

Karen Katlein Dolenkei

Influência da experiência do operador e da técnica de obtenção de molde na percepção do paciente e veracidade dos modelos em escaneamentos de arco total: estudo *in vivo*

Influence of operator experience and impression technique on patient perception and cast veracity in complete arch scans: an in vivo study

Dissertação apresentada à Faculdade de Odontologia da Universidade de Uberlândia, para obtenção do Título de Mestre em Odontologia na Área de Clínica Odontológica Integrada.

Uberlândia, 2023

Karen Katlein Dolenkei

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Odontológica Integrada.

Orientador: Prof. Dr. Luís Henrique Araújo Raposo

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Coordenação do Programa de Pós-Graduação em
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RESUMO

Com o intuito de aprimorar o atendimento, trazer facilidade na execução dos procedimentos e gerar maior conforto ao paciente, hoje no mercado odontológico podemos encontrar diferentes tipos de escâneres, com diversos formatos e softwares, o que pode gerar dúvidas ao profissional que deseja trabalhar com esta tecnologia. O objetivo desse estudo *in vivo* foi avaliar a percepção do paciente frente a diferentes técnicas de obtenção de moldes e experiência do operador, além de analisar o tempo para obtenção dos moldes, tamanho dos arquivos gerados e a veracidade dos modelos obtidos. Os sujeitos de pesquisa (n=15) foram submetidos a escaneamento de arco completo por dois operadores (baixa e alta experiência) utilizando dois tipos de escâneres intraorais (Trios 3; 3Shape/Virtuo-Vivo; Straumann) e moldados por um operador empregando material elástico (Hydrogum V; Zhermack) para obtenção de modelo em gesso escaneado por escâner de bancada (inEos X5; Dentsply Sirona). A percepção dos participantes em relação aos procedimentos foi coletada por meio de questionário fechado. O tempo para obtenção do molde e o tamanho dos arquivos foram registrados. A veracidade foi avaliada em software de análise 3D (Geomagic Control; 3D Systems). Para análise do questionário, utilizou-se teste de Mann-Whitney e Qui-quadrado. Para análise de tempo para obtenção do molde, tamanhos dos arquivos e veracidade, utilizou-se testes ANOVA e Tukey HSD. Correlação de Pearson foi realizada entre o tamanho dos arquivos e tempo de escaneamento. Na análise de percepção do paciente foram verificadas diferenças significativas em relação ao conforto, o escâner Virtuo Vivo recebeu melhor avaliação ($P<.001$) e o operador de maior experiência foi melhor avaliado com ambos os escâneres ($P<.001$). Não foram encontradas diferenças significativas quanto a preferência do paciente em relação à técnica para obtenção dos modelos de arco total (convencional vs. digital) ($P>.001$). Para tempo de escaneamento e moldagem, foi verificada diferença significativa no tempo total (maxila/mandíbula) ($P<.001$), com Trios 3 apresentando menor tempo ($P=.042$). Na análise individual, a moldagem convencional apresentou maior tempo para maxila e mandíbula ($P<.001$), não havendo diferença entre os escâneres ($P>.001$). O operador de menor experiência levou maior tempo para os escaneamentos ($P<.001$). A experiência do operador não afetou o tamanho dos arquivos dos escaneamentos ($P>.001$), entretanto o escâner sim, com Trios 3 produzindo arquivos maiores e Virtuo Vivo tendo maior dispersão. Maiores arquivos foram sempre verificados

para maxila ($P < .001$) e o escaneamento de bancada inEos gerou os maiores arquivos dentre os três sistemas de escâneres ($P < .001$). Para análise de veracidade entre os modelos, não foi encontrado diferença significativa entre as diferentes técnicas, entre os escâneres e entre os operadores ($P > .001$). A correlação entre o tempo de escaneamento e o tamanho dos arquivos foi positiva, porém fraca, independentemente do escâner e operador. Não houve preferência pela técnica de obtenção dos modelos de arco total, porém a experiência do paciente foi influenciada pelo operador e escâner. O tempo de escaneamento e tamanho dos arquivos variou entre os escâneres. Ambas as técnicas (convencional/digital) e escâneres apresentaram veracidade similar para obtenção de modelos de arco total para os diferentes operadores.

PALAVRAS-CHAVES: Prótese Dentária; Confiabilidade dos Dados; Reabilitação Bucal.

ABSTRACT

With the aim of improving care, facilitating the execution of procedures and generating greater comfort for the patient, today in the dental market we can find different types of scanners, with different formats and software, which can raise doubts for the professional who wants to work with this technology. The aim of this in vivo study was to evaluate the patient's perception of different techniques for obtaining impressions and the operator's experience, in addition to analyzing the time taken to obtain the impressions, the size of the files generated and the veracity of the models obtained. The research subjects (n=15) underwent full-arch scanning by two operators (low and high experience) using two types of intraoral scanners (Trios 3; 3Shape/Virtuo-Vivo; Straumann) and molded by an operator using material elastic band (Hydrogum V; Zhermack) to obtain a plaster model scanned by a benchtop scanner (inEos X5; Dentsply Sirona). The perception of the participants in relation to the procedures was collected through a closed questionnaire. The time to obtain the mold and the size of the files were recorded. Veracity was evaluated using 3D analysis software (Geomagic Control; 3D Systems). For the analysis of the questionnaire, the Mann-Whitney and Chi-square tests were used. For analysis of time to obtain the mold, file sizes and veracity, ANOVA and Tukey HSD tests were used. Pearson correlation was performed between file size and scanning time. In the analysis of the patient's perception, significant differences were verified in relation to comfort, the Virtuo Vivo scanner received a better evaluation ($P<.001$) and the operator with more experience was better evaluated with both scanners ($P<.001$). No significant differences were found regarding patient preference regarding the technique for obtaining full-arch models (conventional vs. digital) ($P>.001$). For scanning and impression time, there was a significant difference in the total time (maxilla/mandible) ($P<.001$), with Trios 3 presenting the shortest time ($P=.042$). In the individual analysis, the conventional impression took longer for the maxilla and mandible ($P<.001$), with no difference between the scanners ($P>.001$). The less experienced operator took longer for the scans ($P<.001$). Operator experience did not affect scan file sizes ($P>.001$), however the scanner did, with Trios 3 producing larger files and Virtuo Vivo having greater dispersion. Largest files were always found for the maxilla ($P<.001$) and the inEos benchtop scan generated the largest files among the three scanner systems ($P<.001$). For the analysis of veracity between the models, no significant difference was

found between the different techniques, between the scanners and between the operators ($P>.001$). The correlation between scanning time and file size was positive but weak, regardless of scanner and operator. There was no preference for the technique for obtaining the full-arch models, but the patient's experience was influenced by the operator and scanner. Scanning times and file sizes varied between scanners. Both techniques (conventional/digital) and scanners showed similar veracity for obtaining full arch models for different operators.

KEYWORDS: Dental prosthesis; Data Reliability; Oral Rehabilitation.

1. INTRODUÇÃO E REFERÊNCIAL TEÓRICO

Com o aperfeiçoamento das tecnologias, o sistema Computer-Aided imaging/Computer-Aided Design/Computer-Aided Manufacturing (CAI/CAD/CAM) se tornou promissor, ganhando espaço tanto nos consultórios odontológicos quanto em laboratórios de próteses. Esse sistema foi introduzido na odontologia na década de 80 com o intuito de promover automatização e padronização do processo de fabricação protético e hoje possibilita confeccionar restaurações indiretas, modelos impressos, infraestruturas implantadas e guias cirúrgicos, proporcionando uma nova forma de reabilitar os pacientes e facilitar o processo reabilitador (Kayatt & Neves, 2012; Kayatt, 2013; Carneiro et al., 2016). Normalmente o processo é realizado em três etapas, a primeira é a aquisição de dados (CAI), que pode ser de forma direta, com escaneamento direto na boca do paciente ou de forma indireta, pelo escaneamento do modelo obtido por meio de molde convencional. A segunda etapa dispõe do processamento dos dados (CAD) para que em seguida, seja realizado o planejamento dos casos por meio de um software. Na terceira etapa acontece a manufatura (CAM), que é a concretização do planejamento realizado na segunda etapa, na qual, o projeto realizado no software é enviado para uma máquina de manufatura, normalmente fresadoras ou impressoras 3D (Cho, 2002; Kayatt & Neves, 2012; Kayatt, 2013; Chew et al., 2017). O fluxo digital segue em ascensão na odontologia e é utilizado em diversas especialidades, tendo o intuito de aprimorar o atendimento, trazer facilidade na execução dos procedimentos e gerar mais conforto ao paciente.

O contínuo avanço em melhorias dos escâneres intraorais (IOs) e também em softwares capazes de planejar e auxiliar em casos de reabilitações desde as mais simples até as mais complexas, fazem com que os profissionais e os técnicos em prótese se atualizem constantemente nessas tecnologias (Christensen, 2008; Sebastian et al., 2014; Albduor et al., 2018). A obtenção de modelos que reproduzem a arcada dentária do paciente em sua totalidade pode ser realizada por mais de uma maneira. Ainda que se prevaleça a moldagem convencional, na qual são obtidos modelos em gesso, também é possível adquirir modelos de maneira impressos a partir de modelos digitais 3D obtidos por meio de escaneamentos intraorais (Christensen, 2009; Yuzbasioglu et al., 2014). Tanto o modelo físico como o digital, são utilizados pelas diferentes especialidades

odontológicas para diagnóstico, planejamento e execução do plano de tratamento (Stanley, et al., 2018).

Os IOs oferecem diversas vantagens sobre o processo de moldagem convencional, entre elas, a capacidade de verificar detalhes e falhas sem a necessidade de refazer inteiramente um novo escaneamento, realizando reparos apenas nas regiões necessárias, assim, economizando tempo para o dentista e sendo mais conveniente ao paciente. Além disso, a facilidade na transferência de informações para o laboratório; a eliminação na transmissão de materiais infecciosos do paciente ao laboratório; os riscos de quebra e danos aos moldes e modelos em gesso; a possibilidade de distorção dos materiais de moldagem; e a capacidade em arquivar informações e documentos sem a necessidade de espaço físico (Ryeo-Woon et al., 2014; Yuzbasioglu et al., 2014; Alzahrani et al., 2020).

Com o fluxo digital estando cada vez mais presente no cotidiano do cirurgião dentista, instituições de ensino e do laboratório de prótese, têm-se a necessidade de estudos relacionado ao tema, inclusive sobre a percepção do paciente frente aos procedimentos convencionais e digitais, dados pouco discutidos na literatura. Assim, este trabalho possui como objetivo principal analisar a influência do nível de experiência do operador e do tipo de escâner na qualidade dos modelos obtidos e na percepção do paciente frente ao escaneamento intraoral e moldagem convencional.

Com a incorporação de diversas tecnologias digitais na odontologia e o desenvolvimento de pesquisas na área, os profissionais vêm continuamente se aprimorando e aderindo ao fluxo digital em sua rotina clínica. Para que essas ferramentas tecnológicas sejam incorporadas pela classe odontológica e que valha a pena o investimento, o benefício clínico deve ser investigado e sendo necessário avaliações precisas que ampliem as informações frente ao assunto. Diversos estudos vêm sendo publicados quanto a este tema, sendo a maioria deles estudos in vitro.

Além disso, existem diversos tipos de escâneres e eles possuem diferentes características, como o tamanho e o formato da peça de mão, o que pode influenciar na experiência individual do paciente. O tipo de escâner pode influenciar também na acurácia (exatidão e reprodutibilidade) e isso refletir na qualidade final do trabalho desenvolvido para o paciente. Na acurácia é analisada a exatidão, sendo a capacidade do escâner de produzir imagens próximas ao objeto real digitalizado. Também é analisado a

capacidade do escâner em produzir imagens repetíveis do objeto digitalizado e cada imagem corresponder às outras, sendo esse recurso conhecido como reprodutibilidade. A acurácia está fundamentada pela análise da fidelidade e de precisão (ISO 5725-1) (Alzahrani et al., 2020; Kernen et al., 2021; Resende et al., 2021). Além de que, uma inconstância na exatidão do escaneamento pode estar relacionada a experiência do operador (Jung-Hwa Lim, et al., 2017; Resende et al., 2021). Existem estudos que relatam o aumento na curva de aprendizagem e na capacidade de desempenho à medida que os conhecimentos e habilidades são acumuladas por práticas repetitivas do operador (Chambers, 2012; Kim et al., 2016; Lim et al., 2018).

Estudos *in vitro* analisaram a acurácia entre mais de um tipo de escâner, escaneando 10 modelos de arco completo, analisando a veracidade e a reprodutibilidade com dois escâneres diferentes, tendo demonstrado que o escâner TRIOS 3 foi mais preciso do que o CEREC Omnicam para varreduras de arco completo, além de ter chegado a conclusão que operadores mais experientes obtiveram um escaneamento mais rápido e mais preciso (Resende et al. em 2020). Diferentemente, em outro estudo um modelo com um sextante e um modelo com um quadrante foram escaneados utilizando dois escâneres, TRIOS 3 e Emerald (Saeed et al., 2020). Após análises, os autores chegaram a conclusão que referente a exatidão, o escâner Emerald registrou menor exatidão conforme o campo de varredura aumentou e, referente a precisão, nenhuma diferença significativa foi detectada entre os escâneres. Andreas et al. em 2019 utilizou 8 configurações diferentes de IOs para analisar a acurácia escaneando 1 modelo em gesso 10 vezes e concluiu que os IOs são uma alternativa válida sobre as moldagens convencionais. Os autores reforçam em suas conclusões a necessidade de estudos *in vivo* para assegurarem seus resultados.

Pesquisas realizadas *in vivo* também demonstraram diferenças entre os escâneres utilizados. Um estudo escaneou 5 indivíduos, utilizando 4 diferentes versões de softwares de IOs (Trios3Cart, Trios3Pod, Trios4Pod e Primescan), e chegaram ao resultado que versões mais recentes de softwares demonstram menor desvio na precisão, consequentemente, melhor resultado final (Schmidt et al. em 2020). Outro estudo escaneou uma arcada dentária antes da extração dos dentes e, após a extração os disponibilizou em um modelo em cera, então escaneou novamente analisando apenas as coroas para comparação e concluiu que a técnica de impressão digital é clinicamente tão boa ou melhor que a técnica de moldagem convencional (Albdour et. al em 2018).

O nível de experiência do operador também pode influenciar na acurácia dos escaneamentos, como mostra o estudo que selecionou um grupo de profissionais com níveis de experiência distintos para escanear uma arcada completa ex vivo, e demonstrou que profissionais já experientes tiveram melhores resultados na veracidade de seus escaneamentos, diferentemente dos profissionais com pouca experiência Revell et al. em 2021. Outro estudo teve a participação de 3 operadores de níveis diferentes de experiência (baixo, médio e alto) e chegou a conclusão que quanto maior a experiência do operador, menor o tamanho do arquivo gerado e melhor o desempenho na exatidão do escaneamento realizado em modelo in vitro (Resende et al. 2021). A maioria desses estudos foram baseados em modelos in vitro e por isso eles têm aplicação limitada para prática clínica e pouco acréscimo quanto a possibilidade de melhorar o atendimento ao paciente.

Para que possamos analisar a influência do nível de experiência do operador e de diferentes tipos de escâneres sobre a experiência do paciente, faz-se necessário a realização de pesquisas in vivo com o intuito de correlacionar essas questões. Sendo encontrado na literatura estudos in vivo que não correlacionam a experiência do paciente diretamente com esses fatores (DeLong et al., 2003; Nedelcu and Persson, 2014; Lee JJ, et al., 2017, Resende et al., 2021; HS Oh, et al., 2021).

2. PROPOSIÇÃO

Levando em consideração a escassez de estudos in vivo avaliando a percepção do paciente quanto a técnica de obtenção de modelos de arco total, tipo de escâner utilizado, e a experiência do profissional operador, este estudo objetivou analisar a influência do nível de experiência do operador (baixa e alta) e do tipo de escâner na qualidade dos modelos obtidos (veracidade) e na percepção do paciente frente ao escaneamento intraoral quando comparado à procedimento de moldagem convencional. Além disso, foi avaliada a influência da experiência do operador no tempo de escaneamento e no tamanho dos arquivos gerados a partir de escaneamentos de arco total. As hipóteses nulas testadas foram: 1) a percepção do paciente quanto ao tipo de escâner, experiência do operador e técnica utilizada na obtenção de modelos de arco total não apresenta diferença; 2) o tempo de escaneamento e tamanho dos arquivos obtidos não são influenciados pela técnica de obtenção, tipo de escâner e experiência do operador; 3) a veracidade dos modelos de arco total não é influenciada pela técnica de obtenção, tipo de escâner e experiência do operador.

3. CAPÍTULO 1

ARTIGO

Influência da experiência do operador e da técnica de obtenção de molde na percepção do paciente e veracidade dos modelos em escaneamentos de arco total: estudo *in vivo*

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Influence of operator experience and impression technique on patient perception and cast veracity in complete arch scans: an in vivo study

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Abstract

Statement of the Problem: The patient perception regarding the use of different techniques for obtaining cast can be influenced by several factors, such as the operator experience and the type of scanner used. In addition, with the emergence of new casts of intraoral scanners, one must evaluate the scanning time, file size and the veracity of the three-dimensional (3D) casts obtained.

Purpose: The aim of this in vivo study was to evaluate the patient perception of different techniques for obtaining impressions and the operator experience, in addition to analyzing the time taken to obtain the impressions, the size of the generated files and the veracity of the casts obtained.

Materials and methods: Subjects (n=15) were scanned by two operators (low and high experience) using two intraoral scanners (Trios 3; 3Shape/Virtuo Vivo; Straumann) and molded using irreversible hydrocolloid material (Hydrogum V; Zhermack) to obtain plaster casts scanned on a laboratory scanner (inEos X5; Dentsply Sirona). The participants perception of the procedures was collected through a questionnaire. The time to obtain the mold and the size of the files were recorded. Veracity was evaluated using 3D analysis software (Geomagic Control; 3D Systems). For the analysis of the questionnaire, the Mann-Whitney and Chi-square tests were used. For analysis of time to obtain the mold, file sizes and veracity, ANOVA and Tukey HSD tests were used. Pearson correlation was performed between file size and scanning time.

Results: In the analysis of the patients perception, significant differences were verified in relation to comfort, the Virtuo Vivo scanner received a better evaluation ($P<.001$) and the operator with more experience was better evaluated with both scanners ($P<.001$). No

significant differences were found regarding patient preference regarding the technique for obtaining complete arch casts (conventional vs. digital) ($P > .001$). For scanning and impression time, there was a significant difference in the total time (maxilla/mandible) ($P < .001$), with Trios 3 presenting the shortest time ($P = .042$). In the individual analysis, the conventional impression took longer for the maxilla and mandible ($P < .001$), with no difference between the scanners ($P > .001$). The less experienced operator took longer for the scans ($P < .001$). Operator experience did not affect scan file sizes ($P > .001$), however the scanner did, with Trios 3 producing larger files and Virtuo Vivo having wider distribution. The largest files were always scanned for maxilla ($P < .001$) and the inEos database scan generated the largest files among the three scanning systems ($P < .001$). For the analysis of veracity found between the cast, no significant difference was found between the different techniques, between the scanners and between the operators ($P > .001$). The variation between scanning time and file size was positive but weak, regardless of scanner and operator.

Conclusion: There was no preference for the technique for obtaining complete arch casts, but the patient's experience was influenced by the operator and scanner. Scanning times and file sizes varied between scanners. Both techniques (conventional and digital) and scanners showed similar veracity for obtaining complete arch cast for different operators.

Clinical Implications: The patients perception is an essential factor for the success of dental treatment and must be considered in relation to the operator experience and techniques for obtaining complete arch casts. The veracity of the casts obtained can be influenced by the technique, operator experience, type of scanner, scanning time and size of the final files; however, conventional and digital techniques can present similar veracity when employed in complete arch scans for study casts.

INTRODUCTION

The use of intraoral scanners (IOS) in the clinical routine resulted in greater practicality and agility for professionals and patients.¹⁻³ Because of the increased use of this technology, new types of scanners are constantly available on the market and software updates improvements to the digital work flow, for IOS and laboratory scanner, in addition to the cost that is increasingly accessible.⁴⁻⁷ Three-dimensional (3D) casts obtained from intraoral scans may present adequate precision for orthodontic treatments, hospital planning, manufacturing of single or multiple fixed prostheses on teeth and implants.⁸⁻¹² However, obtaining casts using conventional molds with elastic materials such as irreversible hydrocolloid is still common, being used for making study casts, diagnostic waxing, surgery guides, occlusal splints, removable partial dentures, and others.^{7,13}

The optimization of procedure time is an advantage of intraoral scanning, but in addition, we have other important benefits, like a reduction of mold dysfunction, three-dimensional visualization of the area of interest and the possibility of repairing small areas. In contrast to conventional molding, where it would be necessary to make a new mold.^{2, 14-18} Despite recent developments, complete-arch scanning is still a challenge within the digital flow, and the larger scanned area, can increase errors in obtaining the mesh.^{19, 20} Most errors are located in the buccal and distal region of the last molars, because of the difficulty in scanning these regions.²¹⁻²⁴ The challenge related to capturing images performed in vivo becomes even greater due to factors such as the presence of fluids (saliva, blood, etc.), limited area to move the scanner and tissues attached to the teeth (tongue, cheeks, gums).²² Some studies performed in vitro veracity and reproducibility (accuracy) analyses, following the ISO 5725-1 standard.^{22, 24, 25} However,

they reinforce the need to carry out in vivo studies in individuals to relate the results to the clinical reality, bringing the findings closer to the routine of professionals who work with digital dentistry.

The patient's level and perception are an essential factor for success in dental treatment and must be considered regarding the techniques for obtaining study/work casts, the type of scanner used and the operator's experience. We can find different tip formats in the IOS currently available, and larger tips can cause discomfort and make it difficult to perform adequate scans in patients with reduced mouth opening, presence of third molars and/or wide arches.^{1,2} Another factor that can influence scanning accuracy and patient comfort is the experience of the professional scanner operator.²⁶⁻²⁹ Professionals with less experience tend to generate a greater number of images, leading to the creation of large files, especially when associated with larger areas, such as when scanning complete arch, which can lead to the evolution of errors in capturing the mesh of the casts obtained.^{24, 30-33}

Taking into account the scarcity of in vivo studies evaluating the patient's perception of the technique for obtaining complete arch casts, the type of scanner used, and the operator's professional experience, this study aimed to analyze the influence of the operator's level of experience (low and high) and the type of scanner on the quality of the casts obtained (trueness) and on the patient's perception of intraoral scanning when compared to the conventional impression procedure. Furthermore, the influence of the operator's experience on the scanning time and the size of the files generated from complete arch scans was influenced. The null hypotheses tested were: 1) the patient's perception of the type of scanner, operator experience and technique used in delivering complete arch casts does not differ; 2) scan time and size of received files are not influenced by warranty

technique, scan type and operator experience; 3) the accuracy of complete arch casts is not influenced by acquisition technique, scanner type and operator experience.

MATERIALS AND METHODS

The present clinical study was approved by the research ethics committee (CAAE – 57127022.6.0000.5152-UFU) and the participants signed the consent form. This study followed the 2x2x2 factorial design, having as main study factors two techniques for obtaining casts: conventional and digital; 2 operator experience levels: low and high experience; 2 levels of intraoral scanners: Trios 3 (Trios 3 v22.1.4; 3Shape) and Virtuo Vivo (Virtuo Vivo v3.8.1.978; Straumann). The response variables were the data obtained from the questionnaire, the time to obtain the mold, the size of the generated files and the veracity of the casts obtained by the two techniques.

The experimental unit consisted of 15 individuals (sample calculation $n=10$), who were selected according to the following inclusion criteria: patients over 18 years of age of both sexes; who had all their teeth in their mouths (except for upper and lower third molars); presenting standard Angle Class I occlusion. The following exclusion criteria were applied: patients with signs of trismus and/or restricted mouth opening; presence of metallic restorations; presence of implant-supported prostheses; ongoing orthodontic treatment.

In the operator selection criterion, it was defined that the operator with less experience had clinical experience of less than 10 scans and that the operator with more experience had conducted more than 100 scans, generating a discrepancy of at least 90% between the operators. The operator responsible for the conventional impression should

have high experience, with at least 10 years of clinical practice and specialization in the area. The scanners used have different characteristics in terms of the way images are captured, as shown in Table 1. The operators were previously trained on Typodont mannequins to standardize the scanning technique, using the same sequence of direction and movements for both systems.³⁴ Before acquiring the images, the scanners were calibrated following the calibration guidelines of the respective manufacturers.

Conventional molding was performed using irreversible hydrocolloid material (Hydrogum V; Zhermack) using the water/powder ratio suggested by the manufacturer, being manipulated in a mechanical mixer (Alghamix II; Zhermack). Total perforated stock trays were used to retain the material, and after obtaining the alginate impressions, they were disinfected with 0.5% sodium hypochlorite spray for 10 minutes. Plaster casts were immediately obtained by an experienced dental technician using type IV plaster modified by zero expansion resin (Zero Stone; Dentona AG) manipulated in a vacuum mixer with the water/powder ratio suggested by the manufacturer. The casts were cut out, and after four days of drying, digitized by an experienced operator using a laboratory scanner (inEos X5; Dentsply Sirona) duly calibrated according to the manufacturer's instructions. The time required for conventional impression taking (handling, tray loading and insertion) and for the scans with each type of scanner was measured in seconds using a digital stopwatch, with the time for the maxilla, mandible and total time being individually analyzed (considering occlusal registration).

The individuals included in this research were submitted to the application of a questionnaire (n=15), and none of the participants had previous experience with the use of the digital flow in Dentistry. The subject under evaluation received the necessary guidance on the questionnaire and after drawing lots, he was directed to one of the

procedures in which he would participate. Blinded as to the experience of the operators and the types of scanners, the subject had the questionnaire in hand throughout the entire process, armed with a pencil and eraser. The questionnaire presented only closed questions with the objective of evaluating the degree of satisfaction of the participants in relation to the procedures performed. The same was produced by the research team based on the Brazilian Method for Customer Satisfaction Research, being composed of five categories of responses: 1) Very dissatisfied; 2) Dissatisfied; 3) Neutral; 4) Satisfied; and 5) Very Satisfied, in addition to presenting a visual analogue scale.³⁵ The questionnaire contained five questions, the first described as Step 1 assessed the degree of patient satisfaction with the scanner used and the operator, taking comfort and agility into account. That is, it evaluated comfort and agility for scanning with scanner 1 and operator 1, scanner 1 and operator 2, scanner 2 and operator 1, and scanner 2 and operator 2. Step 2 evaluated the degree of satisfaction of the participants regarding the conventional impression, considering comfort and agility. Step 3 and 4 compared the two techniques for obtaining the complete arch impression (conventional and digital) and the last question presented images of the scanners and the material used for the impression so that the participants could choose which of the three was their preference for use in the service. (Annex I)

The files obtained from the Intraoral and laboratory scanner, for the maxilla and mandible, were exported in *.STL (standard tessellation language) format for analysis of veracity between the casts of the individuals (n=13). In this study, the analysis of veracity was based on the ability of the three-dimensional (3D) cast obtained in intraoral scanning to present a quality comparable to the reference cast obtained through conventional and digital impressions.³⁶ This analysis was performed in 3D comparison software (Geomagic

Control; 3D Systems), considering the reference cast as a parameter and the analysis file being added right away.³² The digital cast files were paired and superimposed in a total of 104 analyzes (subject x arch x scanner x operator), using the initial fit tool, which automatically aligns the reference file and the analysis file (Figure 1). Then, the standardization of the casts was carried out, cutting out the unnecessary areas, keeping 2.0 mm apically to the margin of the gingival margin (Figure 2). Subsequently, the best fit tool was used (refined fit with better precision), followed by the 3D comparison tool, which evaluates the mean, maximum and minimum deviation (in mm) and the standard deviation between the analyzed files (Figure 3). To carry out the analysis, the absolute values of the discrepancies obtained (mm) were converted into micrometers (μm), in order to favor comparisons with the literature. In addition, the sizes of the resulting files (Megabyte – Mb) from the intraoral scans (scanner x operator) and digitalization of the plaster casts were evaluated, and the files obtained for the maxilla, mandible and total files (considering occlusal registration) were analyzed individually.

For the analysis of the participants' perception (satisfaction) in relation to agility and comfort in relation to the cast acquisition technique, between scanners and operators, the Mann-Whitney test was used. To compare satisfaction between the techniques used (conventional and digital), the chi-square test was used. To compare file sizes, molding and scanning times between scanners and operators, the variance analysis test (ANOVA) was used. A logarithmic transformation ($\log(x)$) of the data was performed to meet the assumptions of the parametric analysis. To assess the significant differences in the analyses carried out, the Tukey HSD test was used ($\alpha=0.05$).

For the veracity analyses, the data were evaluated for normality using the Shapiro-Wilk and Levene test. The values obtained were transformed using the logarithmic

transformation ($x+1$) to meet the assumptions of the parametric analysis by analysis of variance (ANOVA), in a basic way for the maxilla and mandible data. The significance level used in all analyses was $\alpha=0.05$ (95%), using a statistical package for the analyses (JAMOV v.1.6, The JAMOV Project).

RESULTS

In the analysis of the perception (satisfaction) of the participants through the answers obtained in the questionnaire, significant differences were found for the item comfort between intraoral scanners ($P<.001$) (Table 2) and between operators ($P<.001$) (Table 3), a better evaluation was observed for the Virtuo Vivo scanner ($P=.02$). The operator with more experience obtained a better evaluation for both scanners, Trios 3 ($P=.022$) and Virtuo Vivo ($P=.0340$). Still, regarding comfort, no significant differences were observed regarding the preference of the participants for the technique used to obtain the complete arch casts (conventional vs. Digital) ($P=.197$).

Regarding the agility item, no significant differences were observed between the intraoral scanners ($P=.209$), however, the highly experienced operator obtained a better evaluation for both scanners in this regard, Trios 3 ($P=.001$) and Virtuo Vivo ($P=.046$) (Table 4). Taking agility into account, no significant differences were found regarding the participants' preference for the technique used to obtain complete arch casts (conventional vs. digital) ($P=.089$). Still, observing the choice of participants regarding the scanners used or the conventional impression technique, no significant differences were observed between the three options ($P=.449$).

Analyzing the time required to perform the scanning procedures with each equipment or conventional impression (Table 5), in the variable total time (associating maxilla and mandible time) of scanning and impression, significant differences were found ($P < .001$), with Trios 3 having the shortest scanning time ($P = .042$). Analyzing the time for the maxilla and mandible individually, the impression resulted in a longer procedure time ($P < .001$); with no significant differences between the scanners. Among the operators, the least experienced operator took the longest time for scans in all analyzes ($P < .001$).

Regarding the size of the resulting files (Table 6), significant differences were found between the files generated by the two intraoral scanners ($P < .001$). Trios 3 resulted in larger files ($P < .001$), regardless of operator and area scanned (total files, maxillary or mandibular). The operator experience did not affect the size of the total files or even for the maxilla or mandible in isolation ($P > .001$), regardless of the intraoral scanners, although a tendency for larger files was verified for the more experienced operator. Larger files were generated for the maxilla compared to the mandible ($P < .001$), regardless of intraoral scanner and operator. When comparing the files generated by intraoral scanners with those from the digitalization of plaster casts in a laboratory scanner, larger files were observed for inEos ($P < .001$), followed by Trios 3 ($P < .001$) and finally, by Virtuo Alive ($P < .001$), in all analyzes (total files, maxilla or mandible). For all scanner systems (Trios 3, Virtuo Vivo or inEos) larger files were observed for the maxilla when compared to the mandible ($P < .001$).

For the veracity analyzes of the files obtained, no significant differences were found between the files generated by the different scanners or even between the operators when compared to the reference cast ($P > .001$) (Table 7). The comparative analyzes

carried out on the casts of the maxilla (IOS x reference cast), did not show significant differences between the intraoral scanners ($P=.511$), nor between the operators ($P=.712$). The comparative analyzes carried out on the casts of the mandible also did not dismantle significant differences between the intraoral scanners ($P=.901$), nor between the operators ($P=.856$). In general, the three-dimensional files of the maxilla and mandible generated by the intraoral scanners, for both operators, presented veracity results compatible with the files generated by the laboratory scanner after digitalization of the plaster casts obtained by the conventional technique from molds in elastic material.

DISCUSSION

In view of the hypotheses tested in this study, the first null hypothesis was rejected, as the results showed a better evaluation of the participants for the Virtuo Vivo scanner in relation to the item of comfort. This result is probably due to the size of the equipment, which has a total weight of 218 g, with an active tip having a diameter of 30.1 mm and a length of 207 mm, which, being smaller, generates less discomfort for the patient. Trios 3 has a total weight of 373 g, with an active tip with a diameter of 42 mm and a length of 274 mm, which results in a weight difference of more than 70% and a tip diameter that is 40% larger when compared to Virtuo Vivo. In addition, the operator with more experience obtained better results for the analyzed items (comfort and agility) for both intraoral scanners. However, no significant difference was verified regarding the preference of the participants in relation to the technique used to obtain the complete arch casts, despite the fact that most participants opted for scanning with Virtuo Vivo, instead of scanning with Trios 3 or conventional molding with material irreversible hydrocolloid.

Most of the individuals participating in this investigation were dentistry students or newly graduated dentists, however, none had previous experience or direct contact with digital dentistry tools. Even though these patients were not completely ignorant of the procedures performed, it is not known whether the analysis carried out in a population with a different profile could result in different data from those found in this study. Patient's preference for the use of intraoral scanning was verified in three other previous studies, however, they used impression material and scanners different from this investigation.¹⁻³ The first used polyether-based impression material (Impregum Penta Soft Quick Step MB; 3M-ESPE) and CEREC Omnicam scanner (Sirona Dental GmBH),¹ the second used irreversible hydrocolloid impression material (imprEssix Color Change, Dentsply Sirona) and iTero Element scanners (Align Technologies) and Trios Color (3Shape),² and the third used polyvinylsiloxane-based material in a double step and an iTero Element scanner.³ Unlike the materials used in the conventional impression procedure, the intraoral scanners and the profile of the analyzed population, may have led to discrepant results between previous studies and the present investigation. Furthermore, operator experience was not taken into account in any of the mentioned studies.

The operator's experience and the type of scan were significant factors in relation to the scanning time and the size of the generated files, therefore, the second null hypothesis was also rejected. The Trios 3 scanner resulted in shorter scanning times for the maxilla when compared to the Virtuo Vivo and the highly experienced operator achieved shorter scanning times when compared to the less experienced operator. Regarding the experience of the operators, the repeatability of the technique accentuates the learning curve, frequent practice leads to a gain in resourcefulness in handling intraoral scanners.²⁶⁻²⁸ These results were evidenced in other in vitro studies that analyzed

the influence of operator and scanning time of Trios 3 and other intraoral scanners.^{24, 29, 31-33}

File size was also influenced mainly by the type of scanner, but the operator experience did not influence this aspect significantly. As in other studies, scanning the maxilla resulted in larger files compared to the mandible.^{23, 32} The benchtop scanner, inEos, generated larger files with the digitization of plaster casts when compared to the files generated in intraoral scans, by Trios 3, which presented intermediate files, and Virtuo Vivo, which generated the smallest files, in all analyses. The technology used in these scanners differs in each of the systems used, and this fact was probably responsible for the differences in the size of the generated files. However, the different sizes observed between the files obtained for the same research subjects, does not seem to have been decisive enough to influence their quality. The correlation observed between the size of the generated files and the scanning time was low, demonstrating that one factor does not affect the other directly; but probably in a reproducibility analysis this correlation of time and file size could present different results.³²

The veracity of the complete arch casts was not influenced by the acquisition technique, type of scanner and operator experience, therefore, the third null hypothesis was accepted. The veracity assessment was carried out using specific 3D analysis software pairing two casts, the reference cast obtained by conventional impression and scanned by a laboratory scanner and a second cast obtained through intraoral scanning.⁶ This result is in agreement with another study that carried out accuracy analyzes with different intraoral scanners (Trios 3, iTero, Planmeca Emerald, CEREC Omnicam, Primescan and Virtuo Vivo) and concluded that Trios 3 presented less deviation in

veracity in complete arch scans, followed by Primescan, Virtuo Vivo and iTero, which did not present significant differences.²⁵

However, other studies have demonstrated differences in accuracy between different intraoral scanners. One of the studies compared Emerald and Trios 3 scanners, however, this in-vitro analysis scanned a quadrant and a sextant only with Trios 3 obtaining better results in veracity and precision.²² Another study that also evaluated the influence of the operator on the veracity of the casts obtained was carried out with CEREC Omnicam and Trios 3 scanners on a Typodont cast printed with two teeth prepared for complete crowns (first premolar and first left molar) and three implants (first and second premolars and right first molar) and demonstrated that operators achieved lower veracity with CEREC Omnicam when compared to Trios 3.³² In another in vitro study, veracity analyzes were performed with seven scanners scanning the printed cast in a sextant or complete arch, concluding that Trios 3 provided the best combination of speed, veracity and accuracy.³⁰ Although the aforementioned studies present different results from the present investigation, with better results in terms of veracity for Trios 3, it is worth mentioning that they were conducted in a controlled laboratory environment (in vitro analysis) without considering the existing variability in the participants of a clinical evaluation.

In the present study, no significant differences were detected between the veracity of the casts generated by operators with low and high experience in relation to the reference cast. This result is in agreement with a previous study that evaluated three different levels of operator experience, with 20 individuals scanned with Trios 3 and Medit i500, and demonstrated that the veracity of the scans was not influenced by the operator experience.³⁰ However, this result differs from another in vitro investigation that

demonstrated that highly experienced operators have greater ability to obtain accurate casts when compared to less experienced operators and that operators had lower veracity with CEREC Omnicam when compared to Trios 3.³² It is important to consider that in the first study mentioned above, the selection criterion regarding the operator experience level for each category was similar to that of this investigation,³⁰ different from the second study, which only provided pre-scanning training to its less experienced operator.³² This may have been a determining factor for the results of this study, as the less experienced operator had previously performed intraoral scans on patients (<10 scans), in addition to having received training on a dummy with the systems used in this investigation.

Virtuo Vivo, despite being new to the market and having a market value considerably lower than that of the Trios 3, has positive reviews that are familiar to scanners that are already established in digital dentistry. Future in vivo studies are needed, evaluating the Trios 3 and Virtuo Vivo scanners with other intraoral scanners already well established in the market in different clinical situations, so that professionals have access to comparative results of these scanner systems.

CONCLUSION

Within the limitations of the present in vivo study, we can conclude:

1. Patient comfort was influenced by the type of scanner used and operator experience.
2. The agility of the procedures was influenced by the technique for obtaining the casts, the type of scanner used, and the operator experience.

3. The operator with high experience presented a better evaluation regarding comfort and agility for both scanners.
4. The intraoral scanners showed similar accuracy compare to the reference cast in obtaining full arch models.
5. The scanning time and size of the generated files varied between the scanners used, not affecting, however, the veracity of the casts obtained.

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TABLES

Table 1. Information about the scanners used in the study.

Scanners	Producer	Technology	Version/Update	Weight	Diameter/height
		Scanning			
<i>Trios 3</i>	3Shape	microscopy and confocal laser.	22.1.4	373 g	42 mm / 274 mm
<i>Virtuo Vivo</i>	Straumann	Active triangulation.	3.8.1.978	218 g	30,1 mm / 207 mm
<i>inEos X5</i>	Sirona Dental	Digital light strip.	22.1	Not applicable	Not applicable

Table 2. Analysis of the perception (satisfaction) of the participants regarding comfort and agility, considering only the scanners.

Aspect	Scanner	Median	25° percentile	75° percentile
Comfort	<i>Trios 3</i>	3	3.00	4.00
	<i>Virtuo Vivo</i>	4	4.00	5.00
Agility	<i>Trios 3</i>	4	4.00	4.50
	<i>Virtuo Vivo</i>	4	3.50	5.00

*For comfort, Virtuo Vivo presented the best result. For the item agility, there was no significant difference between the scanners.

Table 3. Analysis of the participants' perception (satisfaction) regarding comfort, considering the operator's experience.

Scanner	Operator	Median	25° percentile	75° percentile
Trios 3	<i>OP1</i>	3	3.00	4.00
	<i>OP2</i>	4	4.00	5.00
Virtuo Vivo	<i>OP1</i>	4	4.00	5.00
	<i>OP2</i>	5	4.50	5.00

*Operator 1 – low experience (OP1). Operator 2 – high experience (OP2). For comfort, the highly experienced operator showed better results for both scanners.

Table 4. Analysis of the perception (satisfaction) of the participants regarding agility, considering the operator's experience.

Scanner	Operator	Median	25° percentili	75° percentili
Trios 3	<i>OP1</i>	3	3.00	4.00
	<i>OP2</i>	5	4.50	5.00
Virtuo Vivo	<i>OP1</i>	4	3.00	4.00
	<i>OP2</i>	4	4.00	5.00

*Operator 1 – low experience (OP1). Operator 2 – high experience (OP2). For the agility item, the highly experienced operator presented better results for both scanners.

Table 5. Mean time values (seconds) and standard deviation ($\pm$) for procedures according to technique (conventional/digital) and operators.

	Technique	Operator	Mean $\pm$ Standard Deviation
Maxilla and Mandible	Trios 3	OP1	481.1 $\pm$ 140.3Aa
		OP2	232.5 $\pm$ 62.5Ab
	Virtuo Vivo	OP1	517.8 $\pm$ 136.1Ba
		OP2	360.3 $\pm$ 90.4Bb
	Conventional molding	-	464 $\pm$ 11.96B
Maxilla	Trios 3	OP1	216.4 $\pm$ 75.9Ba
		OP2	93.6 $\pm$ 22.5Bb
	Virtuo Vivo	OP1	225.6 $\pm$ 67.1Ba
		OP2	140.8 $\pm$ 41.1Bb
	Conventional molding	-	229 $\pm$ 6.82A
Mandible	Trios 3	OP1	199.1 $\pm$ 60.0Ba
		OP2	101.1 $\pm$ 29.8Bb
	Virtuo Vivo	OP1	216.7 $\pm$ 67.4Ba
		OP2	128.2 $\pm$ 48.0Bb
	Conventional molding	-	234 $\pm$ 7.66A

*Operator 1 – low experience (OP1). Operator 2 – high experience (OP2). Means $\pm$ Standard Deviation followed by different letters in the column, differ statistically by the Tukey test ($p < .001$). Lowercase letters present significant differences for analysis between operators. Uppercase letter present significant differences for analysis between techniques (Trios 3/Virtuo Vivo/ Conventional molding).

Table 6. Mean values for file size of three-dimensional models (gb) and standard deviation ($\pm$).

Scanner x Operator	Maxilla and mandible	Maxilla	Mandible
<i>Trios 3 x OP1</i>	61.74367 $\pm$ 5.89396a	33.27707 $\pm$ 3.96245Aa	28466.60 $\pm$ 2.70149Ba
<i>Trios 3 x OP2</i>	70.28427 $\pm$ 5.80694a	38.10133 $\pm$ 4.31957Aa	32182.93 $\pm$ 2.43447Bb
<i>Virtuo Vivo x OP1</i>	37.97780 $\pm$ 9.58217b	19.62173 $\pm$ 5.13775Ab	18356.07 $\pm$ 4.60328Bb
<i>Virtuo Vivo x OP2</i>	45.59040 $\pm$ 13.60482b	23.55953 $\pm$ 7.19199Ab	22030.87 $\pm$ 6.89463Bb

*Operator 1 – low experience (OP1). Operator 2 – high experience (OP2). Means $\pm$ Standard Deviation followed by different letters in the column differ statistically from each other ($p < .001$). Lowercase letters present significant differences for analysis between scanners. Uppercase letter present significant differences for comparative analysis between maximum and mandible.

Table 7. Mean values for the accuracy of the three-dimensional models (μm) and standard deviation ($\pm$) compared to the digitized reference model (conventional impression).

Scanner x Operator	Maxilla	Mandible
<i>Trios 3 x OP1</i>	14.0 $\pm$ 11.41a	13.5 $\pm$ 14.08a
<i>Trios 3 x OP2</i>	13.5 $\pm$ 12.49a	12.6 $\pm$ 9.48a
<i>Virtuo Vivo x OP1</i>	17.9 $\pm$ 16.13a	16.0 $\pm$ 16.53a
<i>Virtuo Vivo x OP2</i>	15.7 $\pm$ 17.75a	12.9 $\pm$ 11.33a

*Operator 1 – low experience (OP1). Operator 2 – high experience (OP2). No significant differences were detected ($P>.001$).

FIGURAS

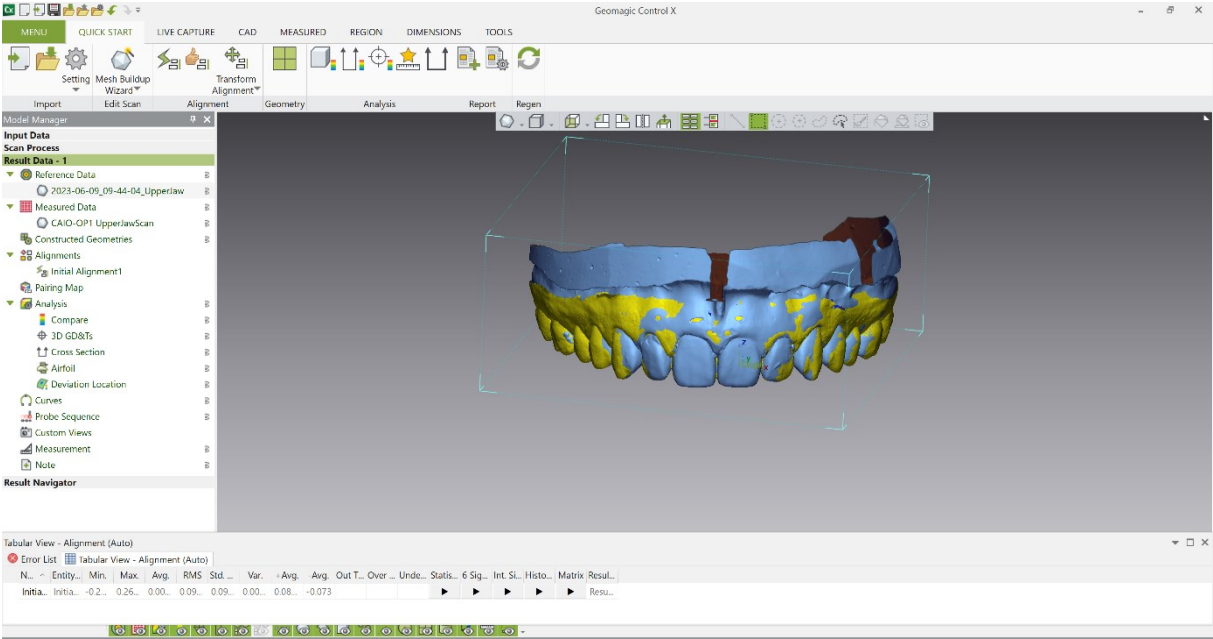


Figure 1. Initial alignment reference caste x test caste Geomagic software.

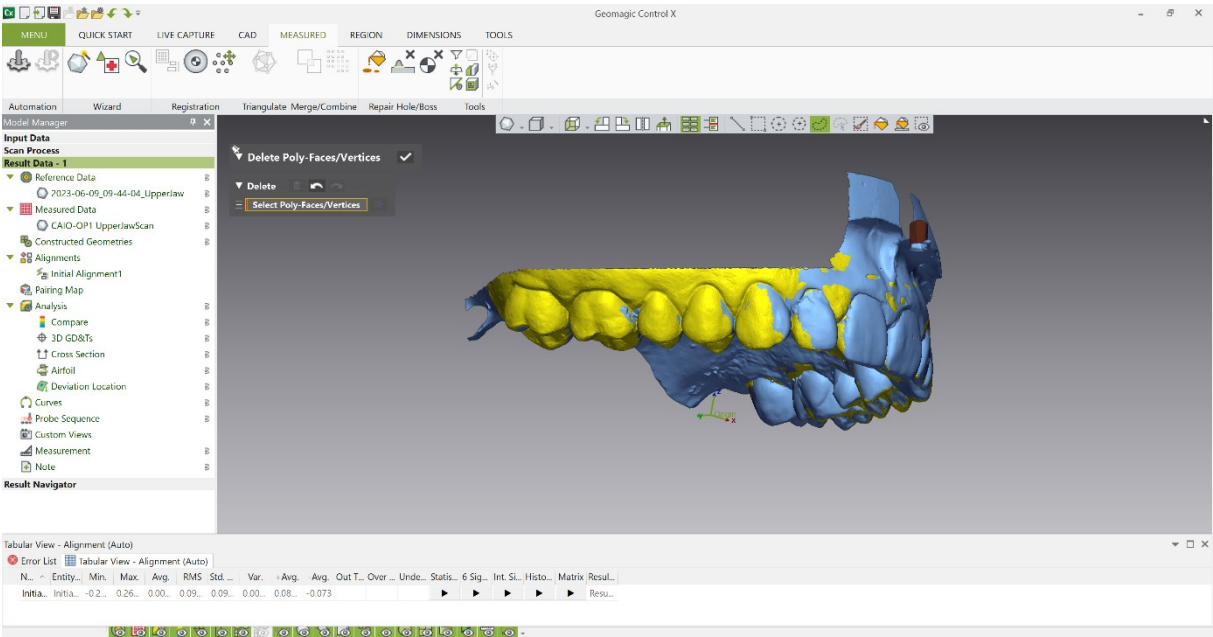


Figure 2. Standardization of three-dimensional castes.

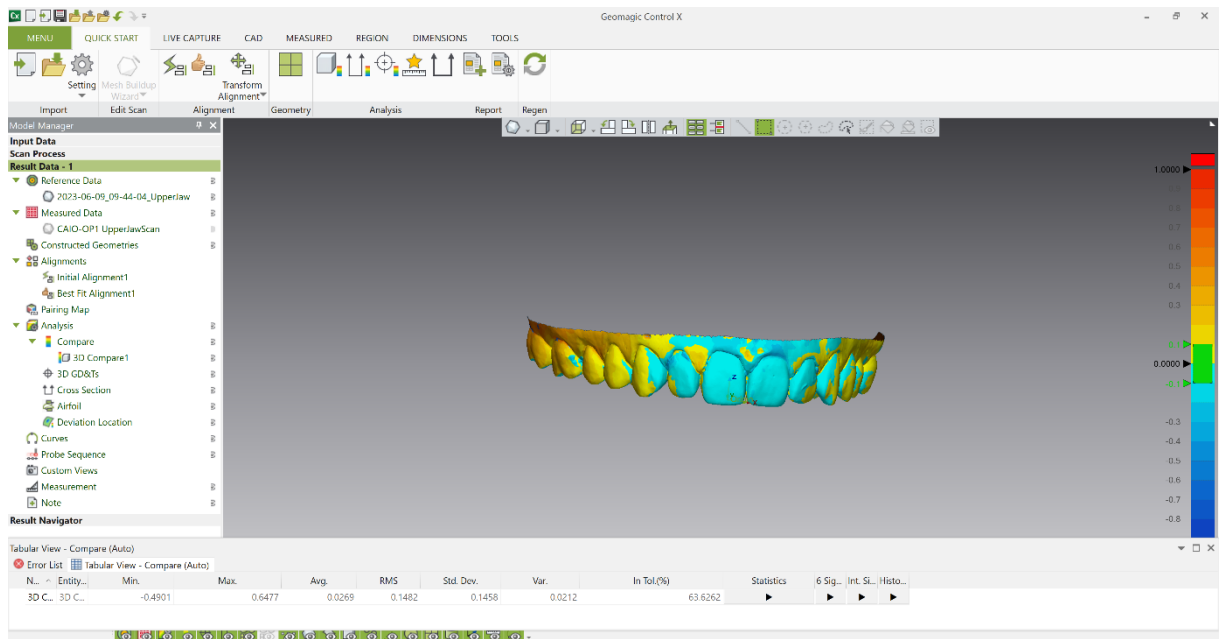


Figure 3. Image after performing the 3D analysis with mean, median and standard deviation values displayed on screen.

Annex I

Pesquisa de satisfação e qualidade de vida de pacientes odontológicos



Marque um X no quadrado da opção escolhida

ETAPA 1: Seu grau de satisfação em relação ao procedimento realizado, equipamento utilizado e operador:					
1 – Escaneamento com <i>scanner</i> 01					
1.1 Conforto	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
1.2 Agilidade	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2 – Escaneamento com <i>scanner</i> 01 e operador 01					
2.1 Conforto	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.2 Agilidade	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3 – Escaneamento com <i>scanner</i> 01 e operador 02					
3.1 Conforto	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.2 Agilidade	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
4 – Escaneamento com <i>scanner</i> 02					
4.1 Conforto	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
4.2 Agilidade	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
5 – Escaneamento com <i>scanner</i> 02 e operador 01					
5.1 Conforto	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
5.2 Agilidade	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
6 – Escaneamento com <i>scanner</i> 02 e operador 02					
6.1 Conforto	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
6.2 Agilidade	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
ETAPA 2: Seu grau de satisfação em relação a moldagem convencional:					
Conforto	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
Agilidade	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
ETAPA 3: Seu grau de satisfação em relação ao meio/técnica de obtenção de modelo (escaneamento intraoral e moldagem convencional):					
Moldagem convencional	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
Escaneamento intraoral	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
ETAPA 4: Comparando os dois métodos de obtenção de modelo, qual você considera mais:					

Confortável	Moldagem ☐	Escaneamento ☐
Ágil	Moldagem ☐	Escaneamento ☐

Qual dessas técnicas você daria preferência caso necessitasse de tratamento odontológico?



4. CONCLUSÃO

Dentro das limitações do presente estudo *in vivo*, podemos concluir:

1. O conforto do paciente foi influenciado pelo tipo de escâner utilizado e pela experiência do operador.
2. A agilidade dos procedimentos foi influenciada pela técnica de obtenção dos modelos, pelo tipo de escâner utilizado e pela experiência do operador.
3. O operador de alta experiência apresentou melhor avaliação em relação ao conforto e agilidade para ambos os escâneres.
4. Os escâneres intraorais apresentaram precisão similar entre si e em relação ao modelo mestre na obtenção de modelos de arco total.
5. O tempo de escaneamento e tamanho dos arquivos gerados variou entre os escâneres utilizados, não afetando, porém, a veracidade dos modelos obtidos.

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