IMPACT OF ORTHODONTIC ATTACHMENTS ON INTRAORAL SCANS

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Palavras-chave: escaneamento intraoral, *attachments* ortodônticos, Ortodontia

RESUMO

Introdução: Com o uso crescente de fluxos de trabalho digitais em Ortodontia, a precisão dos escaneamentos intraorais é crítica para diagnóstico, planejamento e monitoramento precisos. **Objetivo**: avaliar o impacto dos *attachments* ortodônticos nos modelos digitais, comparando escaneamentos intraorais realizados com e sem acessórios nos mesmos indivíduos. **Materiais e Métodos**: Vinte e oito indivíduos com dentição permanente e *attachments* retangulares horizontais colados a um mínimo de oito dentes por arco foram escaneados duas vezes, em um intervalo de uma hora – inicialmente sem *attachments* e posteriormente após a colagem. Todos os exames foram adquiridos utilizando o scanner iTero Element 5D® (Align Technology, Tempe, EUA). Medidas lineares foram realizadas em ambos os arcos em cada modelo digital, seguidas da sobreposição dos pares correspondentes. As comparações estatísticas foram realizadas por meio de testes t pareados ou testes de Wilcoxon, de acordo com a normalidade verificada pelos testes de Shapiro-Wilk e gráficos Q-Q. **Resultados**: Os coeficientes de correlação intraclasse variaram de 0,79 a 1,00, indicando alta reprodutibilidade das medidas. O erro do método variou de 0,08 a 0,30 mm. Não foram observadas diferenças estatisticamente significativas entre os modelos, exceto para o incisivo lateral superior direito, que apresentou uma pequena diferença de 0,1 mm (p = 0,004). A análise de sobreposição mostrou discrepância mínima, com média de 0,04 ± 0,02 mm. **Conclusões**: Esses achados sugerem que a presença de *attachments* ortodônticos não compromete clinicamente a precisão das medidas derivadas do escaneamento intraoral. Os modelos digitais com *attachments* colados são, portanto, considerados clinicamente equivalentes àqueles sem.

Keywords: intraoral scan, attachments, orthodontics

ABSTRACT

Introduction: With the growing integration of digital workflows in orthodontics, the precision of intraoral scans is critical for accurate diagnosis, planning, and monitoring. **Aim**: to assess the impact of bonded orthodontic attachments on the accuracy of digital models by comparing intraoral scans performed with and without attachments in the same individuals. **Methods**: Twenty-eight subjects with permanent dentition and horizontal beveled rectangular attachments bonded to a minimum of eight teeth per arch were scanned twice, within a one-hour interval—initially without attachments and subsequently after bonding. All scans were acquired using the iTero Element 5D® scanner (Align Technology, Tempe, USA). Linear measurements were performed on both arches in each digital model, followed by superimposition of the corresponding pairs. Statistical comparisons between models were conducted using paired t-tests or Wilcoxon signed-rank tests, according to normality verified by Shapiro-Wilk tests and Q-Q plots. **Results**: Intra-class correlation coefficients ranged from 0.79 to 1.00, indicating high measurement repeatability. Method error varied from 0.08 to 0.30 mm. No statistically significant differences were observed between models, except for the maxillary right lateral incisor, which presented a minor difference of 0.1 mm (p = 0.004). Superimposition analysis showed minimal discrepancy, with a mean of means of 0.04 ± 0.02 mm. **Conclusion**: These findings suggest that the presence of orthodontic attachments does not clinically compromise the accuracy of intraoral scan–derived measurements. Digital models with bonded attachments are therefore deemed clinically equivalent to those without.

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INTRODUCTION

Any successful orthodontic treatment is directly related to a correct diagnosis and treatment plan, which are extremely dependent on detailed dental impressions.[1] Recently, clear aligners (CA) have been highly required by patients due to their advantages, such as the reduction of the discomfort, easier hygiene maintenance and the aesthetic appearance.[2,3] With the progress of new technologies, intraoral scanning has been widely used in orthodontics, especially when CA are required, because of their digital flow and easiness to communicate with machines that produce them.[4]

Orthodontic treatment with CA is considered to be an interesting alternative to traditional orthodontic appliances.[5] However, questions related to their efficiency and effectiveness still remains.[6] Although orthodontic forces are delivered at the clinical crown level, this does not inherently result in tipping. Fixed appliances also act by applying forces to the crown, yet they are capable of achieving bodily tooth movement when appropriate biomechanics and adequate force systems are employed. Thus, tipping should be considered a biomechanical limitation intrinsic to clear aligner systems rather than a direct consequence of force application at the crown.[7] In order to enhance the biomechanical performance of clear aligners, composite resin attachments are bonded to the tooth surfaces. Their role goes beyond counterbalancing undesired moments, as they are also essential for increasing aligner retention and for enabling complex movements such as extrusion, rotation, and root control.[8]

It is important to highlight that clear aligner (CA) treatments depend not only on patient compliance[9] but also on proper clinical planning and execution. Therefore, it is common for orthodontic treatments not to achieve the results initially planned in the software, which makes refinements necessary. On average, a CA patient will require three sets of aligners with three refinement scans,[10] which often involves removal and repositioning of attachments. CA companies frequently recommend removing attachments before the registration procedure to ensure accurate refinements.

However, it has already been proven that the removal of composite resin from previous orthodontic treatments can lead to the removal of a substantial layer of enamel and to the roughening of its surface.[11] When performed three times during an orthodontic treatment, the risks are even higher. Also, the possibility of keeping attachments on the dental surfaces could lead to less chair time when refinements are needed. Nevertheless, no *in vivo* study has evaluated the impact of orthodontic attachments on intraoral scans.

Therefore, the purpose of this study was to evaluate the influence of orthodontic attachments in intraoral scanning by superimposing digital models with and without attachments from the same patients and by comparing measurements from the same models.

MATERIAL AND METHODS

This study was approved by the Research Ethics Committee of the Clementino Fraga Filho University Hospital, Federal University of Rio de Janeiro (HUCFF-UFRJ). Sample size was calculated by the formula described by Pandis,[12] based on a study power of 80% (α= 0.05), and considering the standard deviation described by Vargas et al.[13] A minimum sample of 23 patients was stipulated. However, taking in consideration the use of nonparametric statistics and the possibility of attrition,[14] an addition of 25% was added, which increased the minimum number of individuals to 28.

Twenty-eight subjects, 14 males and 14 females, were selected from a private practice. Age ranged from 21 to 43 years (3.55 SD) with a mean age of 25.53. Inclusion criteria consisted of individuals who presented permanent dentition, Class I, II, or III malocclusions, with horizontal beveled rectangular orthodontic attachments bonded to at least 8 teeth in each arch: first molars, canines and incisives. Exclusion criteria consisted of patients with periodontal disease, any dentofacial deformity and syndromic individuals.

All patients were scanned twice with a maximum 1-hour interval between scanning procedures: first without the attachments and lastly after they were bonded. All intraoral scans were performed with the iTero Element 5D® scanner (Align, Tempe, USA), according to manufacturer instructions by the same operator, who had been previously calibrated and received training from an experienced orthodontist specialized in digital workflow. After the dental surfaces were dried with compressed air, the lower arch and the upper arch were scanned. The occlusal registration was also scanned. In order to reduce possible distortions, the scanning procedure started at the left lateral incisor and continued posteriorly to the second right molar[15]. Then, registration was performed towards the left second molar. After the scanning procedure, STL files were exported and manipulated in two different software.

After the two different types of digital models were acquired, with the only difference being the orthodontic attachments bonded to the teeth, reproducibility and fidelity of the STL were compared. First, in the software Autodesk Meshmixer (Autodesk, Califórnia, Estados Unidos), soft tissues and the gingival margins in both digital models were

removed to reduce error and to allow superimposition of the teeth solely. Later, intermolar, intercanine, and the incisors' mesiodistal width were measured in the maxillary and mandibular arches of the two different models for each patient with the same software. 30% of the sample was measured by two examiners within a two-week interval. Superimposition was performed using the best-fit algorithm in CloudCompare (CloudCompare Project, founded by Daniel Girardeau-Montaut). Initial registration used four corresponding points — the mesiolabioincisal angle of the central incisors and the mesiobuccal cusp tips of the first molars — via the align 2 clouds tool. Subsequently, the finely registers tool applied the iterative closest point algorithm for final registration. Surface differences were assessed at all points using color mapping with the compute cloud mesh distance tool.

Initial registration was done by selecting four corresponding points on each model: the tips of the mesiobuccal cusp from the two first molars and the mesiolabioincisal point from both central incisors. After that, the iterative closest point algorithm from the software led to the final superimposition (Figure 1). Color mapping allowed to visualize the surfaces differences between both digital models at all points (Figure 2). This methodology was based on a study which compared the impact of orthodontic brackets on intraoral and extraoral scans.[13]

Descriptive statistics were used to express values from the mean average of minimums and maximums and mean differences between digital models' superimpositions. Also, descriptive statistics revealed the results of measurements from the two types of models (with and without attachments). The paired t-test or the Wilcoxon test was used to assess the differences between the measurements performed in the digital models with and without attachments. Assumption checks were carried out by means of the Shapiro-Wilk test and Q-Q plots. Fifty percent of the sample was randomly selected for repeat measurements after an interval of two weeks. The intraclass correlation coefficient (ICC) and Dahlberg's Formula were used to assess repeatability and the method's error, respectively. The analyses were performed in the software Jamovi 2.3 (https://www.jamovi.org) adopting a significance level of 5%.

RESULTS

The repeatability within the measurements was high, with ICC values from 0.79 to 1. The error of the method varied from 0.08 to 0.30 mm. All measurements evaluated were considered clinically adequate (Table 1). No statistically significant differences between the two types of model measurements were observed, except for the maxillary right lateral incisor, with difference of 0.1 mm ($p = 0.004$) (Table 2). The superimposition of the digital models revealed that minimum difference was observed them, with mean of means of 0.04 mm (± 0.02). The mean of minimums was 0.00, while the mean of maximums was 1.66 (± 0.82). The mean of the coincidence percentage between the digital models up to 0.6 mm distance was 97.88% of coincidence (± 1.61), and up to 1 mm distance was 99.42% of coincidence (± 0.88) (Table 3). Histograms (A and B) illustrate the point-to-point distance distribution from the superimposition analysis, with values concentrated near zero, confirming accurate alignment between the models (Figure 2).

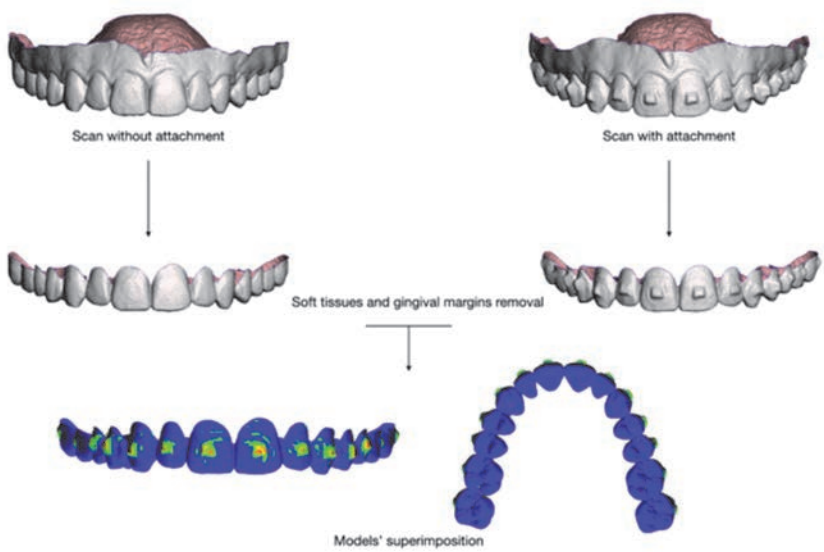


Fig 1. Three-dimensional superimposition of the digital models. After the gingival margins and soft tissue areas were removed, both models were superimposed to assess the surface deviation using the CloudCompare software.

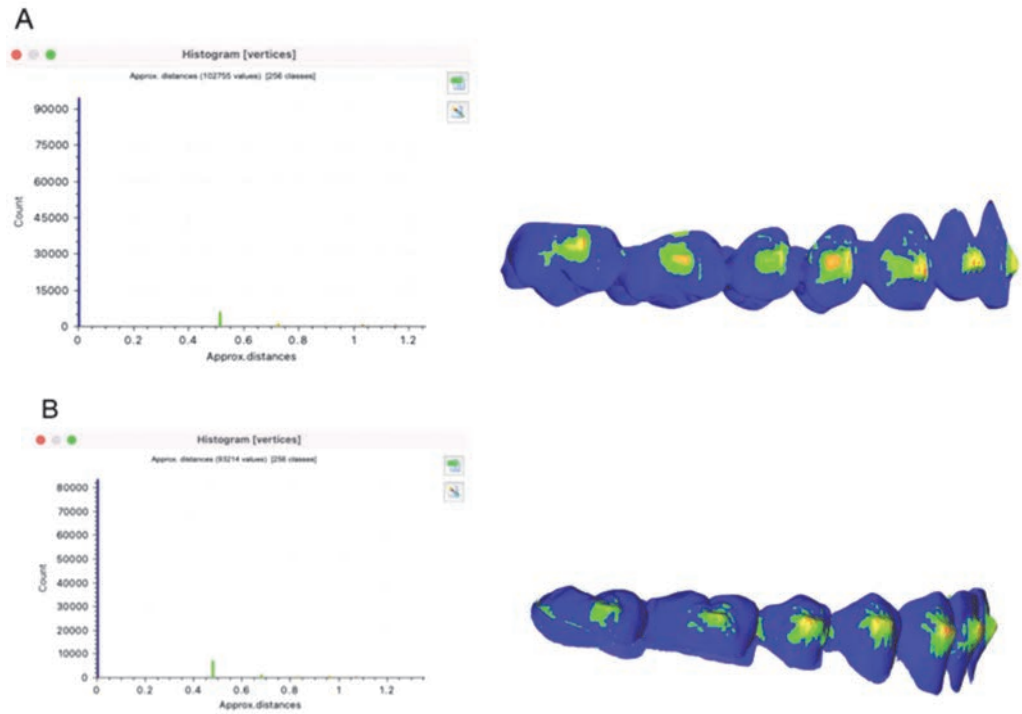


Fig 2. Superimposed image of models with and without attachments. A: Maxillary superimposition; B: Mandibular superimposition.

Table 1. Dental measurements' intraclass correlation coefficients of agreement and Dahlberg's formula of the maxillary and mandibular arches for the digital models with and without attachments.

Variables	No attachment		Attachment	
	ICC (95% CI)	Dahlberg Formula	ICC (95% CI)	Dahlberg Formula
Intra-rater				
Upper 6-6 distance	1.00 (1.00, 1.00)	0.11	1.00 (1.00, 1.00)	0.11
Upper 3-3 distance	1.00 (0.99, 1.00)	0.08	0.99 (0.98, 1.00)	0.12
Upper right central incisor	0.96 (0.89, 0.99)	0.09	0.96 (0.88, 0.98)	0.09
Upper left central incisor	0.95 (0.86, 0.98)	0.08	0.95 (0.86, 0.98)	0.10
Upper right lateral incisor	0.98 (0.94, 0.99)	0.08	0.98 (0.94, 0.99)	0.08
Upper left lateral incisor	0.97 (0.90, 0.99)	0.08	0.88 (0.68, 0.96)	0.14
Lower 6-6 distance	1.00 (1.00, 1.00)	0.10	1.00 (1.00, 1.00)	0.09
Lower 3-3 distance	0.99 (0.98, 1.00)	0.09	0.98 (0.95, 0.99)	0.17
Lower right central incisor	0.93 (0.80, 0.97)	0.08	0.94 (0.83, 0.98)	0.09
Lower left central incisor	0.96 (0.89, 0.99)	0.08	0.96 (0.88, 0.99)	0.08
Lower right lateral incisor	0.93 (0.82, 0.98)	0.08	0.94 (0.84, 0.98)	0.08
Lower left lateral incisor	0.94 (0.83, 0.98)	0.09	0.96 (0.88, 0.98)	0.08
Inter-rater				
Upper 6-6 distance	1.00 (0.99, 1.00)	0.20	0.99 (0.96, 1.00)	0.30
Upper 3-3 distance	0.98 (0.95, 0.99)	0.16	0.98 (0.93, 0.99)	0.19
Upper right central incisor	0.96 (0.89, 0.99)	0.09	0.95 (0.86, 0.98)	0.12
Upper left central incisor	0.94 (0.83, 0.98)	0.11	0.95 (0.87, 0.98)	0.13
Upper right lateral incisor	0.95 (0.86, 0.98)	0.12	0.87 (0.67, 0.95)	0.19
Upper left lateral incisor	0.96 (0.88, 0.99)	0.10	0.79 (0.50, 0.92)	0.19
Lower 6-6 distance	1.00 (0.99, 1.00)	0.18	0.99 (0.98, 1.00)	0.23
Lower 3-3 distance	0.99 (0.97, 1.00)	0.14	0.98 (0.94, 0.99)	0.21
Lower right central incisor	0.90 (0.74, 0.96)	0.11	0.96 (0.89, 0.96)	0.10
Lower left central incisor	0.94 (0.84, 0.98)	0.10	0.92 (0.79, 0.97)	0.13
Lower right lateral incisor	0.82 (0.57, 0.94)	0.17	0.95 (0.87, 0.98)	0.14
Lower left lateral incisor	0.89 (0.72, 0.96)	0.10	0.90 (0.73, 0.96)	0.15

Table 2: Dental measurements of the maxillary and mandibular arches in digital models with and without attachments.

Variables (mm)	No attachment	Attachment	P value	
Upper 6-6 distance	52.5 ± 2.1	52.5 ± 2.2	0.371	**
Upper 3-3 distance	34.3 ± 1.6	34.3 ± 1.5	0.673	**
Upper right central incisor	8.7 ± 0.4	8.7 ± 0.4	0.621	*
Upper left central incisor	8.7 ± 0.4	8.7 ± 0.4	0.782	*
Upper right lateral incisor	6.8 ± 0.5	6.9 ± 0.5	0.004	**
Upper left lateral incisor	6.9 ± 0.5	7.0 ± 0.4	0.186	**
Lower 6-6 distance	45.7 ± 2.5	45.7 ± 2.5	0.726	**
Lower 3-3 distance	25.5 ± 1.7	25.5 ± 1.7	0.633	*
Lower right central incisor	5.3 ± 0.3	5.3 ± 0.3	0.147	*
Lower left central incisor	5.3 ± 0.4	5.3 ± 0.4	0.218	*
Lower right lateral incisor	5.9 ± 0.3	5.9 ± 0.3	0.926	*
Lower left lateral incisor	5.9 ± 0.3	5.9 ± 0.3	0.237	**

*Paired t test * Wilcoxon test ** Assumption checks: Normality test (Shapiro-Wilk) Q-Q Plot*

Table 3. Descriptive statistics between scanned digital models.

Mean of minimums	SD	Mean of maximums	SD	Mean of means	SD	Mean of the coincidence percentage between the digital models at 0.6mm	SD	Mean of the coincidence percentage between the digital models at 1mm	SD
0	0	1.66	0.82	0.04	0.02	97.88	1.61	99.42	0.88

DISCUSSION

Since attachments are common tools in orthodontic treatments with CA, analyzing their influence in intraoral scanning is paramount to orthodontists. Therefore, measurements from digital models with and without attachments from the same patients were performed. Also, the same digital models were superimposed to observe visually and numerically the differences between them. During orthodontic treatment and especially with CA, intraoral scanners provide information and dental images which can be helpful to both patients and clinicians.[10,15,16]

However, orthodontic attachments are commonly already bonded to teeth during the scanning procedure, since they represent a way to achieve better results and predictability with CA.[17] There is still no consensus regarding biomechanics with CA, but some attachments have already been proven to achieve better results than others.[18] Therefore, orthodontists might want to keep them bonded to teeth surfaces, especially when the enamel integrity can be harmed, and assessing the influence of orthodontic attachments in intraoral scanning justifies the study objective.[11]

It is important to mention that the repeatability within the measurements was high, and that the error in the method varied from 0.08 to 0.30 mm (Table 1). Previous studies have already reported differences ranging from 0.20 to 0.30 mm in orthodontic digital models,[19,20] which makes those inconsistencies found negligible in clinical practice.[21] Also, all the intraoral scanning procedures were performed in the same appointment, by the same operator with the same scanner. The subjects would have their arches scanned before and

immediately after the attachments were bonded, minimizing any chance of teeth movement and making the presence of attachments the main difference between the arches.

Six measurements essential to any orthodontic practice were used in this study to compare the fidelity of the intraoral digital models. All the correlation coefficients of agreement for the maxillary and mandibular arches demonstrated reliability with excellent results, except for the maxillary lateral incisor (Table 2). However, the mean difference was 0.1 mm, and similar discrepancies have already been observed in past studies with no concern for the clinical practice.[13,21] In addition, when the models were superimposed, the bigger differences were found in the attachment areas (Figure 2), which corroborates the lack of interference when performing the measurements. Therefore, it is safe to say that the presence of orthodontic attachments did not alter the measurements performed in digital dental models.

The superimposition of the digital models revealed that the difference between them was minimum, and they also focused on the attachments' area. Most of the teeth were colored blue, which represents an almost identical superimposition, as seen in Figure 2. The mean of means was 0.04 mm and the mean coincidence percentage between the digital models up to 0.1 mm was 92.02% (± 4.01) (Table 3). This also reinforces the similarity between the digital models, and it can be seen by the same the blue color, due to the closeness to minimum value.

As the difference between the models increases and the value gets closer the mean of maximums (1.66 mm) (Table 3), the colors orange and red can be seen, and they were focused on the attachments' region. Thus, visually, it is possible to understand where the difference between the models is found[13]. This also justifies the absence of statistically significant values between five from the six measurements performed on the models, since almost all the teeth surface were blue.

An interesting finding was that the mean of coincidence percentage between the digital models up to 0.6 mm was 97.88% of coincidence (± 1.61) (Table 3). This means that most of the models with attachments' surface are coincident to the ones without them and are accepted to be used clinically with no distortion to the teeth anatomy. Past studies have reported that discrepancies up to 0.30 mm are accepted in digital models.[19,20] Hence, the differences found between the models can be considered negligible and measurements performed in digital models with attachments are comparable to the ones performed in the same models without the presence of the attachments.

It is important to mention that all the patients had only beveled rectangular attachments bonded to their teeth, the presence of different shapes of attachments might alter the fidelity of the digital models. Also, all the patients were scanned with the same intraoral scanner iTero Element 5D®.

It is also important to emphasize the need to keep the teeth adequately dry during scanning. Particular attention should be paid when scanning the mesial, distal, and cervical surfaces, as these areas are prone to incomplete capture. Inadequate scanning can result in gaps in the mesh, which the scanner software may attempt to fill automatically, potentially introducing distortions in the digital model. Careful handling and attention to these regions are therefore essential to ensure the accuracy and reliability of digital impressions. Different studies analyzing the precision of different scanners might bring important answers to the orthodontic practice with CA.

It is concluded with the accomplishment of this study that the presence of orthodontic attachments bonded to teeth did not affect clinically the measurements performed in digital models. Also, digital models with attachments are clinically comparable to the ones without the presence of them.

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