Universidade Federal de Uberlândia

Faculdade de Odontologia

Tiago Augusto Quirino Barbosa

Acurácia dos métodos convencionais e digitais para obtenção de moldagem dentária e impressões 3D

Accuracy of conventional and digital methods to obtaining dental impressions and 3D printing

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, 2019

Tiago Augusto Quirino Barbosa

Acurácia dos métodos convencionais e digitais para obtenção de moldagem dentária e impressões 3D

Accuracy of conventional and digital methods to obtaining dental impressions and 3D printing

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

Orientador: Prof. Dr. Flávio Domingues das Neves

Banca Examinadora:

Prof. Dr. Flávio Domingues das Neves
Prof. Dr. Luís Henrique Araújo Raposo
Prof. Dr. Gustavo Mendonça

Uberlândia, 2019

FICHA CATALOGRÁFICA

Dados Internacionais de Catalogação na Publicação (CIP)
Sistema de Bibliotecas da UFU, MG, Brasil.

B238a
2019

Barbosa, Tiago Augusto Quirino, 1993-
Acurácia dos métodos convencionais e digitais para obtenção de moldagem dentária e impressões 3D [recurso eletrônico] / Tiago Augusto Quirino Barbosa. - 2019.

Orientador: Flávio Domingues das Neves.
Dissertação (mestrado) - Universidade Federal de Uberlândia, Programa de Pós-Graduação em Odontologia.
Modo de acesso: Internet.
Disponível em: http://doi.org/10.14393/ufu.di.2020.3628
Inclui bibliografia.
Inclui ilustrações.

1. Odontologia. I. Neves, Flávio Domingues das, 1965-, (Orient.). II. Universidade Federal de Uberlândia. Programa de Pós-Graduação em Odontologia. III. Título.

CDU: 616.314

Nelson Marcos Ferreira - CRB-6/3074

ATA DA DEFESA

UNIVERSIDADE FEDERAL DE UBERLÂNDIA
Coordenação do Programa de Pós-Graduação em Odontologia
Av. Pará, 1720, Bloco 4L, Anexo B, Sala 35 - Bairro Umuarama, Uberlândia-MG, CEP 38400-902
Telefone: (34) 3225-8115/8108 - www.ppgoufu.com - copod@umuarama.ufu.br

ATA

Ata da defesa de DISSERTAÇÃO DE MESTRADO junto ao Programa de Pós-graduação em Odontologia da Faculdade de Odontologia da Universidade Federal de Uberlândia.

Defesa de: Dissertação de Mestrado - COPOD

Data: 26/02/2019

Discente: **Tiago Augusto Quirino Barbosa (11712ODO023)**

Título do Trabalho: ***Acurácia dos métodos convencionais e digitais para obtenção de moldagem dentária e impressões 3D.***

Área de concentração: Clínica Odontológica Integrada.

Linha de pesquisa: Implantodontia e Prótese sobre Implantes.

Projeto de Pesquisa de vinculação: Implantodontia e Prótese sobre Implantes.

As **quatorze horas** do dia **vinte e seis de fevereiro de 2019** no Anfiteatro do Bloco 4L, Anexo A - sala 23, Campus Umuarama da Universidade Federal de Uberlândia, reuniu-se a Banca Examinadora, designada pelo Colegiado do Programa de Pós-graduação em janeiro de 2019, assim composta: Professores Doutores: Luís Henrique Araújo Raposo (UFU); Gustavo Mendonça (University of Michigan); e o orientador(a) do(a) candidato(a): **Flávio Domingues das Neves.** Ressalta-se que o Prof. Dr. Gustavo Mendonça participou da defesa por meio de web-conferência desde a cidade de Michigan (EUA) e os demais membros da banca e o aluno participaram *in loco*.

Iniciando os trabalhos o(a) presidente da mesa **Dr. Flávio Domingues das Neves** apresentou a Comissão Examinadora e o candidato(a), agradeceu a presença do público, e concedeu ao Discente a palavra para a exposição do seu trabalho. A duração da apresentação do Discente e o tempo de argüição e resposta foram conforme as normas do Programa.

A seguir o senhor(a) presidente concedeu a palavra, pela ordem sucessivamente, aos (às) examinadore (as), que passaram a argüir o(a) candidato(a). Finalizada a argüição, que se desenvolveu dentro dos termos regimentais, a Banca, em sessão secreta, atribuiu os conceitos finais.

Esta defesa de Dissertação de Mestrado é parte dos requisitos necessários à obtenção do título de Mestre. O competente diploma será expedido após cumprimento dos demais requisitos, conforme as normas do Programa, a legislação pertinente e a regulamentação interna da UFU.

Nada mais havendo a tratar foram encerrados os trabalhos às _15__ horas e _50__minutos. Foi lavrada a presente ata que após lida e achada conforme foi assinada eletronicamente pela Banca Examinadora.

sei! assinatura eletrônica — Documento assinado eletronicamente por **Flavio Domingues das Neves**, **Presidente**, em 26/02/2019, às 15:58, conforme horário oficial de Brasília, com fundamento no art. 6º, § 1º, do Decreto nº 8.539, de 8 de outubro de 2015.

sei! assinatura eletrônica — Documento assinado eletronicamente por **Gustavo Mendonca**, **Usuário Externo**, em 26/02/2019, às 15:58, conforme horário oficial de Brasília, com fundamento no art. 6º, § 1º, do Decreto nº 8.539, de 8 de outubro de 2015.

sei! assinatura eletrônica — Documento assinado eletronicamente por **Luis Henrique Araujo Raposo**, **Professor(a) do Magistério Superior**, em 26/02/2019, às 16:00, conforme horário oficial de Brasília, com fundamento no art. 6º, § 1º, do Decreto nº 8.539, de 8 de outubro de 2015.

A autenticidade deste documento pode ser conferida no site https://www.sei.ufu.br/sei/controlador_externo.php?acao=documento_conferir&id_orgao_acesso_externo=0, informando o código verificador **0999415** e o código CRC **F035959C**.

Resumo

Este trabalho teve por objetivo avaliar e comparar a acurácia de modelos digitais gerados por dois escâners intra-orais e avaliar e comparar a acurácia de modelos convencionais e modelos impressos em 3D. No capítulo 1 deste estudo, 25 modelos foram confeccionados e dividios em modelos digitais, modelos impressos em impressoras 3D e modelos de gesso convencional. Para que as amostras pudessem ser construídas, foi utilizado um modelo referência que teve os dentes 16 e 14 preparados para receber uma prótese fixa de 3 elementos. Desta forma, os modelos digitais foram construídos a partir de um operador experiente que utilizou dois diferentes sistemas de escaneamento intra-oral (Cerec Omnicam e Trios 3 Shape) para escanear o modelo referência. Estes modelos digitais foram salvos no formato “surface tessellation language” (STL) e enviados à uma impressora 3D (Zenith D) para que fosse realizada a manufatura. Os modelos de gesso convencionais foram fabricados através da moldagem com material elastomérico do modelo referência e posterior vazamento do molde utilizando gesso com zero de expansão. Para análise da acurácia (precisão e fidelidade) dos modelos, foi utilizado um software (Geomagic Control 2015) capaz de realizar análise de medidas em 3D. Para tanto, todos os modelos físicos, incluindo o modelo referência foram escaneados por um escâner de bancada cujo a acurácia é de 5μm (D2000, 3 Shape) e salvos no formato STL. A análise de fidelidade foi realizada para todos os grupos considerando o arco total, arco parcial e apenas a região do preparo dentário, enquanto a análise da precisão foi realizada considerando o arco total. Para quantificar a fidelidade, os modelos foram comparados com o modelo referência e para quantificar a precisão os modelos foram comparados entre si. A distribuição de dados e a igualdade de variâncias foram analisadas pelos testes de Shapiro-Wilk e Levene, respectivamente. O teste one-way ANOVA foi aplicado para as comparações da precisão dos scanners e o teste two-way ANOVA para a avaliação da veracidade, seguido do teste de Tukey para identificar onde havia diferenças entre os grupos. Todos os testes foram realizados com nível de significância de 5%. Não foi observado diferença estatística para precisão e fidelidade entre os sistemas de escaneamento intra-oral. Os modelos impressos apresentaram piores resultados para fidelidade quando analisado arco total e estatisticamente diferente dos modelos de gesso. Por outro lado, para precisão do arco completo o gesso apresentou resultado semelhante ao Trios 3 Shape e diferente do Cerec Omnicam. Sendo assim, os dois sistemas de escaneamento apresentaram acurácia semelhante e os modelos de gesso apresentaram melhores resultados que os modelos impressos para fidelidade quando analisado arco total, mas estatisticamente semelhante quando analisado arco parcial e região de preparo.

Palavra chave

Escâner intra-oral; Impressoras 3D; Moldagem; Modelo digital; Modelo convencional; Acurácia

Abstract

This work aimed to evaluate and compare the accuracy of digital models generated by two intraoral scanners and to evaluate and compare the accuracy of conventional models and 3D printed models. In Chapter 1 of this study, 25 models were made and divided into digital models, 3D printed models and conventional gypsum models. To obtain the samples, a reference model was used that had the teeth 16 and 14 prepared to receive a fixed partial prosthesis. In this way, the digital models were constructed from an experienced operator who used two different intra-oral scanning systems (Cerec Omnicam and Trios 3 Shape) to scan the reference model. These digital models were saved in the "surface tessellation language" (STL) format and sent to a 3D printer (Zenith D) for manufacturing. The conventional gypsum models were manufactured by impression with elastomeric material of the reference model. In order to analyze the accuracy (trueness and precision) of the models, a software (Geomagic Control 2015) was used. Therefore, all physical models, including the reference model, were scanned by an extra oral scanner whose accuracy is 5μm (D2000, 3 Shape) and saved in the STL format. The trueness analysis was performed for all groups considering the complete arch, partial arch and only the tooth preparation area, while the precision analysis was performed considering the complete arch. To measure the trueness, the models were compared with the reference model and to measure the precision the models were compared to each other. Data distribution and equality of variances were analyzed by the Shapiro-Wilk and Levene tests, respectively. One-way ANOVA test was applied to the comparisons of the precision of the scanners, and the two-way ANOVA test for the trueness evaluation, followed by the Tukey test to identify where there were differences between the groups. All tests were performed with a significance level of 5%. No significant intergroup differences in trueness and precision were observed for the two intra oral scanners. 3D printed casts had the lowest trueness when complete arch was analyzed and differs statistically from the stone cast. On the other hand, for complete arch precision, stone cast presented better results, however statistically different only from the Cerec Omnicam.Thus, the two intraoral scanner systems had similar accuracy. Stone casts had higher trueness than 3D printed casts for complete arch, but similar results for partial arch and teeth prepared area. For complete arch precision, 3D printed cast may present similar results to the stone cast.

Key Words: Intraoral scanner; 3D printer; Impression; digital cast; conventional cast; accuracy

Introdução e Referencial teórico

O desenvolvimento e utilização do sistema CAI/CAD/CAM (Computer-Aided imagining/Computer-Aided Design/Computer-Aided Manufacturing) na odontologia propiciou oportunidades ao cirurgião dentista de apresentar soluções rápidas e eficazes para diferentes cenários da prótesse e implantodontia (Kapos et al., 2014). Essa tecnologia permite ao operador a confecção de restaurações protéticas através do conjunto escâner associado a um software de desenho (CAD) , como também, a manufatura através de fresadoras ou impressoras (CAM).

Embora este sistema CAD/CAM esteja disponível a mais de 20 anos (Marchack CB, 1996), o aperfeiçoamento e aprimoramento desta tecnologia foi intensificada a partir dos anos 2000. Este sistema também conhecido como fluxo digital facilita a prática clínica, reduzindo alguns passos e simplificando procedimentos laboratoriais (Kapos et al., 2014). O procedimento se torna mais conveniente tanto para o dentista quanto para o paciente, pela possibilidade de se realizar múltiplos escaneamentos e analisar a imagem em tempo real, além de evitar algumas situações desagradáveis que podem acontecer com os pacientes em moldagens convencionais como: risco de sufocar e engasgar, ânsia de vomito e gostos desagradáveis. (Joda et al., 2014; Morton et al., 2014).

Diversos recursos modernos foram incorporados e têm mostrado resultados promissores (de França et al., 2015). O Computer-Aided imagining/Computer-Aided Design/Computer-Aided Manufacturing (CAI/CAD/CAM) é um sistema que possibilita a obtenção de restaurações, pilares personalizados, modelos odontológicos de maneira digital e tem conquistado cada vez mais o seu espaço dentro das diversas áreas da odontologia, dentre elas, a odontologia restauradora (Neves et al. 2014a, 2014b, 2015, carneiro et al., 2016).

Para obter restaurações, modelos ou ainda pilares personalizados confeccionados por meio dessa tecnologia são necessárias três etapas. A primeira etapa é a aquisição de dados, realizada por meio do escaneamento diretamente na boca do paciente. A segunda etapa é o processamento dos dados, realizado por meio de um software, no qual um projeto virtual da estrutura é obtido. Essa etapa consiste no desenho e planejamento do trabalho no software do computador. As duas primeiras etapas (aquisição e processamento dos dados) constituem o CAD. A manufatura constitui a terceira etapa, denominada CAM. A partir do projeto executado, os dados são enviados para impressora que executará o processo de manufatura da estrutura.

A sociedade Americana para testes e materiais definiiu como manufatura aditiva um processo de unir materiais para construir objetos a partir de dados 3D, geralmente camada sobre camada, ao contrário dos métodos de manufatura subtrativas (Alcisto J, 2011). Foram determinadas sete categorias de manufatura aditiva, no entanto a mais empregada dentro da odontologia consiste na cuba de polimerização.

Uma impressora 3D com base no método de cuba fotopolimerização tem um recipiente cheio com resina de fotopolímero que é então endurecido com uma fonte de luz UV. A tecnologia mais utilizada neste processo é estereolitografia (SLA) . Esta tecnologia emprega uma cuba de resina que é curável por raios ultravioleta. Um laser ultravioleta constrói cada camada do objeto uma de cada vez fazendo a cura do fotopolímero líquido.

O objetivo deste trabalho é avaliar e comparar a acurácia de modelos digitais gerados por dois escâneres intra-orais e avaliar e comparar a acurácia de modelos convencionais e modelos impressos em 3D.

Capítulo 1

Federal University of Uberlândia

Graduate School of Clinical Dentistry

Accuracy of conventional and digital methods to obtaining dental impressions and 3D printing

Tiago Augusto Quirino Barbosa[a]

Caio César Dias Resende[b]

Guilherme Faria Moura[b]

Lucas do Nascimento Tavares[b]

Fabio Antonio Piola Rizzante[c]

Gustavo Mendonça[d]

Flávio Domingues das Neves[e]

[a]Master's Degree student, Graduate School of Clinical Dentistry, Federal University of Uberlandia, Minas Gerais, Brazil

[b]PhD student, Graduate School of Clinical Dentistry, Federal University of Uberlandia, Minas Gerais, Brazil

[c]Assistant Professor, Department of Comprehensive Care, School of Dental Medicine, Case Western Reserve University, Cleveland, OH, USA

[d]Associate Clinical Professor, Department of Biologic and Material Sciences, Division of Prosthodontics, Ann Arbor, MI, USA

[e]Professor, Department of Occlusion, Fixed Prostheses, and Dental Materials, School of Dentistry, Federal University of Uberlândia, Minas Gerais, Brazil

Acknowledgments

The authors thank CAPES, CNPq, FAPEMIG, CPBio and University of Michigan

Abstract:

Statement of problem: Little peer-reviewed information is available regarding the accuracy of digitally fabricated casts compared to conventional methods.

Purpose: The purpose of this study was to evaluate and compare the accuracy of two intraoral scanners and conventional impression methods for the fabrication of working casts.

Material and methods: Conventional impressions of a reference cast (typodont) were obtained using light- and heavy-body addition silicone/PVS,and poured with dental stone. Digital impressions were obtained with two different digital scanners: Cerec Ominicam (CO) and 3Shape Trios (ST). The obtained digital stereolithographic casts were printed on Zenith D 3D printer (Zenith D, Zenith). The reference cast and fabricated casts were scanned with an extra oral scanner (D200, 3Shape), and saved in surface tessellation language/STL format. All STL records were analyzed in a specific software (Geomagic Control 2015) in three different sizes: complete arch (CA), partially arch (PA) and prepared teeth area (PT). The digital impression, stone cast and 3D printed cast were compared with the reference cast for trueness and compared files for each group for precision. One-way and two-way analyses of variance (ANOVA) were performed to compare the accuracy, followed by the Tukey test. All tests were performed with a significance level of 5%.

Results: No significant intergroup differences in trueness and precision were observed for the two intra oral scanners. 3D printed casts had the lowest trueness when complete arch was analyzed and differs statistically from the stone cast. On the other hand, for complete arch precision, stone cast presented better results, however statistically different only from the CO.

Conclusions: The two intraoral scanner systems had similar accuracy. Stone casts had higher trueness than 3D printed casts for CA, but similar results for PA and PT. For CA precision, 3D printed cast may present similar results to the stone cast.

Key Words: Intraoral scanner; digital impression; stereolithography; dental casts; accuracy; precision; trueness.

Clinical Implications

Digital impression and 3D printed cast fabrication methods are becoming increasingly more accurate. In some situations, they may present similar or better results than conventional casts being an interesting option to conventional/analogic methods.

Introduction

Dental impressions consist in an important step in restorative dentistry, it allows to transfer the intraoral situation to an extraoral cast. The accuracy of the cast influences in the restoration fit, an important factor that may affect in the longevity of the final restorations.[1-3] Currently, elastomeric impressions with custom or stock trays are considered as gold standard, resulting in a physical gypsum cast (conventional impression)[4] However, the development of CAI/CAD/CAM (computer Aided-Imaging/Computer Aided design/ Computer Aided-manufacturing) is becoming increasingly popular, offering a digital workflow, such as: 3D planning, crowns and 3D printed casts.[5]

The workflow for fabricating an implant-supported prosthesis or fixed dental prosthesis could be entirely digital. This method uses an intraoral scanner directly in-patient mouth to capture the digital impression that can be also be combined with traditional laboratory procedures, scanning extra orally a conventional cast (indirect technique).[5,6]

The American Society for Testing and Materials (ASTM) has defined additive manufacturing (AM) as “a process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies”.[7] The ASTM international committee on AM technologies has determined 7 AM categories. The stereolithography is a method used for manufacturing dental casts.[8-11] It is based on a 3D CAD design, transferred to a rapid prototyping machine which turns the polymer into a solid object through the repeated solidification of liquid resin through a UV laser (US Patent 4575330 1986).[12-14] Many advantages, such as easy copying, small volume, small size, and low material cost, the possibility to prepare rapid prototypes and trial restorations has been described for this procedure.

Few studies are available assessing the accuracy of dental impression and 3D printed casts produced by digital scans. Accuracy describes closeness to the real dimensions of the object and consists of precision and trueness (ISO 5725-1).[15] Precision describes how close repeated measurements are to each other.[16] Trueness describes how far the measurement deviates from the actual dimensions of the measured object.[16] A high trueness delivers how close or equal to the actual dimensions of the measured object is. To evaluate the accuracy, 3D software has been used (Geomagic Control, 3D system).[17-20]

It is not clear if 3D printer dental casts present similar accuracy of conventional dental casts for prosthesis rehabilitation. Therefore, the purpose of this study was to evaluate and compare the accuracy conventional models based on PVS impressions and 3D printed models using different intraoral scanners. Two null hypotheses will be tested:: 1) There would not be statistical differences in the accuracy of scanners 2) There would not be statistical difference in the accuracy of manufactured casts.

Material and methods

A reference cast with two prepared teeth (first superior premolar and first superior molar right side) to receive a fixed partial prosthesis was used. A sequence of diamond burns (KG Sorensen, Barueri, SP, Brazil) was used to teeth prepare. The tooth preparation was defined with rounded angles and axial walls with 6-degree convergence to the occlusal surface. The margins were prepared in deep bevel with rounded axiogingival angles.

For control group, CG (n=5), conventional impressions using light and heavy body PVS impression were performed (Silagum, DMG, Hamburg, Germany) using the reference cast, and five stone casts were poured (Zero stone, Dentona, *Dortmund* Germany) following the manufacturer's instructions. For the test groups, the reference cast was scanned five times with each of the two intraoral scanners CEREC Ominicam (Dentsply Sirona), CO (n=5) and 3Shape TRIOS (3Shape North America), ST (n=5). All scans were performed by a single trained investigator with over six years of experience.

The digital casts were converted into surface tessellation language (STL) format and sent to manufacture the printed casts with the Zenith D 3D printer (Zenith D, Zenith, Dong-gu, Daegu, Korea). This system is a vat SLA 3D printer with a variable layer thickness from 50 and 100 μm controlled by software. For the present study, 50μm was adopted.

Measuring the accuracy of casts created by conventional elastomeric impression and/or 3D workflow/3D printing is possible with sophisticated 3D software Geomatic Control, manufacturer, which uses best-fit mathematical algorithms to overlap the digital files and objectively measure variances across the entire casts.

Using the software, each impression file was divided and compared in three different sizes: complete arch (CA), partially arch (PA) and prepared teeth area (PT) (Figure 1). To ensure a precise superimposition, irrelevant areas such as below the mucogingival junction and beyond the field of interest were removed.

An extra oral scanner with high precision (3Shape, D2000) was used to obtain 3D reference data of reference cast, stone casts and 3D printed casts. To measure the trueness of scanners, the STL files used to print the casts (5 CO and 5 ST) were compared to the STL file of the reference cast scanned by D2000 extra oral scanner. First CA, complete arch analysis was done, then for PA, the right hemiarch was cut out for analysis and finally the PT area was isolated and analyzed. After each analysis, a new alignment was performed to the reference dataset using the built-in best-fit algorithm. In addition, precision was assessed based after overlapping all the STL files (only for CA) for each group (1x2, 1x3, 1x4, 1x5, 2x3, etc).

To measure the trueness of stone and printed casts, all models were scanned by D2000 extra oral scanner (D2000, 3Shape), transformed into an STL file and calculated by overlapping all the data from each group with the reference data (reference model scanned with the D2000 extra oral scanner), as mentioned above. As well as to evaluate trueness the same protocol describe for CA, PA and PT analyses were performed. The precision was obtained based on the overlap of the CA data within each group.

The differences between reference and test casts were illustrated in a color-coded map (Figure 2). The green areas represent perfectly matching surfaces, the red areas represent positive deviations from the reference cast and the blue areas represent negative differences between the test and the reference casts.

Data distribution and equality of variances were analyzed by the Shapiro-Wilk and Levene tests, respectively. One-way ANOVA test was applied to the comparisons of the precision of the scanners, and the two-way ANOVA test for the trueness evaluation, followed by the Tukey test to identify where there were differences between the groups. All tests were performed with a significance level of 5%.

Results:

Mean and standard deviations for the accuracy of tested scanners are shown in Tables 1 and 2 and statistical data on the accuracy of 3D printer cast is shown in tables 3 and 4. Absolute values were used to assess the differences between the scans because absolute values do not attribute positive or negative values when comparing a scan with the reference.

Table 1: The data comparing the STL files generated by each scanner with the STL file of the reference cast generated by the Scanner D2000 is presented. A comparative evaluation between the two systems shows that there was no statistical difference between the groups. In the intra-group analysis, comparing the trueness of the CA, PA and PT, it was observed that there was no statistical difference for the ST, whereas in the CO a statistical difference was observed between total arch and prepared teeth.

Table 1 **–** Scanners trueness: Comparison with the STL file of reference cast scanned on D2000

Dental cast method	**Complete arch** μm	**Partial arch** μm	**Prepared teeth** μm
Trios	172.0 Aa	150.4 Aa	142.2 Aa
Omnicam	161.2 Ba	126.4 ABa	91.6 Aa

* Different letter means significant difference calculated by Tukey HSD test (P < .005).

Table 2: In this table is presented the precision data of the STL files generated by the Omnicam and Trios scanner. It was verified that the scanners presented no statistical difference between them.

Table 2. Scanners precision: Comparison of original scans files (pre-print) with each other.

Dental cast method	**Accuracy of complete arch** μm	**Tukey's ranking**
Trios	31.94 ± 22.0	***a***
Omnicam	32.29 ± 10.0	***a***

* Different letter means significant difference calculated by Tukey HSD test (P < .005).

Table 3: The trueness data of the digital casts printed by the 3D printer and stone is presented. For CA, the stone cast presented a statistically superior result to the digital casts. For PA the stone cast were statistically similar to the omnicam system and different from the trios system. For PT, there was no statistical difference between the 3 groups. In the intra group comparison, the stone cast showed no statistical difference. For both scanning systems, no statistical difference was observed between PA and PT, however, these were statistically superior to the CA.

***Table 3* –** Cast trueness: Comparison of the stl file of the printed models and stone obtained by the D2000 with the stl file of the reference model

Dental cast method	**Complete arch** μm	**Partial arch** μm	**Prepared teeth** μm
Trios	230.13 Bb	153.2 Ab	124.2 Ab
Omnicam	184.55 Bb	111.8 Aab	76.0 Aa
Stone	87.0 Aa	87.0 Aa	80.87 Aab

* Different letter means significant difference calculated by Tukey HSD test (P < .005).

Table 4: The precision data of the casts printed by the 3D printer is shown. The stone cast presented better results, however statistically different only from the omnicam system.

Table 4 – Cast precision: Comparison of the stl file of the printed cast and stone obtained by the D2000 with each other.

Dental cast method	**Accuracy of complete arch** µm	**Tukey's ranking**
Omnicam	89.1± 23.0	***b***
Trios	66.35± 16.0	***ab***
Stone	60.15± 9.0	***a***

* Different letter means significant difference calculated by Tukey HSD test (P < .005).

Discussion:

The present study investigated the accuracy of two different scanners and respectively 3D printed casts, as well as the accuracy of a conventional impression technique. Based on the results of this study, the first null hypotheses were accepted because no significant differences were found among the accuracy of the scanners. The second null hypotheses were rejected because significant differences were found among the accuracy of conventional manufactured cast and 3D printed casts.

The CO scanner is a powder-free, color video speed scanning system. It uses active triangulation and emits white light to measure surfaces and is based on video technology that captures the anatomy and color of the oral tissues with a broad focal depth camera.[21,22] The ST scanner is based on confocal microscopy capturing multiple images in a very short time.[21-23]

Even if there is a difference in the acquisition mechanism there is no difference between the two evaluated scanners. The present study showed difference just when compared ca against pt in the co group.

When the deviation patterns were evaluated from the color map, the CO tended to produce images that had higher deviations in the molar region and the phenomenon of arch expansion at the posterior region is more likely to occur[23] (Figure 2). Besides that, ST group presented images a little bit thinner on posterior areas.

Three-dimensional printed models obtained using an intraoral scanner can eliminate the use for a conventional impression and model fabrication. There are several advantages, such as the permanent storage of data, and reduction of patient discomfort associated with the use of impression materials[22,24]. Furthermore, physical casts can be created based on datasets obtained by an intraoral scanner using either milling or a 3D printer.

In this study we used the 3D printer of the stereolithography category (Zenith). This printer is based on technology by digital light processing (DLP) 3D printing. DLP 3D printers use a digital projector screen to flash a single image of each layer across the entire platform at once. Because the projector is a digital screen, the image of each layer is composed of square pixels, resulting in a layer formed from small rectangular bricks called voxels.

Comparing the three groups by using complete arch, the trueness of the stone cast was significantly better than 3D printed. On the other hand, in these small areas of the dental arch, 3D printed casts presented high accuracy and no statistical difference with conventional stone models. In other words, the digital method is compatible with conventional methods in terms of prepared teeth surface accuracy. Because prepared teeth surface accuracy is critical for fitting of fixed prosthodontic restorations, digital impression and cast fabrication could be a useful method for achieving adequate internal fit and marginal gap

DLP printing can achieve faster print times for some parts, as each entire layer is exposed all at once, rather than drawn out with a laser. Though faster, printing full volume with DLP 3D printers introduce tradeoffs in resolution and surface finish, whether with large parts or sets of many smaller, finely detailed parts

For printed and stone casts precision analysis, both printed casts presented worse results compared to the stone cast, however just the group CO against the group CG presented statistical difference.

In the spite of having statistical difference between the manufactory methods, all the models presented a acceptable clinical values.

Conclusion:

Within the limitations of this in vitro study, the following conclusions were drawn:

1)The two intraoral scanner systems had no significant differ in trueness and precision.

2)3D printer cast presented lowest trueness than conventional manufactured cast when analyzed complete arch, but similar results for PA and PT. Therefore, cautious clinical use for complete arch models is suggested

References:

Referências:

1. Perakis N, Belser U, Magne P. Final impressions: a review of material properties and description of a current technique. Int J Periodontics Restorative Dent 2004;24:109-17.
2. Wettstein F, Sailer I, Roos M, Hammerle C. Clinical study of the internal gaps of zirconia and metal frameworks for fixed partial dentures. Eur J Oral Sci 2008;116:272-9. https://doi.org/10.1111/j.1600-0722.2008.00527.x
3. Persson A, Oden A, Andersson M, Sandborgh- Englund G. Digitization of simulated clinical dental impressions: virtual threedimensional analysis of exactness. Dent Mater 2009;25:929-36. https://doi.org/10.1016/j.dental.2009.01.100
4. Ragain JC, Grosko ML, Raj M, Ryan TN, Johnston WM. Detail reproduction, contact angles, and die hardness of elastomeric impression and gypsum die material combinations. Int J Prosthodont 2000;13:214-20.
5. Guth JF, Keul C, Stimmelmayr M, Beuer F, Edelhoff D. Accuracy of digital models obtained by direct and indirect technique data capturing. Clin Oral Investig 2013;17:1201-8. https://doi.org/10.1007/s00784-012-0795-0
6. Van der Meer WJ, Andriessen FS, Wismeijer D, Ren Y. Application of intraoral dental scanners in the digital workflow of implantology. PLoS One 2012;7:e43312. https://doi.org/10.1371/journal.pone.0043312
7. Alcisto J, Enriquez A, Garcia H, Hinkson S, Steelman T, Silverman E, et al. Tensile properties and microstructures of laser-formed Ti-6Al-4V. J Mater Eng Perform 2011;20:203-212. https://doi.org/10.1007/s11665-010-9670-9

8. Fleming PS, Marinho V, Johal A. Orthodontic measurements on digital study models compared with plaster models: a systematic review. Orthod Craniofac Res 2011;14:1-16. https://doi.org/10.1111/j.1601-6343.2010.01503.x
9. Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi CL. Diagnostic accuracy and measurement sensitivity of digital models for orthodontic purposes: a systematic review. Am J Orthod Dentofacial Orthop 2016;149:161-170. https://doi.org/10.1016/j.ajodo.2015.06.029
10. Stansbury JW, Idacavage MJ. 3D printing with polymers: Challenges among expanding options and opportunities. Dent Mater 2016;32:54-64. https://doi.org/10.1016/j.dental.2015.09.018
11. Torabi K, Farjood E, Hamedani S. Rapid prototyping technologies and their applications in prosthodontics, a review of literature. J Dent 2015;16:1-9.
12. Apparatus for production of three-dimensional objects by stereolithography. US Patent 4575330; 1986
13. Jacobs PF: Rapid Prototyping and Manufacturing: Fundamentals of Sterolithography (ed 1). Dearborn, MI, Society of Manufacturing Engineers, 1992, pp. 49-61
14. Horn TJ, Harrysson OL. Overview of current additive manufacturing technologies and selected applications. Sci Prog 2012;95:255-282. https://doi.org/10.3184/003685012X13420984463047
15. 15 DIN Deutsches Institut fur Normung. Accuracy (trueness and precision) of measurement methods and results -- Part 1: General principles and definitions (ISO 5725-1:1994). Berlin: Beuth Verlag
16. Ziegler M. Digital impression taking with reproducibly high precision. Int J Comput Dent 2009;12:159-63.

17. Rhee YK, Huh YH, Cho LR, Park CJ. Comparison of intraoral scanning and conventional impression techniques using 3-dimensional superimposition. J Adv Prosthodont 2015;7:460-7. https://doi.org/10.4047/jap.2015.7.6.460

18. Mangano FG, Veronesi G, Hauschild U, Mijiritsky E, Mangano C. Trueness and Precision of Four Intraoral Scanners in Oral Implantology: A Comparative in Vitro Study. PLoS One 2016;11(9): e0163107. https://doi.org/10.1371/journal.pone.0163107

19. Cho SH, Schaefer O, Thompson GA, Guentsch A. Comparison of accuracy and reproducibility of casts made by digital and conventional methods. J Prosthet Dent. 2015;113(4):310-5. https://doi.org/10.1016/j.prosdent.2014.09.027

20. Jeong ID, Lee JJ, Jeon JH, Kim JH, Kim HY, Kim WC. Accuracy of complete-arch model using an intraoral video scanner: An in vitro study. J Prosthet Dent. 2016;115(6):755-9. https://doi.org/10.1016/j.prosdent.2015.11.007

21. Hack GD, Sebastian B, Patzelt M. Evaluation of the accuracy of six intraoral scanning devices: An in-vitro investigation. ADA Professional Product Review 2015;10:1-5.

22. Patzelt S, Emmanouilidi A, Stampf S, Strub J, Att W. Accuracy of full-arch scans using intraoral scanners. Clin Oral Invest 2013;18:1687-94. https://doi.org/10.1007/s00784-013-1132-y

23. Ender A, Zimmerman M, Attin T, Mehl A. In vivo precision of conventional and digital methods for obtaining quadrant dental impressions. Clin Oral Invest 2016;7:1495-504. https://doi.org/10.1007/s00784-015-1641-y

24. Birnbaum NS, Aronson HB, Stevens C, Cohen B. 3D digital scanners: a high-tech approach to more accurate dental impressions. Inside Dent 2009;5:70–4.

Figures:

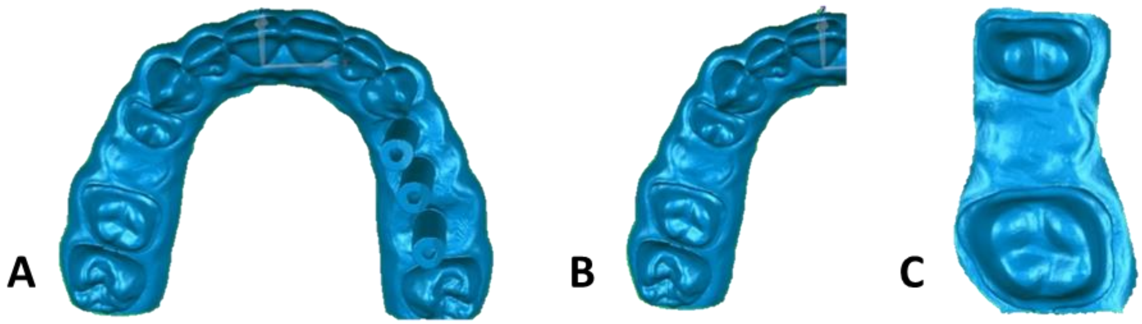

Fig. 1. A) Complete arch; B) Partially arch; C) Prepared teeth area

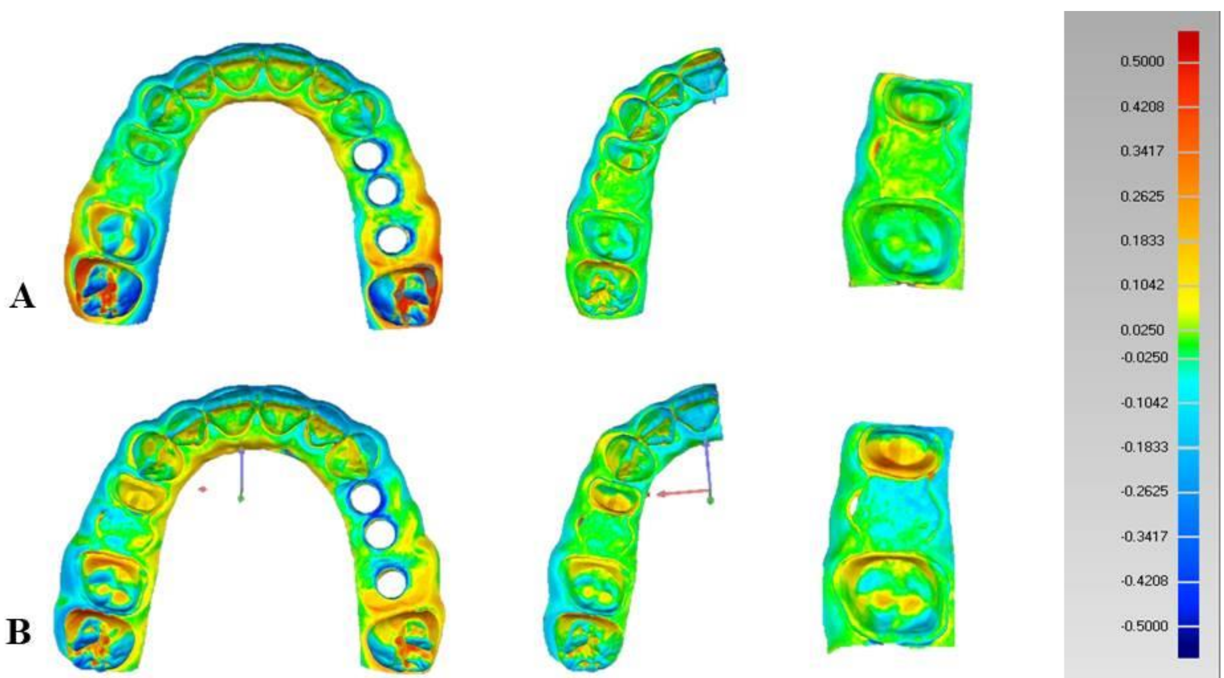

Fig. 2. Color-coded map. Images of the 3D analysis comparing the 3D printed cast Ominicam (A) and Trios (B) with the reference cast.

Referências bibliográficas:

- Kapos T, Evans C. CAD/CAM technology for implant abutments, crowns, and superstructures. Int J Oral Maxillofac Implants. 2014;29 Suppl:117-36. https://doi.org/10.11607/jomi.2014suppl.g2.3

- Marchack CB. A custom titanium abutment for the anterior single-tooth implant.J Prosthet Dent. 1996 Sep;76(3):288-91 https://doi.org/10.1016/S0022-3913(96)90173-0

- Joda T, Wittneben JG, Brägger U. Digital implant impressions with the "Individualized Scanbody Technique" for emergence profile support. Clin Oral Implants Res. 2014 Mar;25(3):395-397. https://doi.org/10.1111/clr.12099

- de França DG, Morais MH, das Neves FD, Barbosa GA. Influence of CAD/CAM on the fit accuracy of implant-supported zirconia and cobalt-chromium fixed dental prostheses. J Prosthet Dent. 2015; 113(1):22-28. https://doi.org/10.1016/j.prosdent.2014.07.010

- Neves FD, Prado CJ, Prudente MS, Carneiro TA, Zancopé K, Davi LR, et al. Micro-computed tomography evaluation of marginal fit of lithium disilicate crowns fabricated by using chairside CAD/CAM systems or the heat-pressing technique. J Prosthet Dent 2014a;112:1134-1140. https://doi.org/10.1016/j.prosdent.2014.04.028

- das Neves FD, de Almeida Prado Naves Carneiro T, do Prado CJ, Prudente MS, Zancopé K, Davi LR, et al. Micrometric precision of prosthetic dental crowns obtained by optical scanning and computer-aided designing/computer-aided manufacturing system. J Biomed Opt 2014b;19:088003. https://doi.org/10.1117/1.JBO.19.8.088003

- das Neves FD, do Prado CJ, Prudente MS, Carneiro TA, Zancope K, DaviLR, et al. Microcomputed tomography marginal fit evaluation of computer-aided design/computer-aided manufacturing crowns with different methods of virtual model acquisition. Gen Dent 2015;63:39-42.

- Carneiro TAPN, Prado CJ, Prudente MS, Zancope K, Davi LR, Mendonca G, Cooper LF, Soares CJ, Neves FD. Micro CT analysis of in-office computer aided designed / computer aided manufactured dental restorations. Computer Methods in Biomechanics and Biomedical Engineering: Imaging & Visualization, 2016. https://doi.org/10.1080/21681163.2016.1165146

- Morton D, Chen ST, Martin WC, Levine RA, Buser D. Consensus statements and recommended clinical procedures regarding optimizing esthetic outcomes in implant dentistry. Int J Oral Maxillofac Implants. 2014;29 Suppl:216-20. https://doi.org/10.11607/jomi.2013.g3

- Alcisto J, Enriquez A, Garcia H, Hinkson S, Steelman T, Silverman E, et al. Tensile properties and microstructures of laser-formed Ti-6Al-4V. J Mater Eng Perform 2011;20:203-212. https://doi.org/10.1007/s11665-010-9670-9