upper model with orthodontic brackets from the alginate impression was 92.80 ± 2.49 microns. The maximum surface deviation was 88 microns, and the minimum surface deviation was 100 microns. There was no statistical difference among all groups ($p < 0.05$) as in Table 1.

Table 1. Average surface deviation (mean difference and standard deviation) in measurements by IOS, alginate, and control in the upper arch.

Upper Arch	IOS Mean ± SD (Min-Max) (Micron)	Alginate Impression Mean ± SD (Min-Max) (Micron)	Repeated Measure ANOVA * (p-Value)
Without brackets	86.80 ± 3.11 (85–101)	89.60 ± 3.97 (88–96)	0.606
With brackets	90.80 ± 1.64 (72–94)	92.80 ± 2.49 (88–100)	0.451
Repeated measure ANOVA * (p-value)	0.555	1.000	

* p-value < 0.05 is statistically significant.

The average trueness of the lower arch model without orthodontic brackets from the TRIOS3® intraoral scanner was 88.00 ± 7.69 microns. The maximum surface deviation was 78 microns, and the minimum surface deviation was 104 microns. The average trueness of the lower model without orthodontic brackets from the alginate impression was 92.40 ± 3.95 microns with a maximum surface deviation of 87 microns and a minimum surface deviation of 97 microns. The average trueness of the lower model with orthodontic brackets from the TRIOS3® was 94.70 ± 6.43 microns. The maximum and minimum surface deviations were 85 and 102 microns, respectively. The average trueness of the lower model with orthodontic brackets from the alginate impression was 96.10 ± 5.99 microns. The maximum surface deviation was 93 microns, and the minimum surface deviation was 102 microns. There was no statistical difference among all groups ($p < 0.05$) as in Table 2. Color maps showing the trueness assessment measured through the alginate impression and TRIOS3® intraoral scanner are shown in Figure 5.

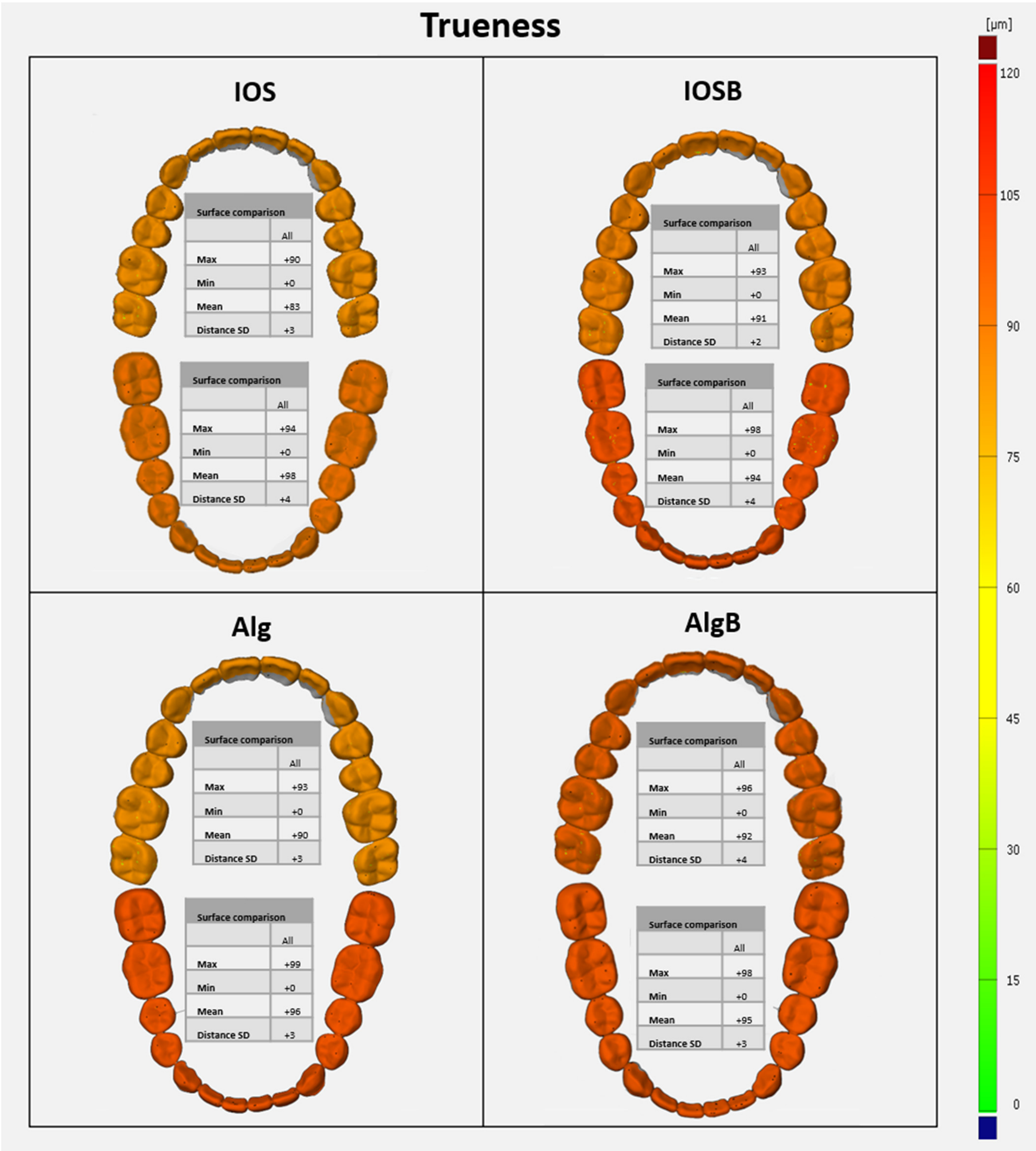

Figure 5. Color maps showing the trueness assessment measured through the alginate impression and TRIOS3® intraoral scanners.

Table 2. Average surface deviation (mean difference and standard deviation) in measurements by IOS, alginate, and control in the lower arch.

Lower Arch	IOS Mean ± SD (Min-Max) (Micron)	Alginate Impression Mean ± SD (Min-Max) (Micron)	Repeated Measure ANOVA * (*p*-Value)
Without brackets	88.00 ± 7.69 (78–104)	92.40 ± 3.95 (87–97)	1.000
With brackets	94.70 ± 6.43 (85–102)	96.10 ± 5.99 (93–102)	1.000
Repeated measure ANOVA * (*p*-value)	0.461	0.188	

* p-value < 0.05 is statistically significant.

3.2. Precision

The average precision of the upper model without orthodontic brackets from the TRIOS3® intraoral scanner was 90.80 ± 3.03 microns. The maximum surface deviation was 78 microns, and the minimum surface deviation was 98 microns. The average precision of the upper model without orthodontic brackets from the alginate impression was 92.00 ± 3.81 microns with a maximum surface deviation of 80 microns and a minimum surface deviation of 93 microns. The average precision of the upper model with orthodontic brackets from the TRIOS3 was 93.20 ± 2.39 microns. Maximum and minimum surface deviations were 92 and 108 microns, respectively. The average precision of the upper model with orthodontic brackets from the alginate impression was 94.00 ± 5.24 microns. The maximum surface deviation was 80 microns, and the minimum surface deviation was 103 microns. There was no statistical difference among all groups ($p < 0.05$) as in Table 3.

Table 3. Average surface deviation (mean difference and standard deviation) in measurements by IOS, alginate, and control in the upper arch.

Upper Arch	IOS Mean ± SD (Min-Max) (Micron)	Alginate Impression Mean ± SD (Min-Max) (Micron)	Repeated Measure ANOVA * (*p*-Value)
Without brackets	90.80 ± 3.03 (79–98)	92.00 ± 3.81 (80–93)	1.000
With brackets	93.20 ± 2.39 (92–108)	94.00 ± 5.24 (80–103)	1.000
Repeated measure ANOVA * (*p*-value)	0.365	1.000	

* p-value < 0.05 is statistically significant.

The average precision of the lower model without orthodontic brackets from the TRIOS3® intraoral scanner was 94.90 ± 4.09 microns. The maximum surface deviation was 85 microns, and the minimum surface deviation was 100 microns. The average precision of the lower model without orthodontic brackets from the alginate impression was 92.40 ± 4.55 microns with a maximum surface deviation of 87 microns and a minimum surface deviation of 99 microns. The average precision of the lower model with orthodontic brackets from the TRIOS3® was 96.80 ± 4.69 microns. The maximum and minimum surface deviations were 94 and 104 microns, respectively. The average precision of the lower model with orthodontic brackets from the alginate impression was 95.30 ± 1.95 microns. The maximum surface deviation was 94 microns, and the minimum surface deviation was 100 microns. There was no statistical difference among all groups ($p < 0.05$) as in Table 4.

Color maps showing the precision assessment measured through the alginate impression and TRIOS3® intraoral scanners are shown in Figure 6.

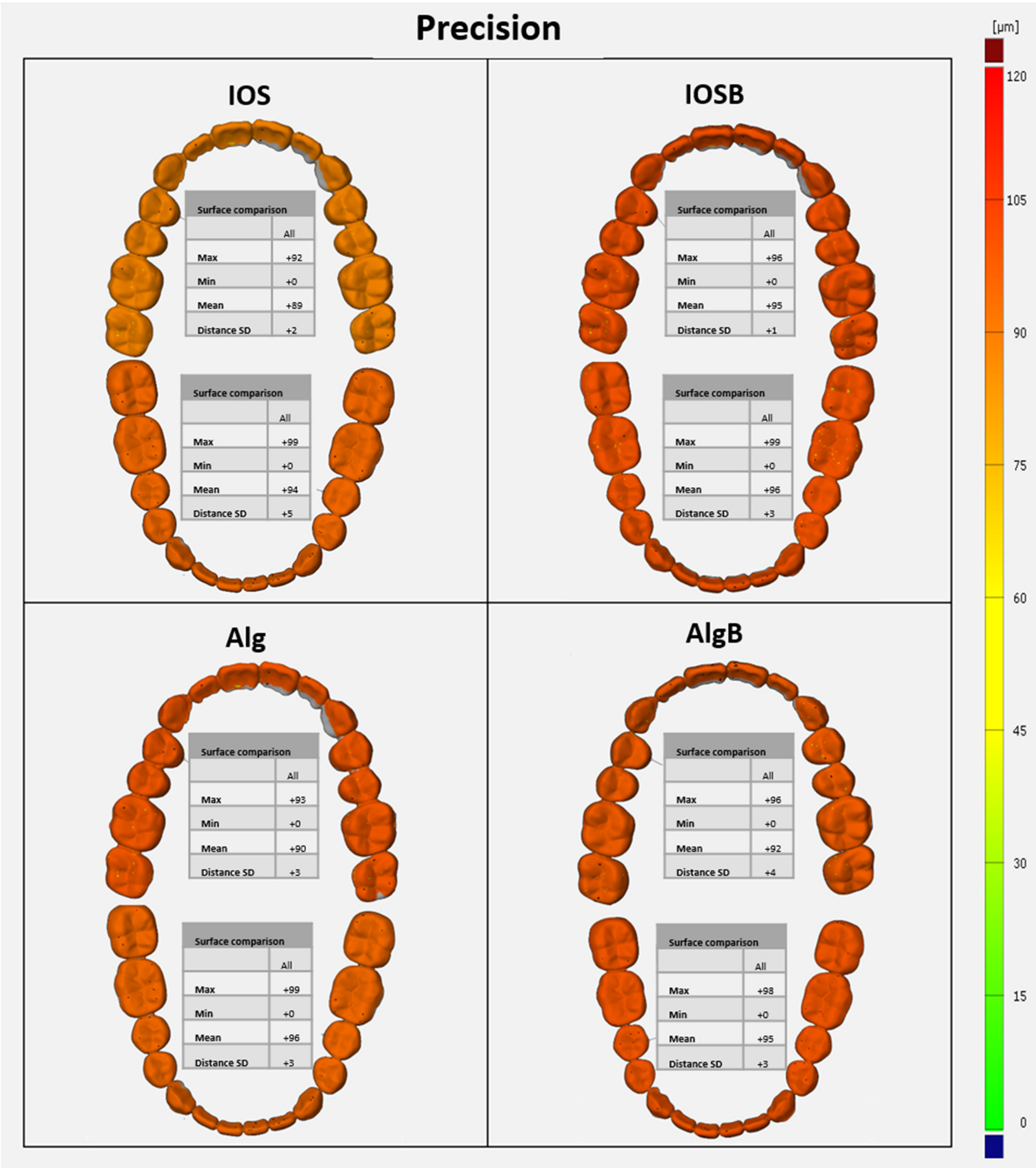

Figure 6. Color maps showing the precision assessment measured through the alginate impression and TRIOS3® intraoral scanners.

Table 4. Average surface deviation (mean difference and standard deviation) in measurements by IOS, alginate, and control in the lower arch.

Lower Arch	IOS Mean ± SD (Min-Max) (Micron)	Alginate Impression Mean ± SD (Min-Max) (Micron)	Repeated Measure ANOVA * (*p*-Value)
Without brackets	94.90 ± 4.09 (85–100)	92.40 ± 4.55 (87–99)	1.000
With brackets	96.80 ± 4.69 (94–104)	95.30 ± 1.95 (94–100)	0.210
Repeated measure ANOVA * (*p*-value)	1.000	0.803	

* p-value < 0.05 is statistically significant.

4. Discussion

In our study, the trueness and precision of both IOS and alginate impression measurements were not statistically different. We found that the trueness and precision of the alginate impressions in all groups ranged from 87–102 microns and 80–103 microns, respectively. Peutzfeldt et al. [18] showed that alginate impression accuracy ranged from 44–188 microns in full arch models without orthodontic brackets, whereas Ender et al. [19] found that the mean precision of an alginate impression was 162.2 ± 71.3 microns in the complete arch. Dimensional changes can be caused by water temperature, environment, water, or powder ratio.

Nowadays, digital technology provides an alternative pathway of data acquisition in dental fields. Although IOS has many advantages such as ease of use, time saving, and improved patient satisfaction, its accuracy depends on its system and version [1]. This study demonstrated that the trueness and precision of intraoral scanners in all groups were 72–102 microns and 79–108 microns, respectively. Many studies have found that TRIOS® intraoral scanners have high accuracy. One study found that no statistically significant difference was recorded between four IOS systems (Trios®, 3Shape, CEREC Omnicam®, and Sirona) [20]. Mangano et al. [21] studied the accuracy of intraoral scanners in complete arch maxillary models and found that accuracy (both trueness and precision) was as follows: CS 35001® (trueness 63.2 microns and precision 55.2 microns) > Trios® (trueness 71.6 microns and precision 67.0 microns) > Zfx Intrascan1® (trueness 103.0 microns and precision 112.4 microns) > Planscan1® (trueness 253.4 microns and precision 204.2 microns). Moreover, Nedelcu et al. [11] studied the accuracy of intraoral scanners in complete arch models and found that the accuracy of 3M® and TRIOS® intraoral scanners was higher than that of OMNI®. Park et al. [14] found that iTero and Trios had better trueness and precision than Zfx IntraScan® and E4D Dentist®. Winkler and Gkantidis compared the accuracy of CS 3600® and TRIOS 3® intraoral scanners in full arch models and reported that TRIOS 3® had better precision than CS 3600®, with the precision of around 20–70 microns [22]. In addition, Amornvit et al. [23] studied the accuracy of several intraoral scanners (Trios 3®, Trios 4®, iTero Element®; and iTero Element2®, and iTero Element5D®. They concluded that the Trios® series showed the highest accuracy. TRIOS® may show particularly high accuracy because it is a confocal intraoral scanner.

In this study, the selected areas of STL files were all just above the reference markers. As the surgical splint used in orthognathic surgery must attach to the occlusal surfaces of teeth and areas around 3 mm from incisal or occlusal surfaces of teeth, we applied the reference markers at 3 mm below the incisal or occlusal of teeth and cut STL files above them.

Ender et al. [19] found that IOS systems had higher levels of deviation in local areas than alginate impressions. The errors of intraoral scanners often occurred at posterior teeth and palatal areas of anterior teeth [22]. Furthermore, local deviations along the palatal surfaces of the molars and incisal edges of the anterior teeth were less than 100 microns [11,20].

As shown in our study, some areas of maxillary and mandibular posterior teeth were measured with lower accuracy. In this study, the overall deviations between IOS measurements in models with and without orthodontic brackets were within 0.10 mm. Kang et al. [24] reported that overall deviations between IOS measurements with and without orthodontic brackets were within 0.30 mm. Moreover, the accuracy of intraoral scans of the model is clinically acceptable even with the brackets. Few errors are likely to have occurred due to the high accuracy IOS system and alginate impression protocol.

Although Schirmer and Wiltshire [25] mentioned that a measurement error of <0.20 mm between the actual model and the scanned images can be permitted, a study by Hiroki et al. [26] found that an orthodontic model can still be clinically useful if its accuracy is approximately 0.30 mm. This is supported by another study by Kang et al. [24], which showed that errors in all 3D images in the presence or absence of brackets were within 0.30 mm. These conclusions can be used clinically in 3D images in orthodontics.

A limitation of this study was that the situation during data acquisition was not the same as it might be in a patient's oral cavity. There was no saliva, metal restorations, or mini-implant anchorages that might interrupt the impression or operator's skills and therefore affect the accuracy of STL files. Moreover, crowding or angulation of teeth, cheeks, small mouth openings, gag reflex, and tongue movement can affect the accuracy of STL files. Future studies could try to include different models that have crowding or angled teeth, which have been found to distort the alginate impression upon removal. The accuracy of the intraoral scanner and the alginate impression in this study were not statistically different in models with and without orthodontic brackets. Thus, we can conclude that both TRIOS3® intraoral scanners and alginate impressions can be used for the acquisition of STL files from upper and lower models. The accuracy was around 100 microns in both groups. Further in vivo studies are required to confirm these results.

5. Conclusions

This study showed that the TRIOS3® intraoral scanner and alginate impressions had similar results in trueness and precision. Orthodontic brackets did not affect the accuracy of either the TRIOS3® intraoral scanner or the alginate impression. Within the limitations of this study, the accuracy of both the TRIOS3® intraoral scanner and the alginate impressions was less than 0.1 mm in absolute deviation, which is acceptable to use for orthognathic surgical splints.

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