Universidade Federal de Uberlândia

Faculdade de Odontologia

Thiago de Almeida Prado Naves Carneiro

Avaliação da adaptação marginal de diferentes tipos de restaurações obtidas por CAD/CAM e métodos convencionais.

Tese apresentada ao Programa de Pós-Graduação em Odontologia da Faculdade de Odontologia da Universidade Federal de Uberlândia, como parte dos requisitos para obtenção do título de Doutor em Odontologia, Área de concentração em Clínica Odontológica.

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Orientador: Prof. Dr. Flávio Domingues das Neves

Banca examinadora:

Prof. Dr. Flávio Domingues das Neves

Prof. Dr. Alfredo Júlio Fernandes Neto

Prof. Dr. Paulo Cezar Simamoto-Junior

Prof. Dr. Eduardo Miyashita

Prof. Dr. Gustavo Mendonça

Uberlândia, 2016

SERVIÇO PÚBLICO FEDERAL
MINISTÉRIO DA EDUCAÇÃO
UNIVERSIDADE FEDERAL DE UBERLÂNDIA
FACULDADE DE ODONTOLOGIA
PROGRAMA DE PÓS-GRADUAÇÃO EM ODONTOLOGIA

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

Defesa de: Tese de Doutorado nº 015 - COPOD
Data: 29/04/2016
Discente: Thiago de Almeida Prado Naves Carneiro; Matrícula: (11313ODO012)
Título do Trabalho: Avaliação da adaptação marginal de diferentes tipos de restaurações obtidas por CAD/CAM e métodos convencionais.
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 nove de abril do ano de 2016** no Anfiteatro 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 2016, assim composta: Professores Doutores: Alfredo Júlio Fernandes Neto (UFU); Paulo Cézar Simamoto Júnior (UFU); Eduardo Miyashita (UNIP); Gustavo Mendonça (University of Michigan); Flávio Domingues das Neves (UFU) orientador(a) do(a) candidato(a) **Thiago de Almeida Prado Naves Carneiro.**

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(a)(s), que passaram a argüir o(a) candidato(a). Ultimada a argüição, que se desenvolveu dentro dos termos regimentais, a Banca, em sessão secreta, atribuiu os conceitos finais.

Em face do resultado obtido, a Banca Examinadora considerou o(a) candidato(a) Aprovado(a).

Esta defesa de Tese de Doutorado é parte dos requisitos necessários à obtenção do título de Doutor. 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 19 horas e 10 minutos. Foi lavrada a presente ata que após lida e achada conforme foi assinada pela Banca Examinadora.

Prof. Dr. Eduardo Miyashita – UNIP

Prof. Dr. Gustavo Mendonça – University of Michigan

Prof. Dr. Alfredo Júlio Fernandes Neto – UFU

Prof. Dr. Paulo Cézar Simamoto Júnior – UFU

Prof. Dr. Flávio Domingues das Neves – UFU
Orientador(a)

EPÍGRAFE

"Cerque-se com algumas das melhores mentes em seu campo, você é obrigado a ter sucesso. "

Per-Ingvar Brånemark

DEDICATÓRIA

A **DEUS**

Por ter me concedido a vida e ter me conduzido até aqui debaixo de seus cuidados

Por ser a minha dianteira e a minha retaguarda

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SUMÁRIO

RESUMO:

As últimas décadas trouxeram muitas mudanças para a prática clínica odontológica e a tecnologia tem sido cada vez mais inserida no mercado. O resultado de um tratamento reabilitador satisfatório depende basicamente do equilíbrio entre os fatores biológicos e mecânicos. A adaptação marginal de coroas e/ou estruturas protéticas é fator vital para o sucesso em longo prazo. O desenvolvimento da tecnologia CAD/CAM na fabricação de próteses dentárias revolucionou a odontologia, esta tecnologia consiste na obtenção de um modelo virtual a partir do escaneamento digital direto na boca, modelos ou moldes, possibilitando o desenho e planejamento da estrutura em um *software* no computador e a partir do projeto, a obtenção de peças com significativa diminuição do tempo clínico e laboratorial. Sendo assim, o presente estudo avaliou (Capítulos 1, 2 e 3) por microtomografia computadorizada, diferentes materiais, diferentes sistemas, diferentes maneiras de obtenção de modelo virtual (com escaneamento direto ou indireto), além de avaliar também, a influência do agente cimentante na adaptação final de peças obtidas por CAD/CAM. Além disso, este trabalho buscou ainda (Capítulos 3, 4 e 5) verificar se há diferenças significativas nos desajustes vertical ou horizontal em infraestruturas fundidas sobre implantes Hexágono Externo (HE) utilizando UCLAs totalmente calcináveis, UCLAs calcináveis com base de cobalto-cromo e infraestruturas usinadas por sistema CAD/CAM em CoCr ou Zircônia por diferentes sistemas de escaneamento e usinagem. Para isto, foram utilizadas a microscopia eletrônica de varredura e a interferometria. Concluiu-se que a tecnologia CAD/CAM e capaz de produzir restaurações, *copings* e estruturas implantadas aparafasudas em diferentes materiais e sistemas oferecendo resultados satisfatórios no ponto de vista da adaptação marginal.

Palavras-chave: CAD/CAM, Prótese Dentária, Junção Pilar/Implante; Implantodontia.

ABSTRACT:

The past few decades have brought many changes to the dental practice and the technology has become ready available. The result of a satisfactory rehabilitation treatment basically depends on the balance between biological and mechanical factors. The marginal adaptation of crowns and prosthetic structures is vital factor for long-term success. The development of CAD / CAM technology in the manufacture of dental prostheses revolutionized dentistry, this technology is capable of generating a virtual model from the direct digital scanning from the mouth, casts or impressions. It allows the planning and design of the structure in a computered software. The virtual projects are obtained with high precision and a significant reduction in clinical and laboratory time. Thus, the present study (Chapters 1, 2 and 3) computed microtomography was used to evaluate, different materials, different CAD/CAM systems, different ways of obtaining virtual model (with direct or indirect scanning), and in addition, also aims to evaluate the influence of cementing agent in the final adaptation of crowns and copings obtained by CAD / CAM. Furthermore, this study (Chapter 4, 5 and 6) also aims to evaluate significant differences in vertical and horizontal misfits in abutment-free frameworks on external hexagon implants (HE) using full castable UCLAs, castable UCLAs with cobalt-chromium pre-machined bases and obtained by CAD / CAM with CoCr or Zirconia by different scanning and milling systems. For this, the scanning electron microscopy and interferometry were used. It was concluded that the CAD / CAM technology is capable to produce restorations, copings and screw-retained implant-supported frameworks in different materials and systems offering satisfactory results of marginal accuracy, with significative reduction in clinical and laboratory time.

Palavras-chave: CAD/CAM, Dental Prostheses, Implant/abutment Interfface; Implantology.

Introdução

1. INTRODUÇÃO E REFERENCIAL TEÓRICO

Parte I: Referente aos capitulos 1, 2 e 3.

Nas últimas décadas, muitas mudanças ocorreram na odontologia e a tecnologia tem sido cada vez mais inserida na prática clínica diária. Muitos recursos modernos foram incorporados e têm mostrado resultados promissores. O Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) é um sistema usado desde os anos 80 por cirurgiões dentistas e técnicos em prótese dentária ao redor do mundo e tem conquistado cada vez mais o seu espaço dentro da Odontologia Restauradora. Nos últimos anos, com o avanço tecnológico, a diminuição dos custos e maior informação, os sistemas CAD/CAM tem se tornado cada vez mais populares. (Kayatt & Neves, 21012; Carneiro et al 2014)

Os sistemas CAD/CAM presentes na odontologia contemporânea podem ser classificados em duas diferentes vertentes: Direto ou Indireto. O CAD Direto (de consultório) pode acelerar muito os procedimentos da clínica diária da odontologia restauradora (Kayatt & Neves, 21012; Carneiro et al 2014). Com a utilização de um scanner intra-oral, o que caracteriza a técnica como direta, é possível obter modelos digitais e desenvolver trabalhos restauradores em um software, que atua após a captura da imagem pelo escâner. Com a utilização destes softwares, é possível projetar estruturas para próteses cimentadas, pilares para próteses implantadas, estruturas para próteses aparafusadas, além de coroas parciais e totais, demonstrando grande versatilidade para as várias situações clínicas. O CAD Indireto esta relacionado a otimização das técnicas e agilidade nas atividades desenvolvidas em laboratório e o CAD - Indireto, (de bancada) pode acelerar muito procedimentos como enceramento, inclusão, fundição e aplicação de porcelana (Kayatt & Neves, 2012; Carneiro et al 2014). Após a digitalização de modelos de gesso, o que caracteriza a técnica como indireta, e desenho da restauração será o próximo passo. O CAD (Computer Aided Design) propriamente dito, atua após a captura da imagem pelo escâner e trata-se de um software. Estes softwares, após a geração do modelo digital proveniente do escaneamento do modelo de gesso, são capazes de projetar copings para próteses cimentadas, pilares para implantes, estruturas para próteses aparafusadas, além de coroas parciais e totais, demonstrando grande versatilidade para as várias situações clínicas. Grande parte desses softwares tanto para sistemas diretos ou indiretos permite ainda que o operador possa personalizar o trabalho gerado, restando apenas enviar o arquivo gerado, para uma máquina que ira materializar o projeto gerado no CAD, através de obtenção robotizada.

A adaptação marginal de coroas protéticas é fator vital para o sucesso em longo prazo (Lin, 2012). Quando a dissolução do cimento ocorre (Jacobs e Windeler, 1991), uma fenda é estabelecida entre a estrutura dental e a coroa. A medição da fenda marginal, que é uma medição perpendicular a partir da superfície interna da coroa para a margem do dente preparado (Holmes, 1989), têm sido amplamente discutida na literatura. Diferentes técnicas foram utilizadas para avaliar a adaptação marginal de coroas (Neves, 2014ª, 2014b e 2015). O presente trabalho utilizou uma nova técnica para investigar a desadaptação marginal, que utiliza micro-tomografia computadorizada (micro-CT) e tem a vantagem de ser não destrutiva (Borba et al, 2011; Krasanaki et al, 2012; Pelekanos et al. 2009). Esta técnica permite a investigação de pequenos objetos em 3D com alta resolução. A desadaptação marginal é obtida dentro do intervalo de alguns micrometros em vários locais e direções (Seo et al., 2009). Deste modo, para comparar a desadaptação marginal vertical e horizontal, o presente estudo avaliou por microtomografia computadorizada, diferentes materiais, diferentes sistemas, diferentes maneiras de obtenção de modelo virtual (com escaneamento direto ou indireto), além de avaliar ainda, a influência do agente cimentante na adaptação final de peças obtidas por CAD/CAM.

Parte II: Referente aos capitulos 4, 5 e 6.

O aumento na popularidade e a demanda do uso de implantes dentários para substituir os dentes perdidos tem incentivado o avanço na clínica, com tecnologias e materiais para melhorar a aceitação dos pacientes e os resultados clínicos. O resultado de um tratamento satisfatório com implantes depende basicamente do equilíbrio entre os fatores biológicos e mecânicos. Os biológicos geralmente são multifatoriais, e os mecânicos associam-se à estabilidade da junção implante/parafuso/intermediário protético (Goodacre, 1999). Dependendo do grau de desadaptação da estrutura protética sobre os implantes, podem ocorrer complicações biológicas incluindo reação adversa dos tecidos circundantes, dor, reabsorção óssea peri-implantar e até perda da osseointegração (Adell et al., 1981; Carlson & Carlsson, 1994). As complicações mecânicas vão desde a fratura do parafuso de fixação, fratura da peça protética até a fratura de implantes (Naert et al., 1992; Zarb & Schmitt, 1990). Uma melhoria no assentamento das estruturas traria uma passividade muito benéfica, entretanto difícil de ser conseguida nos processos utilizados atualmente pelos diversos laboratórios de prótese dentária. A importância dos aspectos biomecânicos em tratamentos com implantes osseointegrados tem sido enfatizada e condutas têm sido sugeridas para otimização do equilíbrio biológico e mecânico do sistema pilar/implante (May et al., 1997; Wee et al., 1999). Novos materiais e técnicas como: solda laser, eletroerosão e sistemas computadorizados para usinagem de estruturas protéticas são recomendados na literatura com objetivo de minimizar os efeitos das distorções inerentes às etapas clínicas e laboratoriais, contudo poucos resultados direcionam para soluções precisas e confiáveis, mediante a complexidade para determinar qual o ajuste e o erro aceitável para a interface pilar/implante (Jemt et al., 1996). Além disso, estes desajustes podem trazer tensões não somente para o conjunto pilar/implante, mas também na interface osso/implante. O nível exato de tensão estática que a interface implante / osso pode tolerar ainda não está bem definido na literatura.

Distorções, inerentes ao processo de união na confecção de pilares plásticos calcinaveis tipo UCLA, utilizados em ampla escala no mercado brasileiro, apresentam maiores risco de desajuste na interface pilar/implante em relação aos pilares pré-fabricados (Byrne et al., 1998). Várias pesquisas foram publicadas comparando, por meio de microscopia eletrônica de varredura no sistema Hexágono Externo (HE) o assentamento (desajuste vertical e horizontal) de infraestruturas confeccionadas por diferentes laboratórios, materiais e técnicas de soldagem (Barbosa, 2007, 2010; Silveira Júnior, 2009). As próteses sobre implantes segmentadas (que possuem intermediário) apresentam-se biomecanicamente superiores em relação às confeccionadas diretamente do implante, também chamadas de não-segmentadas. Muito se deve ao fato de os intermediários protéticos ou pilares serem usinados e possuírem melhor adaptação, e normalmente serem fabricados em titânio, um material biocompatível e bioinerte. As próteses não-segmentadas, por sua vez, exigem um menor número de componentes protéticos e são bastante versáteis, pois se pode aplicar porcelana em toda a sua extensão, solucionando casos com envolvimento estético de difícil resolução sem ocorrer a exposição de uma cinta metálica. Uma característica comum às duas maneiras seria a reversibilidade e a previsibilidade de retenção. Entretanto em função dos grandes desajustes ocorridos durante as fundições de peças calcináveis e da alergia ao Níquel, presente na maioria das ligas não nobres utilizadas (Ni-Cr), o uso de estruturas não segmentadas (diretas de implantes) tem sido desestimulado. Cilindros de Co-Cr para sobre-fundições foram desenvolvidos com esta finalidade, mesmo assim as empresas ainda sugerem o uso de pilares como uma alternativa mais segura tanto no ponto de vista biomecânico como pela biocompatibilidade.

O desenvolvimento da tecnologia CAD/CAM na fabricação de estruturas de próteses sobre implantes revolucionou a odontologia, proporcionando adaptação com maior precisão de assentamento e menores valores de desajuste quando comparados aos métodos convencionais (Fuster-Torres, 2009; Patel, 2010; Drago, 2006). Esta tecnologia consiste na obtenção de um modelo virtual a partir do escaneamento digital direto na boca, modelos ou moldes, possibilitando o desenho e planejamento da estrutura em um *software* no computador e a partir do projeto da estrutura pronta no *software*, os dados são enviados para uma máquina fresadora, que executará o processo de usinagem das peças com alto grau de precisão e uma significativa diminuição do tempo clínico e laboratorial (Drago, 2006). Ainda assim, existem trabalhos que apontam que o uso da tecnologia CAD/CAM pode não ser o fator mais importante para a adaptação marginal em estruturas sobre implantes (Hjalmarsson, 2010) e que isto poderia estar mais relacionado ao material do que a forma de obtenção (Karataşli, 2011). No entanto, ainda existe uma escassez de estudos disponíveis que comparam estruturas obtidas por CAD/CAM utilizando diferentes scanners e diferentes tecnologias para sua obtenção.

Diante deste contexto, é necessário avaliar o desajuste na interface dos implantes hexágono externo com diferentes métodos de fabricação, desde os componentes totalmente calcináveis, que dependem diretamente das habilidades do técnico em prótese dentária e do processo de fundição até as estruturas obtidas por CAD/CAM. Sendo assim, este trabalho almeja verificar se há diferenças significativas nos desajustes vertical ou horizontal em infraestruturas fundidas sobre implantes Hexágono Externo (HE) utilizando UCLAs totalmente calcináveis, UCLAs calcináveis com base de Cobalto-Cromo (CoCr) e infraestruturas usinadas por sistema CAD/CAM em Cobalto-Cromo (CoCr) ou Zircônia por diferentes sistemas de escaneamento e usinagem. Para isto, foram utilizados dois métodos, a microscopia eletrônica de varredura e a interferometria.

Capítulo 1

Microcomputed tomography marginal fit evaluation of computer-aided design/computer-aided manufacturing crowns with different methods of virtual model acquisition

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Abstract:

This in vitro study used microcomputed tomography to evaluate the marginal fit of crowns fabricated using a chairside computeraided design/computer-aided manufacturing (CAD/CAM) system with different methods of virtual model acquisition. Crowns were fabricated to fit in a cast containing a single human premolar. Four methods of virtual model acquisition were used: Group 1 (control), digital impressioning of a typodont; Group 2, digital impressioning of a powdered typodont; Group 3, digital impressioning of a regular impression; and Group 4, digital impressioning of a master cast. Statistically significant differences were found between the marginal gap of Group 2 and the other groups ($P < 0.05$); no differences were found among Groups 1, 3, and 4. The results showed that crowns fabricated using the chairside CAD/CAM

system exhibited significantly smaller vertical misfit when a thin layer of powder was applied over the typodont before digital impressioning.

Introduction:

Ceramic crowns can be produced using different techniques, including computer-aided design/computer-aided manufacturing (CAD/CAM) procedures, available in dental practices, laboratories, and production centers.[1] The major advantage of this technology when compared to conventional fixed prostheses is the reduction of both chair and laboratory time.[2] A new CAD/CAM material, Lava Ultimate Restorative (3M ESPE), is a resin nanoceramic block that reportedly achieves superior esthetic results and can be used in chairside CAD/CAM systems (E4D, E4D Technologies LLC).[3-5] These blocks are made of nanoceramic particles embedded in a highly cured resin matrix; therefore glaze firing is not recommended, as it would melt the restoration. This nanoceramic material only needs to be subjected to a polishing process before fixation, thus enabling intra- or extraoral adjustments.[3] An important issue to consider regarding the clinical success of an all-ceramic restoration is the marginal fit.[6-8] There is currently no consensus regarding a defined clinically acceptable marginal fit. Some studies have shown that a marginal fit ≤120 μm is clinically acceptable, whereas others have recommended ≤100 μm or ≤75 μm.[9-14] The survival of ceramic inlays is also fundamentally dependent on durable bonding.[15] Stereomicroscopy, scanning electron microscopy, optical microscope and microcomputed tomography (μCT) are methods used to evaluate marginal fit.[7,13,16-26] Stereomicroscope techniques require a transverse section of the sample to measure the marginal gap, but this procedure can cause sample deformations.[13] Analyses involving a scanning electron microscope can be inaccurate, considering the overlap, depending on the positioning of the sample.[22] The μCT system can be relatively expensive; however, it is a nondestructive method.[24-27] This 3-dimensional (3D) system also provides detailed highresolution imaging, allowing an internal view of the sample.[28,29] To date, there has been little research on the marginal fit of resin nanoceramic crowns captured using the E4D chairside CAD/CAM system.[5] In this study, μCT was used to evaluate the marginal fit of crowns. The null hypothesis of this study was that different methods of virtual model acquisition would not influence the marginal fit of resin nanoceramic crowns.

Materials and methods:

Sample preparation A human mandibular left first premolar and adjacent teeth were fastened to a typodont model and prepared by an experienced operator for an all-ceramic crown. This procedure was approved by the Federal University of Uberlandia Ethics Committee (381/06). A standard set of diamond burs (1014, 3145, 3098, and 3098F, KG Sorensen) was used. The preparation was free of undercuts, the angles were rounded, and the walls were tapered 6 degrees to the occlusal surface. The margins were prepared with shoulders and rounded axiogingival line angles.[30] Restoration fabrication The 4 experimental groups were based on different methods for acquiring the virtual models. All groups used Lava Ultimate Restorative and were designated as Group 1 (control), digital impressioning of a typodont; Group 2, digital impressioning of a typodont with a thin layer of titanium dioxide powder; Group 3, digital impressioning of a regular impression; and Group 4, digital impressioning of a master cast. The same scanning technology (E4D laser scanner, E4D Technologies LLC) was used for the 4 groups. For the control group (Group 1), 5 digital impressions were made of the prepared tooth fastened to a typodont. For Group 2, 5 digital impressions of the prepared tooth were made, but not before a thin layer of Dental) was applied. For Group 3, 5 regular impressions with heavy and light vinyl polysiloxane impression material (Imprint 3 Quick Step, 3M ESPE) were taken from the prepared tooth. For Group 4, 5 regular impressions with Imprint 3 Quick Step were made to obtain 5 stone dies with type V dental stone (Die-Keen Green, Heraeus Kulzer). For all 4 groups, the same operator made all the impressions at room temperature and obtained all the stone dies. The crowns were designed for all 4 groups using E4D DentaLogic software (version 2.0, E4D Technologies LLC) with luting space and an adhesive gap set to 10 μm. Finally, an E4D mill (E4D Technologies LLC) was used for CAM processing of the designed crowns. The same experienced operator made all the crowns. Measuring procedures No adjustments were made to the ceramic crowns before marginal fit measurements. The prepared tooth was removed, and each crown was fixed to the same tooth using silicone material (Fit Checker, GC America, Inc.). To acquire images for marginal fit measurements, all specimens were scanned using μCT (SCANCO CT40, SCANCO Medical AG). Imaging was performed at 70 kVp and 112 μA with a resolution of 1024 x 1024 pixels. Pixel size and slice width were both 8 μm, and the scan time was approximately 1 hour. A total of 630 2-dimensional images were acquired for each specimen. Transaxial images of the crown and prepared tooth were captured first. Thirteen images from the sagittal set and 13 images from the coronal set (Fig. 1 and 2) were selected to illustrate sample extension in 2 different planes. The 13 selected images were evenly distributed between the first and last images that contained the cervical margin. For each image, 2 measurements of horizontal fit and 2 measurements of vertical fit were performed at 400X magnification using CTAn processing software (version 1.12.0.0, Skyscan, Bruker microCT). For vertical fit, measurements were taken from the external crown margin to the most external point of the tooth (Fig. 3). For horizontal fit, measurements were taken from the most external point at the prepared margin of the tooth to the crown margin (Fig. 4). The marginal fit was measured at 52 sites for each specimen, according to the method used by Groten et al.20 Statistical analyses Statistical analyses were performed with Sigma Plot statistical software (version 12.0, Systat Software, Inc.). A 1-way ANOVA test was performed to determine the significance among groups, followed by the Tukey test (α = 0.05) for post hoc comparisons. Vertical marginal fits were grouped according to the following values from previous studies: <75 μm, 75-100 μm, 100-120 μm, and >120 μm.[9-12,14,31] The maximum acceptable vertical misfit was set to 75 μm.[32,33] In addition, horizontal misfit values were placed into 3 categories: underextended, equally extended, and overextended.[31,33]

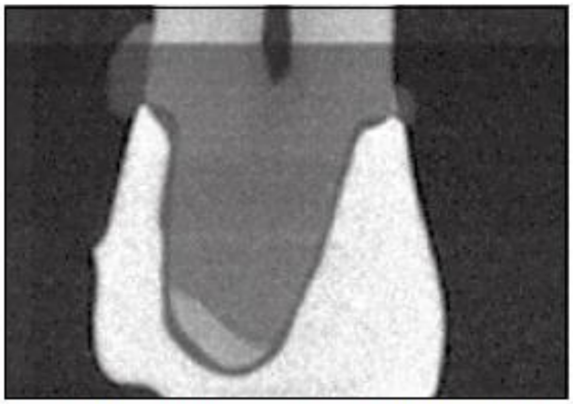


Fig. 1. Microcomputed tomography (μCT) sagittal image of a crown fixed on a prepared tooth.

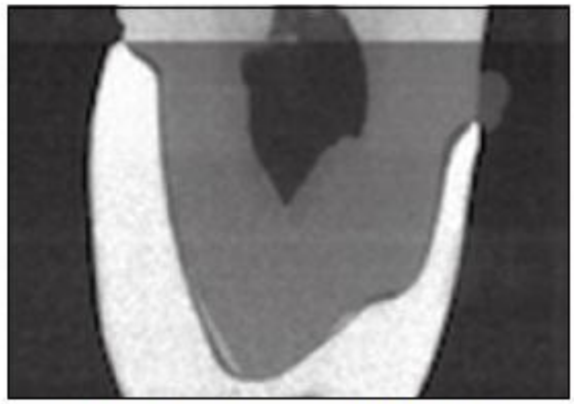


Fig. 2. μCT coronal image of a crown fixed on a prepared tooth.

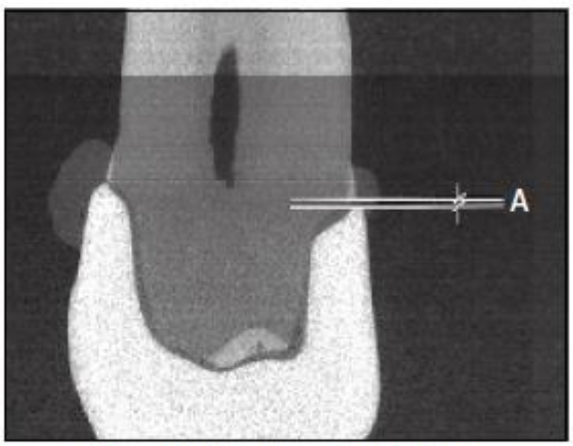


Fig. 3. Schematic showing vertical misfit measurements (A).

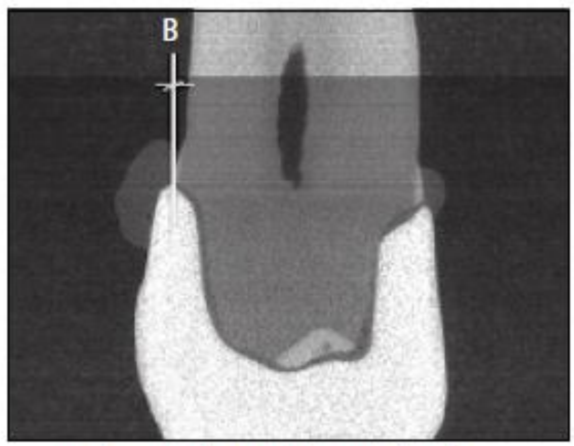


Fig. 4. Schematic showing horizontal misfit measurements (B).

Results:

With the exception of Group 4, the majority of vertical misfit values for the crowns were <75 μm (Table). Chart 1 shows the vertical misfit (μm) and standard deviation (SD) for each group. The mean vertical misfits (SD) were Group 1, 66.5 (29.97); Group 2, 34.9 (6.67); Group 3, 59.7 (17.45); and Group 4, 92.34 (21.51). Statistically significant differences in vertical fit between Group 2 and the other groups were detected (P = .042), but no difference was detected among Groups 1, 3, and 4, which exhibited low vertical misfit values. Horizontal misfit values (defined as underextended, equally extended, or overextended) were also calculated for each group: Group 1, 83.1%; Group 2, 93.7%; Group 3, 75.4%, and Group 4, 84.6% (Chart 2).

Table. Vertical misfit for each group

	Minimum vertical misfit		Misfit range (%)				Maximum vertical misfit (μm)
Group	μm	%	<75 μm	75-100 μm	100-120 μm	>120 μm	
1	0	13.5	63.5	13.8	6.2	16.5	272.9
2	0	21.2	83.8	8.6	3.8	3.8	284.6
3	0	18.8	70.4	10.8	3.8	15.0	280.6
4	0	11.5	47.3	70.8	9.6	32.3	599.0

Chart 1. Vertical misfit (μm) and standard deviation (SD) for each group.

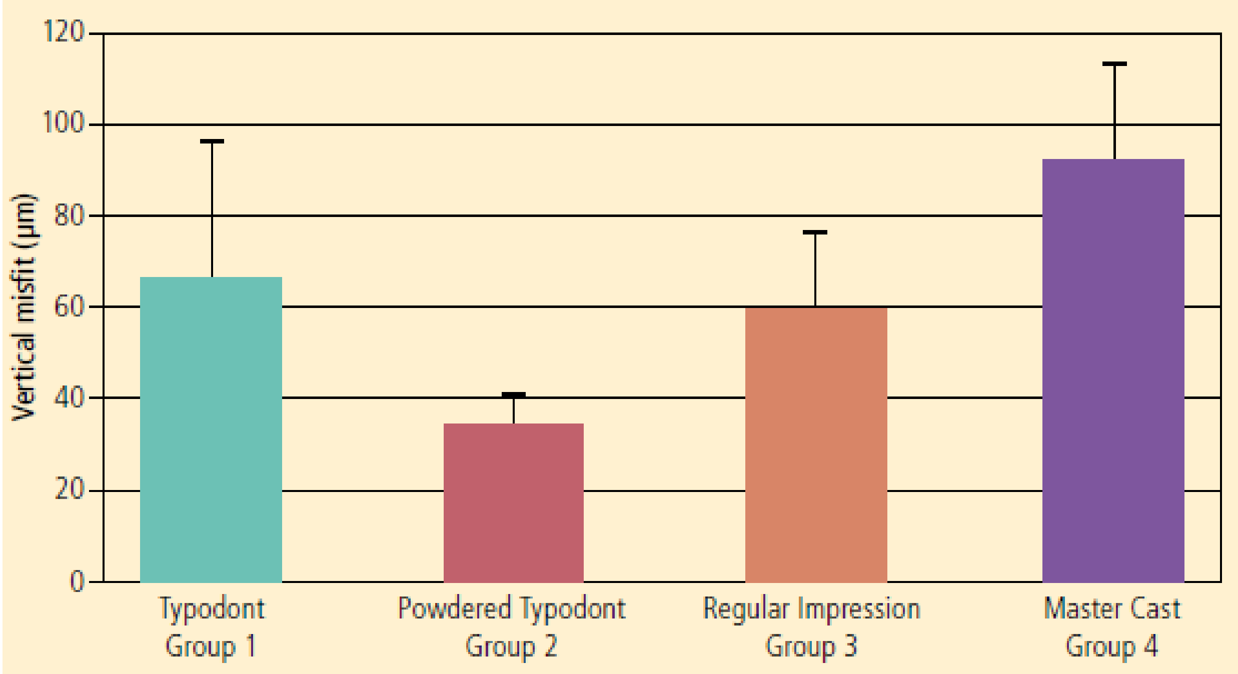
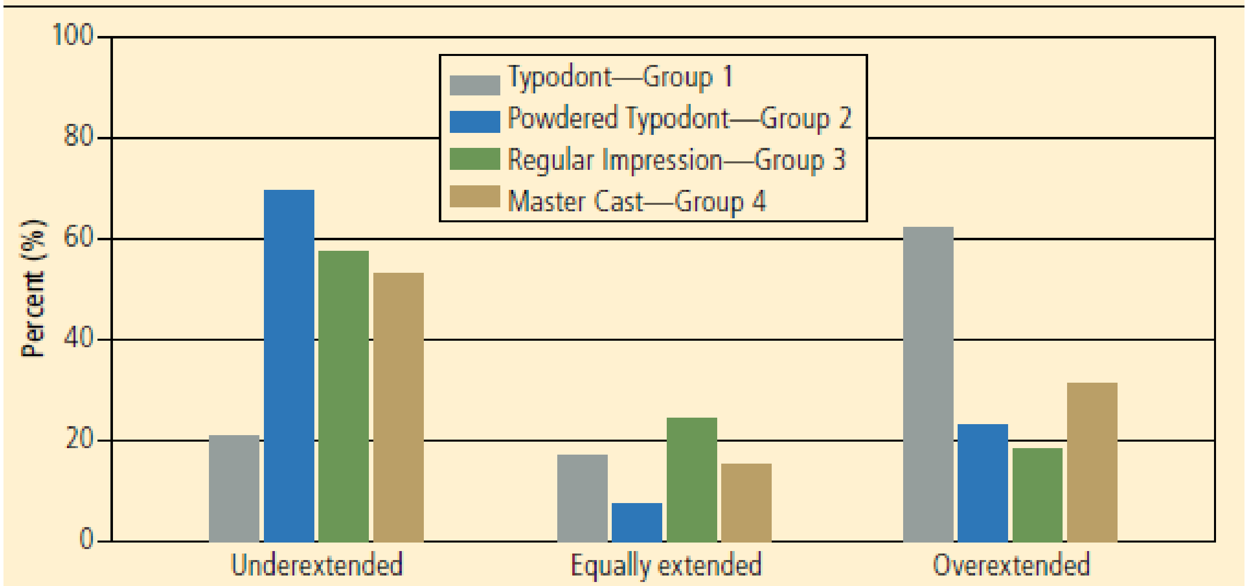


Chart 2. Percentage of underextended, equally extended, or overextended crowns fitted to the prepared tooth.



Discussion:

The null hypothesis—that a different method of virtual model acquisition does not affect the marginal fit of resin nanoceramic crowns—was rejected. Data from this study revealed statistically significant differences in marginal fit when resin nanoceramic crowns were produced with different methods. application.[5] Digital impressioning of the typodont with powder could result in lower misfit values. The present study suggests that the upper limit of acceptable misfit should be 75 µm. Results of the horizontal misfit comparisons favored the digital impression of Group 3. This may be due to the way 3D scanners convert the optical data to a 3D model, based on the distance from the scanner's sensor tip to the object.[34] The margin surface of Group 3 was the nearest to the scanner sensor tip of all groups tested. Restorations with significant horizontal misfit can facilitate the retention of food and bacterial plaque.6 This makes a patient's hygiene more difficult to maintain, leading to periodontal problems and possible caries that may reduce restoration longevity. Nevertheless, a horizontal misfit could be reduced by adjusting the crown or tooth. This adjustment is not possible with a vertical misfit. Five different impressions were made to generate 5 virtual models, eliminating the effect of variation associated with preparation. This revealed marginal fit discrepancies that specifically resulted from different digital impression methods. Previous in vitro studies have used different numbers of specimens per group.[10,15,25,26,29,35] In the present study, 52 measurements were performed per sample. While other studies have used magnifications of 250X, the present study analyzed at 400X magnification.[8.11] The clinical cementation process could damage the master die, thus increasing the marginal discrepancy, and a crosssection may be necessary before the measurements are taken.[8,13,25,29] In the current study, a silicone material was used to temporarily fix each crown in the same tooth, using digital pressing. Long-term clinical data are required to verify the relative efficacy and importance of these techniques. Within the limitations of this study, the crowns manufactured by the E4D chairside CAD/CAM process exhibited significantly smaller vertical misfit when a thin layer of powder was applied over the typodont before digital impressioning. Further studies should be performed using different types of dental stone to understand their influence on vertical misfit.

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Disclaimer

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Capítulo 2

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Micro CT analysis of in-office computer aided designed/computer aided manufactured dental restorations

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ABSTRACT
Purpose: The current study evaluated two different materials, using micro-CT to compare the marginal gap of feldspathic ceramic (*V*) and resin nano-ceramic (*L*) crowns obtained by two different computer-aided design/computer-aided manufacturing (CAD/CAM) systems, CEREC CAD/CAM system and E4D Technologies. *Methods:* A human lower left first premolar was mounted on a typodont model and prepared for an all-ceramic crown. Two groups ($n = 5$) were divided based on the system for obtaining the crowns and the material used for it (*V* and *L*). Micro-CT images were obtained for marginal gap measurements of each crown, and the data were statistically analysed by one-way analysis of variance followed by Tukey's *post hoc* test for pairwise comparisons (α¼ 0.05). *Results:* There were no statistically significant differences between marginal gap of groups *V* and *L* ($p = 0.473$). The mean and standard deviation for the vertical misfit was $V = 62.6$ (65.2) and $L = 66.5$ (59.0). For the horizontal misfit, the values were divided into three groups: underextension ($L = 20.8\%$) and ($V = 54.6\%$), equally extended ($L = 16.9\%$) and ($V = 36.9\%$) and overextension ($L = 62.3\%$) and ($V = 8.5\%$). *Conclusion:* The results revealed no difference in the marginal fit of crowns produced by different materials and different chairside CAD/CAM systems. Both are considered clinically acceptable according to all cited classifications.

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1. Introduction

The science of dental materials is one of the most important issues in the contemporary dentistry. The increasing demands for alternative restorative materials that are aesthetically acceptable has led to the development of many different alternatives that are now available on the market. The technical advances in computer technologies and materials provided improved options for indirect prosthodontics. Computer-aided design/ computer-aided manufacturing

(CAD/CAM) technologies are becoming more popular year by year and several options to fabricate dental crowns and restorations are now available for dentists and technicians. The development of intraoral scanning and in-office milling units has driven to a revolution in restorative dentistry [1]. With this new concept the treatments become faster and more comfortable for the patients, due to the fact that they don’t have to return to the office several times. In order to make this kind of treatment even faster, a new class of CAD/CAM materials has been developed. This consists in materials that firing is not required and milling, polishing and adjustment are easier, making a faster procedure compared to other CAD/CAM materials.

Within this concept, the VITABLOCS Mark II (VITA-Zahnfabrik, Bad Säckingen, Germany) is available since 1991. These CAD/CAM blocks are fabricated from feldspar porcelain particles embedded in a glass matrix and have a flexural strength of approximately 150 MPa according to the manufacturer. This material has proven its durability and success over the years [2-5]. Recently, a new material with this concept has been introduced on the market, the Lava Ultimate (3M ESPE, Seefeld, Germany). According to manufacturer’s information, Lava Ultimate CAD/CAM blocks are made from resin nano-ceramic material (RNC). The material is a mixture of nano-ceramic fillers (zirconia and silica nano-particles agglomerated into clusters) incrusted in a resin composite matrix. The Lava Ultimate crowns also have a flexural strength of 200 MPa.

The marginal fit of prosthetic crowns is a vital factor for success because the cement is a weak agent in the restorative process [6]. When the cement dissolution occurs, a gap is established between the dentin and the crown [7]. Different techniques have been chosen to evaluate the marginal adaptation crowns, a new technique using micro-computed tomography (micro-CT) was used to investigate the mismatch, and has the advantage of being a non-destructively method of evaluation [8-10]. This technique allows the investigation of small objects in 3D with high resolution. The marginal misfit is obtained within the range of a few microns in various locations and directions [11].

Therefore, the current study evaluated two different materials, using micro-CT to compare the marginal gap of feldspathic ceramic and RNC crowns obtained by two different CAD/CAM systems, CEREC CAD/CAM system and E4D Technologies. The null hypothesis of this study was that the material and method of fabrication would not influence the marginal fit of chairside in-office CAD/CAM restorations.

2. Method of research

As already described on some studies designed by the same group [12-14], a human lower left first premolar was mounted with its adjacent teeth on a typodont and prepared by an experienced operator for an all-ceramic crown (Ethics Committee approval 381/06). A standard set of diamond burs (1014, 3145, 3098, 3098F - KG Sorensen, Barueri, Sao Paulo, Brazil) suitable for ceramic preparations was used. The preparation was free from undercuts, the angles were rounded, and the walls were tapered 6 degrees to the occlusal surface. The margins were prepared with shoulders and rounded axiogingival line angles (Fig.1) [15]. Greater convergence favors marginal adaptation. It is evident that the improvement of adhesive systems has changed all cementation process of indirect restorations and the preparations, however, a 6 degrees wall to the occlusal surface is the most traditional way to prepare a tooth, increasing the frictional retention.

Two groups (n=5) were divided based on the system for obtaining the crowns and the material used for it. For the first group (V), digital impressions were made with the CEREC 3D Bluecam scanner (Sirona Dental Systems GmbH, Salzburg, Germany). A thin layer of titanium dioxide powder was applied to the surface of the preparation, the adjacent teeth, and the surrounding soft tissues with an aerosol (Cerec powder; Vita Zahnfabrik). This optimizes image quality by creating a matte surface. Optical impressions of the prepared tooth were made by using the Cerec 3D Bluecam scanner (Sirona Dental Systems GmbH, Salzburg, Germany). The Bluecam was positioned as per manufacturer's instructions, and the optical images were taken (Fig. 2A). All crown designs were made in CEREC 3D software 3.8 (Sirona Dental Systems GmbH, Salzburg, Germany) and the luting space and adhesive gap were set at 0 μm (Fig. 2B). The milling unit in Lab MC XL (Sirona Dental Systems GmbH, Salzburg, Germany) was used for CAM processing all designed crowns, using blocks of VITABLOCS Mark II (VITA-Zahnfabrik, Bad Säckingen, Germany).

For the second group (L), digital impressions of the prepared teeth were made by using the E4D Laser scanner (D4D Technologies), without powdering (Fig. 2C). The crowns were designed in E4D Dental-Logic software (v2.0) with luting space and adhesive gap set to 10 mm (Fig. 2D). An E4D milling unit was used for CAM processing of the designed crowns in Lava Ultimate CAD/CAM blocks (3M ESPE Dental, St. Paul, USA). A single experienced operator who was previously calibrated made all the crowns with the CAD/CAM systems. One experienced operator obtained all the crowns for both systems and the scanners and milling units had been recently calibrated prior to this study. The luting space for both systems was defined according to the manufacturer's instructions.

For measuring procedures, no internal adjustments, glazing, or polishing were made to the crowns before the marginal gap measurements to avoid any human interference. The prepared tooth was removed from the typodont and each crown was fitted and fixed. The fixing procedure was made for each crown at the same prepared tooth with a silicone material (Fit Checker, GC Dental Industrial Corp, Tokyo, Japan), by finger pressing, simulating a clinical situation (by a prosthetic specialist). To obtain images for marginal gap measurements, all samples were scanned using micro-CT (Micro-CT Scanco CT40, Scanco Medical AG, Zürich, Switzerland) at the Biological Research Imaging Center (University of North Carolina). Imaging was performed at 70 kVp and 112 μA with a resolution of 1024 × 1024 pixels. Pixel size and slice width were both 8 μm and the scan time was ∼1 h. A total of ∼600 two-dimensional images were acquired for each specimen.

Transaxial images of the crown and prepared tooth were first obtained; 13 images from the sagittal set and 13 from the coronal set were selected to show the sample extension in two dimensions. From the total amount of the obtained images, the authors selected 13 images that were equally distributed between the first and last image in which the cervical margins appear. In each image, two measurements for horizontal fit and two for vertical misfit were done at 400× magnification using the CTAn processing software (Version 1.12.0.0, Skyscan, Kontich, Belgium). For vertical misfit, the measurements were made from the most external point at the preparation margin of the tooth to the crown margin (Fig. 3). For horizontal misfit, the measurements were made from the external crown margin to the most external point of the tooth (Fig. 4). The marginal gaps were measured at 52 sites for each sample [16]. In this way, 260 vertical misfit and 260 horizontal misfit measurements were done per group. Three independent examiners were involved in the measurements and the mean value was obtained. To ensure standardization among examiners, they were calibrated prior to the measurements.

The values of the vertical measurements were submitted to statistical analysis by one-way analysis of variance followed by Tukey's post hoc test for pair-wise comparisons ($\alpha = 0.05$), using the statistical program Sigma Plot (Systat Software Inc. version 12.0, San Jose, California). The vertical marginal gap values were grouped according to the following values: (1) up to 75 μm [17]; (2) 75 to 100 μm [18-20]; (3) 100 to 120 μm [21]; and (4) >120 μm [22]. These values were based on different reference values obtained in the literature.

In this study, it was considered 75 μm as the maximum acceptable vertical gap to be considered clinically acceptable. Additionally, the horizontal measurement values were divided in three categories [12-14]: (1) underextension, (2) equally extended, and (3) overextension of crowns fitted to the prepared finish line. The percentage for each category was calculated.

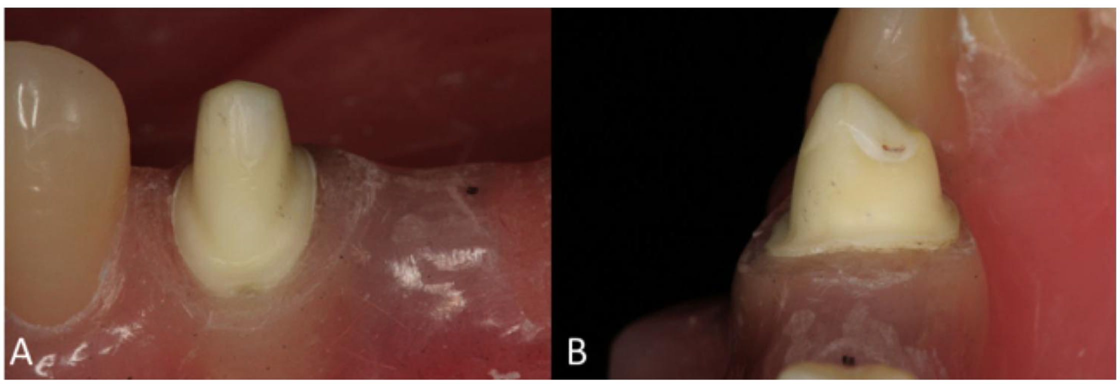

Figure 1. Human lower left first premolar prepared for an all-ceramic crown.

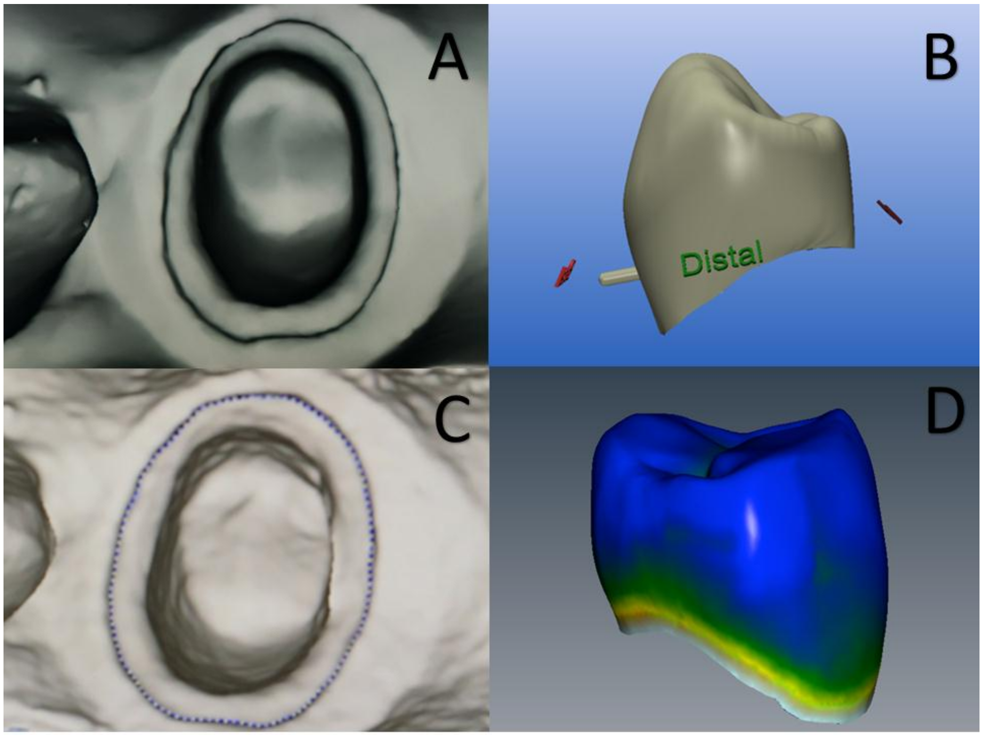

Figure 2. (A) Optical image taken with CEREC. (B) CEREC designed crown. (C) Optical image taken with E4D. (D) E4D designed crown.

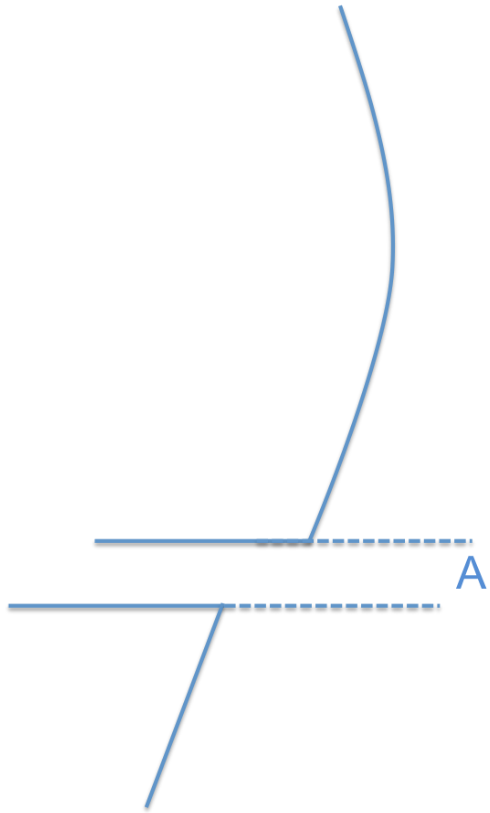

Figure 3. Vertical misfit measurements made from the most external point at the preparation margin of the tooth to the crown margin.

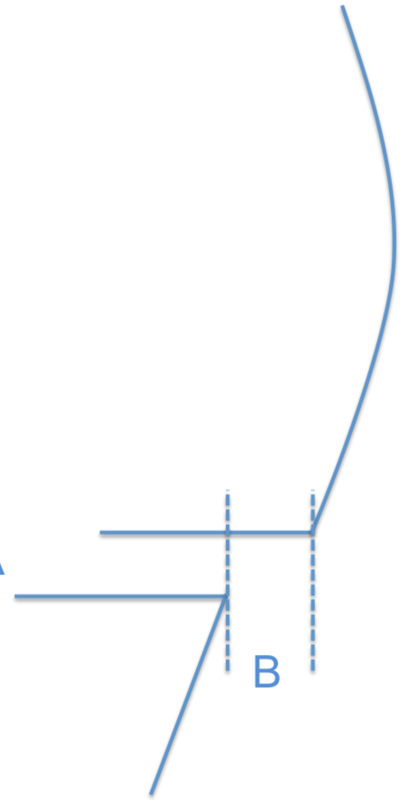

Figure 4. Horizontal misfit measurements made from the external crown margin t the most external point of the tooth.

3. Results

Table 1 shows the results for vertical marginal gap (µm) and standard deviation (SD), by Student's T test. There were no statistically significant differences between marginal misfit of groups V and L (P=0.473).

Table 2 shows the marginal fit percentage of each system of the present study. Considering the percentage measured up to 75 µm, 71.5% of measures of group V achieved this result, and 63.5% of group L.

The horizontal measurements showed results with underextension, equally extended or overextension of the crowns fitted to the prepared finish line (Fig. 5).

Table 1. Vertical marginal gap (SD) in µm.

V	*L*
62.6 (65.2) A	66.5 (59.0) A

Note: Same letters represent no significant difference ($\alpha = 0.05$).

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Table 2. Minimum and maximum values of marginal fit (µm) and percentage of each group up to 75, 75–100, 100–120 µm and over 120 µm.

Group	Minimum value	Up to 75 µm (%)	75–100 µm (%)	100–120 µm (%)	Over 120 µm (%)	Maximum value
V	0 (12.3%)	71.5	9.6	3.9	15.0	362.1
L	0 (13.5%)	63.5	13.8	6.2	16.5	272.9

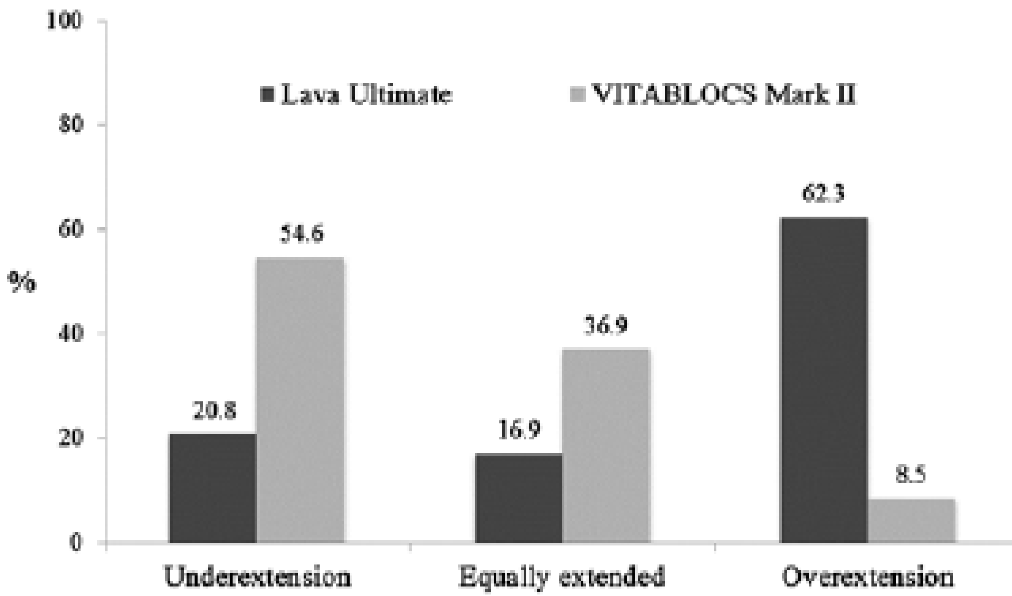

Figure 5. Horizontal measurements classified by underextension, equally extended or overextension of the crowns fitted to the prepared finish line.

4. Discussion

The null hypothesis that the used material would not influence the marginal fit of the crowns was accepted. The results revealed statistically equality in the marginal fit of chairside in-office CAD/CAM crowns produced by different materials and different systems.

Clinical problems can occur metal-free restorations, but all of them occur in a very low incidence [23-28]. Dental caries is a problem that can lead to failure of the restorations [29], as the exposure of the cementing agent to the oral environment can be directly related to bacterial activity in the microgap[30]. Based on that, this study focused only in this important area. It was proposed that the clinically acceptable marginal misfit of successful restorations might be less than 120 micron [21]. This criterion has been cited in some articles [22,31,32]. Other authors considered that 100 micron is the acceptable limit [18-20], and it is possible to remove cement excess without any damage to the inner portion of restoration [33]. Finally, Hung et al. [17] reported that the clinical acceptability of a vertical misfit must be below 75μm. All this variation may be related to the evaluation method, operator and different materials analyzed, all this can lead to different results and dubious information. Despite the development of new resin cements, much less soluble than zinc phosphate-based cements, the larger the marginal discrepancy, the larger the difficulty in finishing and polishing this area, especially in subgingival restorations. Thus, this situation favors the marginal food accumulation and possibly secondary caries.

The results from a small sample may be challenged [34]. However, when the technique leads to very similar products, the increased number of samples does not influence the results and significantly increase costs. This study evaluated five crowns fixed to the same tooth and measures were conducted in 52 locations of each crown, totaling 260 values for each group. The suggestion comes from a previous study [16] that reported that with a greater number of measurements more confident results could be achieved. This study suggests being necessary at least 50 measures well distributed along the margin of the sample to obtain clinically relevant information. In vitro studies have evaluated the marginal adaptation of ceramic crowns with a great variation of sample sizes [9,35-39]. Other studies conducted just a few measurements per sample [17,19,22], which could not be clinically representative. The present study analyzed 260 locations per group. Many studies present their results by mean values, which refer to the whole marginal adaptation crown or the average per group [36,38,40]. This does not represent the clinical reality because of areas of large mismatches, masked in average values. Other studies show a very high variety of values, demonstrating large discrepancy and high standard deviation, which can be observed in the present study [35,41-44]. Normally, researchers do not emphasize the standard deviation that occurs or the significance of this variability in clinical situations [19]. To avoid these occurrences, the present study presents the results in a qualitative manner for which the percentile seems to be ideal, and could be seen on table 2. In this way, is possible to figure the variance of values that can be found in the margins of a prepared tooth that receives a prosthetic crown.

The micro-CT was used for all measurements. The accuracy and precision are such equipment have been proved and several studies used this method to evaluate marginal fit [9,12-14,35,37]. In addition, it also has the advantage of being a non-destructive method. It provides faithful three-dimensional reconstructions and allows an analysis by slices and sections every 8 micron in any plan you want in order to not overlap, differently to other techniques such as Scanning Electron Microscopy (SEM) [20,45]. In this way, measurements can occur in different sections and distances along the marginal zone. In the present study, the measurements were executed at 400X of magnification with good resolution. However, micro-CT analysis takes a lot of time and can be very costly [46]. To standardize the comparisons, all the crowns were fixed to the same tooth. For that, a silicone material was used, avoiding the removal of the crowns after the micro-CT scan. The crowns demonstrated high resistance to being removed from the tooth, confirming that there were no movements during the micro-CT scanning.

Horizontal misfits are relevant and have a lot of clinical implications. Food retention and bacterial plaque adhesion can be related to this horizontal mismatches [30,47]. Such problem can turn hygiene into a difficulty, bringing periodontal problems and secondary dental caries, which can decrease the longevity of rehabilitation. Overhangs or over-extensions can be easily corrected after clinical adjustments and polishing. At the present study none adjustments or polishing were done prior the micro-CT analysis. The precision and accuracy of CAD/CAM crowns is dependent on several factors such as the size of the drill, the number of axis of the milling unit, the precision of the digital model acquisition [36,38], as well as calibration of the machines and software parameters. In this study, all the machines have been previously calibrated to the study and the parameters of the software were the same for both groups to make a fair comparative analysis. It is important to highlight that CAD/CAM systems are in a constant evolution and both companies passed through changes in their systems in the last years. Although, the machines and materials tested in this paper were and still are widely used. However, the results demonstrated in this study must not extrapolate to new equipments, such as Cerec- OmniCam and E4D – Palnmeca Planscan.

5. Conclusion

Within the limitations of the present study, the results revealed no difference in the marginal fit of crowns produced by different materials and different chairside CAD/CAM systems.

Acknowledgments

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Conflict of interest statement

The authors whose names are listed certify that they have NO affiliations with or involvement in any organization or entity with any financial interest, or non-financial interest in the subject matter or materials discussed in this manuscript.

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Capítulo 3

Micro-CT analyses of the marginal fit of CAD/CAM copings with two different types of luting agents.

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Abstract:

The acceptable marginal misfit existent on fixed restorations is still controversial on the literature. The clinical acceptability and an ideal marginal gap between the preparation and the restoration is difficult to be precisely defined. Basically, this large variation can be attributed to the absence of standardization of the methods in the published data. In this way, this in vitro study evaluated CAD/CAM ceramic copings before and after cementation using a Micro-CT analysis to verify if luting methods used in research tests are equivalent to a real fixation used in a clinical situation and if it would influence the marginal fit. For this, eight CAD/CAM feldspatic copings were fabricated and analyzed before definitive cementation, with PVS as a fixing material and after definitive cementation with resin cement. The mean (SD) of vertical misfit values (µm) demonstrated significant difference (P<.005) among the analyzed groups. The PVS showed higher values of vertical misfit when compared to the definitive luting material. Although significant statistical differences were found before and after definitive cementation, the use of PVS as a fixing test material for examination of the marginal gaps seems to be acceptable. Furthermore, the methods seem to be much more influent on the results when compared to the fixing material.

Keywords: CAD/CAM; Marginal Fit; Cementation; Micro-Computed Tomography

Introduction:

All-ceramic restorations have recently gained large popularity due to its esthetics and acceptable biocompatibility. With the introduction of the CAD/CAM, it is possible to obtain all ceramic copings by milling. Given the importance of the fitting accuracy of restoration, many studies had been designed to measure the precision of CAD/CAM copings, crowns and any kind of dental restoration (Lee 2008, Keshvad 2011, Baig 2010, Grenade 2011, Vanliouglu 2012, da Costa 2010, Krasanaki, 2012, Seo 2009, Pak 2010, May 1998, Oyague 2010). The acceptable marginal misfit existent on fixed restorations is still controversial in the literature. The clinical acceptability and an ideal marginal gap between the preparation and the restoration is difficult to be precisely defined. Although, there are still so many different classifications of an acceptable limit for marginal gaps in the literature (Keshvad, 2011, Davis 1998, Holmes 1992, Hung 1990), where 120 μm seems to be the highest value proposed (McLean 1971). Basically, this large variation can be attributed to the absence of standardization of the methods in the published data. In Vitro studies have used the most variable methods to evaluate the precision fit of dental restorations, such as stereomicroscopy, (Lee 2008, Keshvad 2011, Baig 2010, Grenade 2011, Vanioglu 2012, Yuksel 2011) scanning electron microscopy, (Grotten 2000, Oyague 2010, Trifkovic 2012) and optical microscopy (da Costa 2010). Most of these tests requires a transversal section of the sample to measure the internal and marginal gap (Grenade 2011, Keshvad 2011, Vanioglu 2012). A new technique that uses microcomputed tomography (micro-CT) has been used to investigate the marginal gap and has the advantage of being nondestructive. (Borba 2011, Krasanaki 2012, Pelekanos 2009, Neves 2014, Neves 2014, Neves 2015, Carneiro 2016) This technique allows the three-dimensional exploration of little objects with high resolution. The marginal gap can be visualized within a range of a few micrometers at multiple sites and in multiple directions. It also permits, very proximate sections with a high magnification (Neves 2014, Neves 2014, Neves 2015, Carneiro 2016). Another important issue to be considered is how the crown is fixed to the sample for the in vitro evaluations, non destructive methods have been used, for this, silicone materials have been used for reversible fixation. In this way, this in vitro study evaluated CAD/CAM ceramic copings, before and after definitive cementation using a Miro-CT analysis. The null hypothesis of this study was that different methods of cementation would not influence the marginal fit of feldspatic ceramic copings.

Materials and Methods:

One master die was developed from a maxillary molar (860 series; Columbia Dentoform Corp). One molar was prepared with a 0.8-mm chamfer and a uniform 2.0-mm occlusal reduction. Preparation was made with diamond rotary burs using a high-speed laboratory handpiece (Carv-aire; Jelenko) mounted on a milling machine (Fräsgerät F1; Degussa) following accepted principals of tooth preparation. Impressions to obtain the master dies were made with polyvinyl siloxane (Extrude light-bodied; Kerr Corp) and used as templates for the fabrication of 8 epoxy resin dies (Epoxy Potting Resin; General Polymer Corp). A power calculation was performed based on previous studies with a similar methodolology (Bindl 2005, Lee 2008) with software (nQuery Advisor version 7.0; Statistical Solutions, Ltd). According to the analysis, a sample size of 4 to 5 in each group would have a 90% power to detect a difference in marginal fit (Moser 1989). It was decided to use 8 specimens to increase the statistical power of the results. The Feldspatic copings were fabricated with the Cerec CAD/CAM system (Sirona Dental Systems GmbH, Bensheim, Germany), using the software CEREC 3D software 4.0 (Sirona Dental Systems GmbH). Each epoxy die was digitized by the Bluecam (Sirona Dental Systems GmbH, Bensheim, Alemanha), and a coping was designed virtually by using the manufacturer's design software to a standard thickness of 0.8 mm. Data were sent electronically to the system's milling unit in Lab MC XL (Sirona Dental Systems GmbH)and used to fabricate the feldspatic copings from VITABLOCS Mark II (VITA Zahnfabrik, Bad Sackingen, Germany) To measure the precision of fit of the copings to the die, a thin layer of extra-low-viscosity polyvinyl siloxane impression material (Aquasil Ultra XLV, Dentsply Caulk, Milford, DE, USA) was used to simulate a luting agent and was placed inside the copings. Light-bodied elastomers have been used previously by investigators to simulate the luting agent and found to be reliable. The copings were seated on the die and held under a 49-N load until the polyvinyl siloxane was set.

After setting, all samples were scanned in a µCT-40 (Scanco Medical, Wayne PA, USA) with the following settings: 70 kV, 114 mA, and 0.01 mm isotropic voxels. Images were processed with µCT-40 evaluation software with a 2.5 μm resolution. After the Micro-CT scan, all the copings were removed, cleaned and then cemented again with a definitive resin luting cement (RelyX U100 (3M ESPE, Saint Paul, MN, USA). Once again, the copings were seated on the die and held under a 49-N load until the resin cement was cured. After the definitive cementation, all the samples were scanned again on the Micro-CT. The images generated by the Micro-CT were analyzed on the software at 16X magnification where the measurements were performed. 40 measurements were performed all along the marginal extension for each sample with both types of cements (PVS and RelyX), 10 measurements in each face of each crown (Buccal, Lingual, Mesial and Distal), totaling 320 measurements for each luting agent. Data were analyzed statistically by T-Test with significant difference (P<.005)

Fig 1 – Luting space settings in the CAD software.

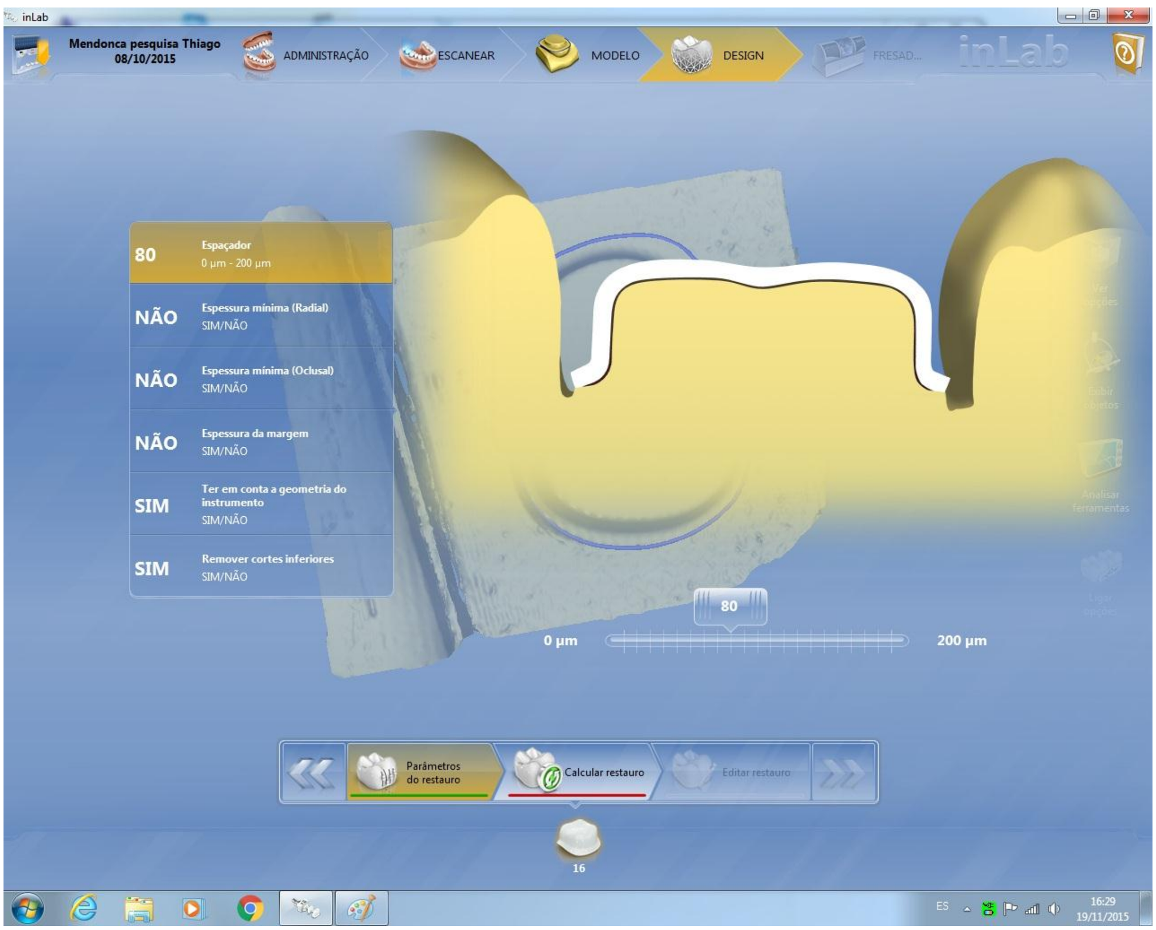


Fig 2 – Pressure controller device used to standardize the cementation for both materials.

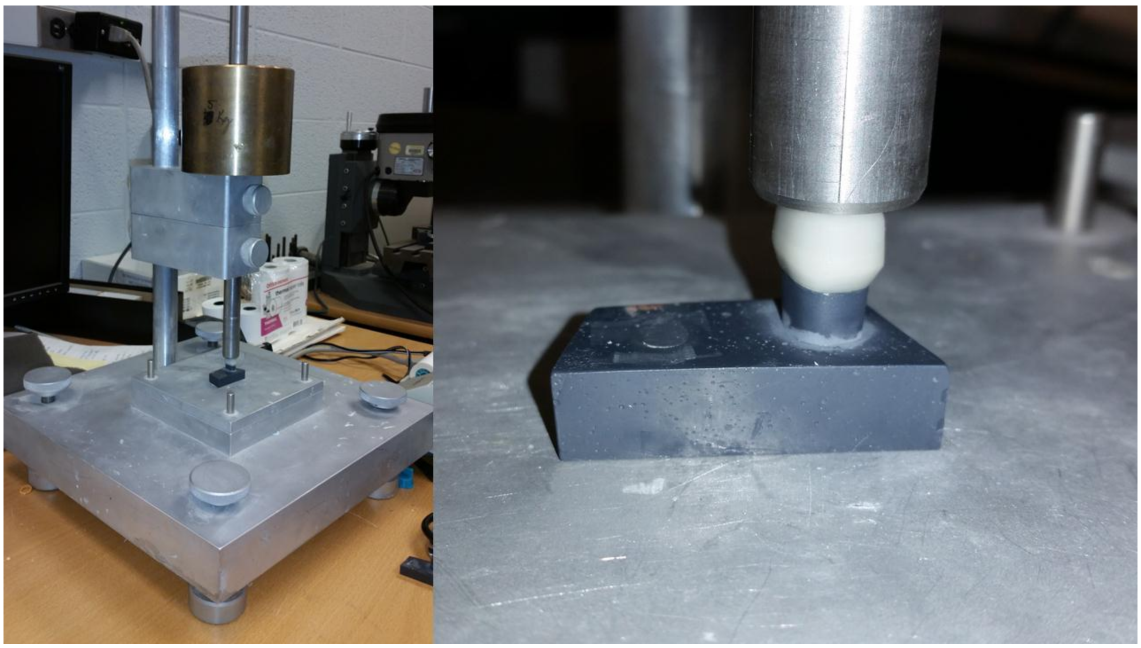
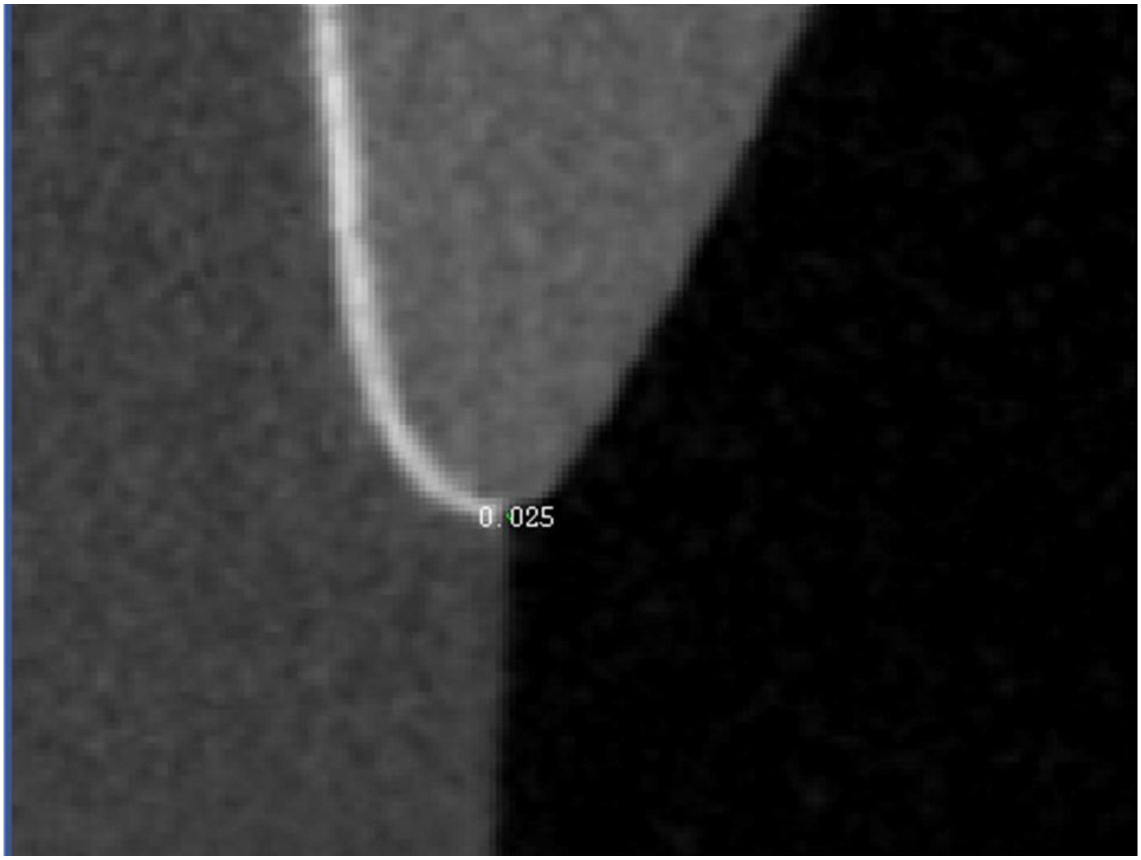


Fig 3 – Micro-CT analyzes of a cemented crown in 16X magnification.



Results:

The mean (SD) of vertical misfit values (µm), are shown in Fig.4. The T-test demonstrated significant difference ($P<.005$) among the analyzed groups. Vertical misfit percentages for each group are classified in Table I.

Fig 4 – Mean and Standard Deviation of the values found for both groups ($p < 0.005$).

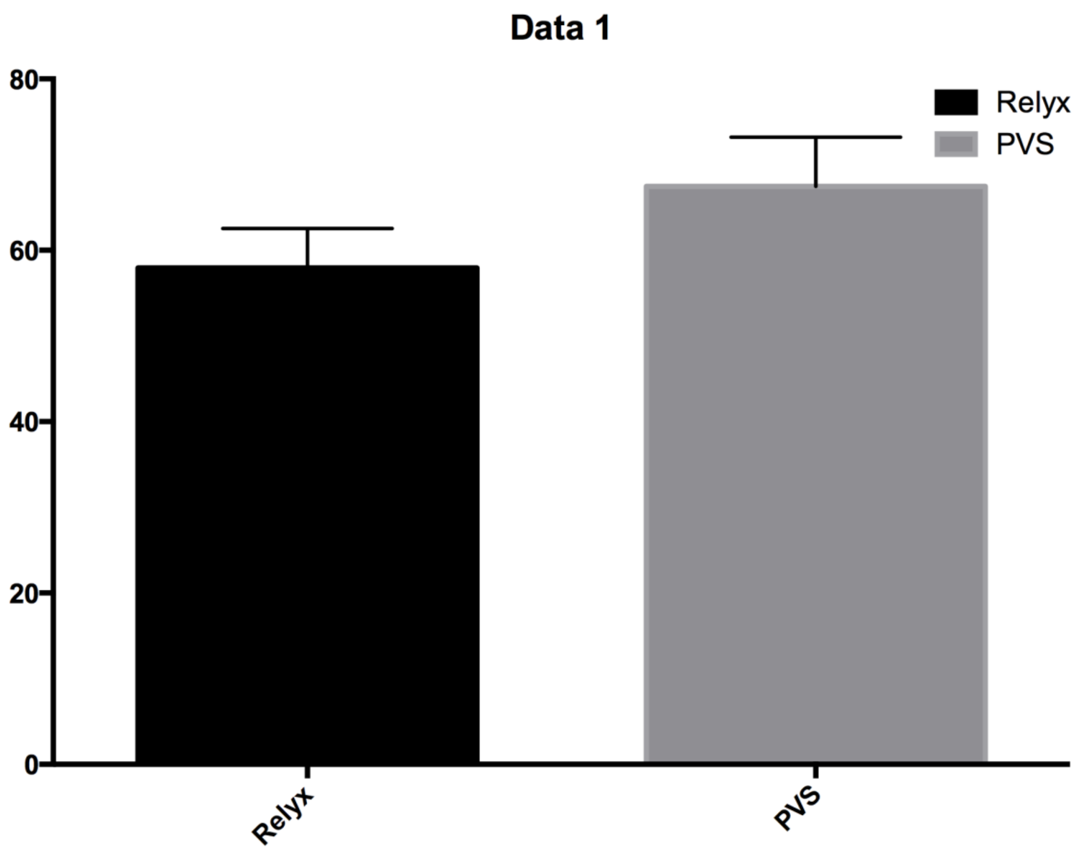


Table 1 – Percentile of misfits values of both groups classified into three categories (%) and minimum and maximum values in (μm):

Group	0–75μm	>75–120μm	>120μm	Min-Max (μm)
PVS	63,25%	23%	13.75%	0 - 219
Rely X	74%	17%	9%	0 - 198

Discussion:

An acceptable limit for all ceramic restorations obtained by the contemporary ceramic systems have been largely investigated and the ideal values reported are widely diverse and controversial. This large variation can be mainly attributed to the fact that the term ideal is totally vague and subjective. There is also a lack of standardization of the methods in the published data. To measure internal and marginal gaps, many equipment has been used and also with different parameters of use.

Among the most popular tests in the literature are Stereomicroscopy, scanning electron microscopy, optical microscope and microcomputed tomography (μCT). (Baig, 2010, Keshvad 2011, Lee 2008, Grenade 2011, Yuksel 2011, Vanlioglu 2012, Groten 2000, Oyague 2010, Trifkovic 2012, da Costa 2010, Pelekanos 2009, Borba 2011, Krasanaki 2012). Normally, Stereomicroscope techniques requires transverse section of the samples to measure the misfit, but this can cause deformations (Keshvad, 2011). Analyses involving a scanning electron microscope can provide false reuslts if the angle of the specimen is not correct, promoting an overlap. It has also been reported that Scanning Electronic Microscopy (SEM) evaluation was better than light microscopy to analyze marginal misfits [Schmalz 1995]. However, Groten et al. [Groten, 1997] reported, no significant difference between the two techniques, although according to the authors, SEM provides more realistic observations than a light microscope particularly with complex margin morphologies. Other kind of microscopes can also be used, such as digital microscopes [Sulaiman, 1997] and travelling microscopes [Albert 2004]. Although, they exhibited limited results and the calculated means usually demonstrate large standard deviations, in this way, the results reported might be questionable [May, 1998]. In this study, although the results are presented by the conventional statistical analyses, the results are also organized in percentile, which seems to be the best way to quantify misfits in any kind of restoration, that is capable to give a very reliable idea about the accuracy of the tested materials or technique (Neves 2014a, Neves 2014b, Neves2015, Carneiro 2016).

The present study used Micro-CT for the evaluation of the marginal opening gaps in ceramic copings. The Micro-CT system is a relatively expensive and time consuming, but on the other hand is nondestructive method of evaluate marginal discrepancies. This revolutionary 3-dimensional, high resolution imaging equipment provides detailed cross-sectional information about the intaglio of the sample and consequently the fit without damaging the specimen (Borba 2011, Krasanaki 2012, Pelekanos 2009, Neves 2014, Neves 2014, Neves 2015, Carneiro 2016). It was possible to measure the same crown in two different moments, before and after cementation in the same preparation, which can enhance the standardization in this kind of test. It was also possible to magnify the images and explore the measurements with a very good resolution. Both fixing materials showed good contrast with the crown and preparation, permitting a goode separation of the area of interest.

Some studies also stated that the cementation process can damage the teeth and interfere in the result (Borba 2011, May 1998). Furthermore, it was set that the cement can increase the discrepancy of the marginal fit (Pak, 2010). Measuring the marginal gap of cemented or uncemented crowns can also influence the results of the measurement [Stappert 2004, Wolfart 2003, Okutan 2006, Suarez 2005, Hung 1990]. It has been stated that marginal discrepancy generally increases after cementation [Quintas 2004, Byrne 1992]. Moreover, the type of cement was reported to alter the final fit of dental crowns [Oliveira 2006, White 1993, Clark 1995].

In the present study, the same preparation was used with two methods of cementation with the same crowns. They were fixed by a prosthodontist with a silicone material, by finger pressing, simulating a clinical situation and after that, the copings were seated on the die and held under a 49-N load until the fixation material was set, standardizing the comparisons. It is noteworthy that after fixing with PVS, the crowns showed high resistance to being removed from the preparation, confirming that there was no movement during measurement as reported in other studies (Neves 2014, Neves 2014, Neves 2015). Although significant statistical differences were found between the two groups, the use of PVS as a fixing test material for examination of the marginal gaps seems to be acceptable. Furthermore, the methods seem to be much more influent on the results when compared to the fixing material. This micrometric difference does not seems to be clinically significant. Other studies must be performed with other similar materials; it is difficult to compare studies that used the most different methods in the in vitro tests. In the present study, the PVS seem to be an applicable method to evaluate different methods of restoration obtaining, different restoration materials, different CAD/CAM system, different milling units and even different scanners.

Conclusions:

Although significant statistical differences were found before and after definitive cementation, the use of PVS as a fixing test material for examination of the marginal gaps seems to be acceptable. Furthermore, the evalution methods seem to be much more influent on the results when compared to the fixing material.

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Capitulo 4

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Perspective

Digital Technology in Implant Dentistry

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Introduction

The last few decades have brought a technological revolution in all areas of knowledge, computer systems are making everything more precise and fast, it would not be different in the clinical practice of dentistry. The technology is gaining more and more space; many modern features have been introduced in the market and have shown incredible results. The purpose of this article is to make a historical contextualization of the contemporary implant dentistry in order to identify which are the most used equipment and digital tools.

Digital Planning and Guided Surgery

The implanted prosthesis planning should start much time before the implant placement surgery or even the choice of the implant itself. This is the concept of reverse planning [1]. The emergence of computerized tomography has revolutionized the image exams by the obtaining of much clearer images of the anatomical structures and three-dimensional reconstructions. Associating the concept of stereolithography and CAD / CAM technology it becomes possible to generate prototyped surgical guides with high precision [2-14]. Because of this great conceptual revolution in implant therapy, comes the guided surgery. This technology is based on real images of the bone anatomy obtained through CT scans and the design of a computerized prototyped surgical guide to implant placement based on mathematical 3-D models.

The CT scan images are manipulated on a specific software, enabling a virtual surgery simulating the implant placement, always looking for the best position, bone anchorage and of course, respecting the future prosthesis that these implants will receive [2-14]. Guided surgeries are suitable for the most varying types of rehabilitation with implants, including totally edentulous patients, partial or single unit restorations. This technology has been widely used with scientifically proven success [6,9-14], to succeed with this therapy, achieving optimal aesthetic and functional results, we need a proper study on the selection of cases and a detailed planning. Although it seems to be extremely easy and simple, it requires a lot of expertise and experience of the involved staff, in addition to a detailed planning, avoiding any complications during the procedure. The guided surgery may be considered as a viable alternative for the rehabilitation of edentulous spaces within the correct indications. The highlight of this technique is the detailed planning necessarily performed prior to the surgery, a fact that should be routine and should be performed in all clinical situations, computer-guided or not.

The CAD / CAM technology in implant dentistry.

The CAD / CAM technology represents a major revolution within the current context of modern dentistry. It is now possible to generate a virtual model from the direct digital scanning from the mouth, models or even impressions, enabling the design and manufacture of the structure by computer assistance. With this technology, it is possible the manufacture structures for implant bridges, custom abutments, bars, copings, surgical guides and everything that can be developed in the software. Many software already comes with data libraries with the settings of many different implants from all over the world, favoring the adaptation of the manufactured components. (Figure 1)

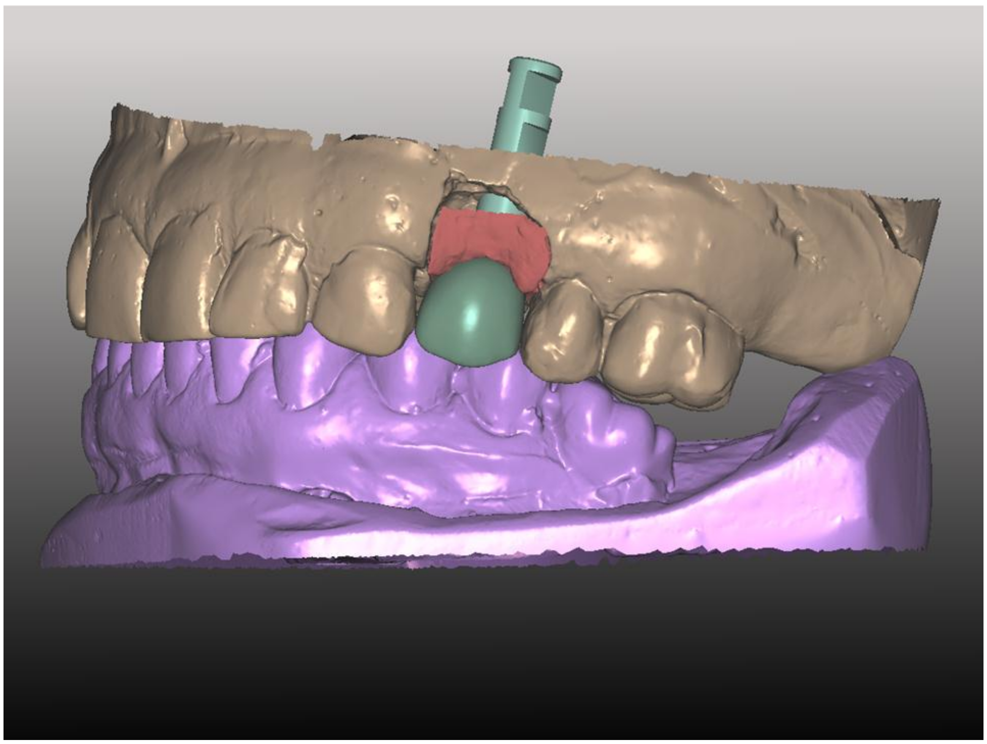

Figure 1 - Design of a CAD/CAM restoration.

This technology has already been described in the 80's [15], but due to technological advances added to the process in recent years, it has gained more and more popularity around the world. The first direct system or also known as "in office" was the CEREC system, by Sirona Dental Systems GmbH, of German origin. [15]. The PROCERA concept by Nobel Biocare was the first system to offer indirect CAD / CAM technology. The first scanner owned a sapphire crystal tip with high hardness for contact scanning. Many years has passed and the technology has changed. Recently Nobel Biocare launched a new scanner, the " Nobel Procera optical scanner " with conoscopic holography technology, which is a collinear scanning technology that measures steep angles and deep cavities, making possible a more precise scanning. Nowadays, many other manufacturers are on the market with different optical technologies for digital scanning.

After the obtaining of the virtual model, the structure or restoration can be virtually designed on the software. The data is sent to a milling unit, which performs the process of machining the designed digital project with high precision and a significant reduction of the clinical and laboratorial. This technique, where the obtaining of the projected is done by milling is classified as a subtraction process. It is possible to obtain prosthetic restorations, abutments or structures in several materials such as wax, acrylic resin, composites, titanium and cobalt chromium alloys, zirconia, alumina, feldspar ceramics, ceramics reinforced with leucite and lithium disilicate. The materials may be present in blocks or pellets, in different sizes and colors [16].

There is another situation where the process is by addition. A concept that nowadays is the subject of discussion all around the world, the obtaining of objects by 3D printing. The direct metal laser sintering (DMLS) technology uses a high temperature laser beam to heat a metal substrate powder selectively, according to the data obtained from the CAD software [17].

Selective laser sintering is a technology that can be used to produce both ceramic and metal restorations. However, instead of cutting, the material is sintered, by continuously adding of the material until the designed piece is completely obtained without any waste of material [17].

Nowadays, it is possible to find many different manufacturers of CAD/CAM systems available on the market. Three different production concepts are available depending on the location of the components of the CAD/CAM system: chairside or in office production; laboratory production or centralized fabrication in a production center [16]. The clinician or technician must know and understand the differences between the systems and the possibilities of each one before making a decision.

The development of CAD / CAM technology in the manufacture of implant structures revolutionized dentistry, providing good clinical outcomes [18,19] and a very good adjustment, with higher accuracy and lower seating mismatch between the components when compared to conventional methods [20-29]. Within the technological advances in implant dentistry it is possible to plan cases virtually, reducing errors and optimizing clinical outcomes. It is even possible to produce computerized surgical guides for faster and less invasive surgeries, accurate prosthetic restorations with high strength and in a great variety of materials. Despite all the advantages and convenience of CAD / CAM systems, the success is not dependent only on of the technology itself, as it involves several steps. All the involved clinical steps should be carried out respecting the right techniques, always seeking the success and the balance between the biological and mechanical factors.

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Capítulo 5

A COMPARATIVE ANALYSES OF THE MISFIT OF IMPLANT-SUPPORTED COBALT-CHROMIUM FRAMEWORKS OBTAINED BY MILLING CENTER CAD/CAM, SINTRON AND CONVENTIONAL CASTING TECHNIQUES.

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Abstract

Purpose: This in vitro study was performed to compare the marginal fit accuracy of 3-unit screw-retained abutment-free frameworks including a very new technology – the Sintron. ***Materials and Methods:*** The frameworks were fabricated with cobalt-chromium (Co-Cr) by two CAD/CAM systems (Production Center – Neodent Digital and Laboratory System – Amann Girrbach and conventionally fabricated by casting, including the UCLA premachined Co-Cr castable abutments and the UCLA fully castable abutments. Two different methods were used to measure the misfit: Scanning Electron Microscopy (SEM) and Interferometry. Vertical misfit values were grouped as percentages and horizontal misfit values were divided as under, equal and overextensions. The data of the vertical misfit for SEM and Interferometry were analyzed by Kruskal-Wallis test followed by Mann-Whitney U test (α=0.05). ***Results:*** The group UCLA fully castable presented significantly higher values of vertical misfit when all screws were tightened compared with all groups. No difference was detected between the Neodent cobalt-chromium CAD/CAM group and the groups UCLA cobalt-chromium or Amann Girrbach cobalt-chromium CAD/CAM. ***Conclusion:*** Within the limitations of this in vitro study, it can be concluded that conventionally fabricated frameworks with UCLA fully castable abutments exhibited the highest vertical misfit values when compared to UCLA premachined Co-Cr castable abutments and CAD/CAM frameworks. All the groups evaluated in this study presented a significant percentile of overhangs in the analysis of horizontal misfit. Furthermore, CAD/CAM fabricated Co-Cr frameworks can be obtained by smaller milling units- Laboratory System and achieve similar fit accuracy as industrial milling units of huge production centers in implant-supported fixed dental prosthesis.

Keywords: Implant/Abutment Interface, Scanning Electron Microscope, Vertical and Horizontal Misfit, Interferometry, Implant-supported frameworks.

Introduction

Metal-ceramic restorations have been available in Dentistry for decades and the use of high-noble alloys for frameworks has been challenged by the introduction of base-metal alloys such as cobalt-chromium. Although, cobalt-chromium alloys have been used in Dentistry for such a long time, very little is known about their behavior and biological impact as framework materials in implant-supported prostheses[1]. Originally, most of the treatments involving implants are composed by several parts, that is called segmented implanted-prostheses. It is a mechanical system that involves the fixture itself, an abutment screwed to the implant platform and the prosthesis placed over the abutment. There is also another option where the prostheses can be connected directly to the implant, which is classified as non-segmented prostheses, abutment-free or implant-level technique[2-5]. Only a few comparative studies have evaluated the clinical results of abutment and abutment-free techniques. Further, very little is known about the differences between abutment and abutment-free prostheses.

Cast frameworks for implant-supported prostheses are associated with misfit problems due to unavoidable casting distortions, especially in multiple frameworks[6-13]. An interface is generated between the implant and abutment, structure or crown. A perfect fit and closure of the interface between the parts is critically important to the success of the restoration since an excessive level of gap could cause harm, such as plaque accumulation, mechanical instability and stress in the cervical area of the implant, leading to bone resorption and soft tissue complications [14-18]. The misfit between the components of any mechanical system can cause instability and in the case of implant-supported restorations can cause several mechanical problems. Additionally, the microleakage present in the misfit between the components of implanted restorations allows the passage of bacteria, and/or their metabolic products as acids and enzymes. These fluids can affect directly the peri-implant tissue, causing inflammation and adverse reactions to the surrounding tissues; the bacteria can start the development of peri-implantitis and subsequent bone and implant loss[19-23]. Many previous studies have discussed the harmful effect caused by marginal misfit of the implant–abutment interface; however, there is no evidence of the acceptable range of misfit.

In the way to solve these kind of problems, several techniques as different types of casting and welding were evolved to minimize the implant abutment misfit and consequently the mechanical and biological complications. With the technological revolution that the world passed in the last years, the CAD/CAM systems become popular and showed great results [10,13,24-31]. Production and milling centers are producing frameworks all over the world for so many years and had proven success[24,32,33]. Although, many other companies are investing in smaller equipment for dental labs and clinics, showing a new concept in CAD/CAM solutions, milling pre sintered Co-Cr blanks. Although, little is known about their accuracy.

This in-vitro study was performed to compare the marginal fit accuracy of 3-unit screw-retained abutment-free frameworks, fabricated with Co-Cr by two CAD/CAM systems (Production Center – Neodent Digital and Laboratory System – Amann Girrbach) and conventionally fabricated by casting, including the UCLA premachined Co-Cr castable abutments and the UCLA fully castable abutments. For this, two different methods were used to measure the misfit: scanning electron microscopy (SEM) and Interferometry. The null hypotheses of this study is that the vertical misfit of abutment-free frameworks fabricated by CAD/CAM technology would be the same of the frameworks conventionally fabricated by casting.

Materials and Methods

Milling Center CAD/CAM, Laboratorial CAD/CAM and conventional casting techniques were evaluated in this study. Twenty frameworks were fabricated with Co-Cr alloy:

- CAD/CAM-fabricated Co-Cr frameworks obtained in an industrial milling unit of a Milling Center – positive control - (Neodent Digital - Neodent, Paraná, Brazil);
- CAD/CAM-fabricated Co-Cr frameworks (Sintron) obtained in a laboratorial smaller equipment (Amann Girrbach, Koblach, Austria);
- Conventionally fabricated Co-Cr alloy frameworks with UCLA premachined Co-Cr abutments with plastic overcastable sleeves (UCLA Co-Cr);
- Conventionally fabricated Co-Cr frameworks with UCLA fully castable abutments – negative control - (UCLA castable).

The conventional casting groups were used as negative controls and the industrial CAD/CAM group was set as positive control. Three external hexagon (EH) implants with regular platforms (4.1 mm diameter × 10 mm, Implant Titamax Cortical Ti; Neodent, Paraná, Brazil) were inserted in an aluminum matrix. Three external hexagon implant transfer copings (antirotational, ⌀4.1 mm, EH, open tray; Implant transfer; Neodent, Paraná, Brazil) were used for implant impression to replicate the matrix into twenty master dyes. The transfer copings were tightened with 10Ncm and splinted with metallic bars fixed with red autopolymerized acrylic resin (Dencrilay; Dencril; São Paulo, Brazil). Then were splinted to the replication device, designed to stabilize the transfers and avoid any displacement during the replication. Implant analogs were attached and Type IV dental stone (Durone IV; Dentsply Intl; Rio de Janeiro, Brazil) was used to obtain the working casts.

For the Neodent CAD/CAM group, the plastic abutments with Co-Cr bases (rotational, ⌀4.1 mm, EH, UCLA Abutment; Neodent) were attached to the analogs for framework waxing. The waxed frameworks were sent to a milling center (Neodent Digital; Neodent, Paraná, Brazil) to standardize the dimensions of the CAD/CAM structures. Initial scanning of the set was performed in a digital, 3-dimensional (3D) laser scanner (3series - Dental Wings Inc. Montreal, Canada) to standardize the dimension of the frameworks. After that, each one of the five master casts was scanned. The images obtained by scanning were managed and the frameworks were developed with a 3D software (DWOS - Dental Wings Open Software). After obtaining the CAD file, the information was conducted to mill the frameworks with a high-speed 5-axis simultaneous motion milling unit. Five frameworks were fabricated from Co-Cr blocks (Co-Cr Neodent Digital; Neodent, Paraná, Brazil). (Fig. 1)

For the Amann Girrbach CAD/CAM - Sintron group, the working casts were also scanned using scan bodies to determine the implants position during the scanning procedure. But in this group, the casts were scanned in another system, ideal for laboratories and much smaller than the industrial equipment of the milling center. The casts were scanned with the Amann Girrbach light scanner (Amann Girrbach, Koblach, Austria) and five virtual models were obtained. The frameworks were designed on the software Ceramill Mind (Amann Girrbach, Koblach, Austria) and after obtaining the CAD file, the information was conducted to the high-speed 5-axis simultaneous motion laboratorial milling unit CeraMill Motion (Amann Girrbach, Koblach, Austria). Five frameworks were fabricated from Co-Cr blanks, the Ceramill Sintron (Sintron; Amann Girrbach, Koblach, Austria); a Co-Cr sinter metal which is processed by dry-milling while still in a soft state and is an interesting option for CAD/CAM in-house fabrication of cobalt-chromium frameworks, respecting the standardized dimensions of all the other samples. After milling, the Co-Cr is sintered using the Ceramill Argotherm sinter furnace (Amann Girrbach, Koblach, Austria), which was specially developed for this indication. All frameworks were simultaneously milled and left unfinished and unpolished for both CAD/CAM groups, each one in its respective system. (Fig. 1)

For the castable groups, a total of ten three-unit frameworks were waxed, five with UCLA fully castable abutments (rotational, ⌀4.1 mm, EH, UCLA abutment; Neodent, Paraná, Brazil) and five with UCLA premachined Co-Cr castable abutments (rotational, ⌀4.1 mm, EH, UCLA abutment; Neodent, Paraná, Brazil). An index was used to standardize the wax dimensions. The structures were polished using sculpture wax (Sculpture Wax, Kota Ind e Com Ltd., São Paulo, Brazil). During the waxing, all the connectors were separated with a blade (Surgical Blade 12 R0304; Swann-Morton Ltd, Sheffield, United Kingdom) and were invested for casting separately. It was then performed the casting by the lost wax technique. For this, the connectors were sectioned to cast separately and avoid severe deformations due to expansion and contraction involved in the casting process. (Fig. 1)

The segments were then included in phosphate coating for high-temperature fast-setting (heat shock, Polidental, São Paulo, Brazil) provided and mixed mechanically in the presence of vacuum, according to the manufacturer's recommendations. After casting, all the frameworks were carefully cleaned by airborne-particle blasting with aluminum oxide particles of 100μm under pressure of 5.08Kg / cm (Jetpro, EDG, Brazil), protecting the cervical of UCLAs and implant analogs. After cleaning, all Co-Cr frameworks were soldered in the master casts and were left unfinished and unpolished. The vertical gap between the framework platform and implant shoulder was evaluated after tightening all retaining screws according to manufacturer's instructions (definitive fit).

Scanning electron microscopy (SEM) was performed at 400x of magnification by the Hitachi Analytical Table Top Microscope TM3000 (Hitachi, Ltd. Japan) for the topographical analysis and measurement of the microgap in the interface. The SEM was regulated under acceleration voltage 20KV, WD = 25mm and spotsize ranging from 25pA to 100pA. For definitive fit, the frameworks were tightened to 20 Ncm with a torquemeter (Neodent, Paraná, Brazil). One mesial and one distal image were obtained for each element; a total of 30 images were obtained per group (n=30). The same operator made all vertical and horizontal misfit measurements in the SEM software. The distance from the implant platform and abutment base was measured (Fig. 2).

After the SEM evaluation, the samples were also analyzed by Interferometry. The implant/abutment interface was analyzed after final fit with all the screws tightened in 20Ncm as recommended by the manufacturer (final fit). The interface was examined in three points on each implant using a white-light interferometer, totaling 45 measurements (n=450) - NewView™ 7300 (Zygo NewView™ 7300, Zygo Corp., USA). The scanning interferometry mode was set with optical resolutions of x5 magnification. The measurements were measurements were performed from the implant platform to the abutment base as done prior on the SEM test, permitting a comparison between both methods (Fig. 3).

The minimum and maximum values in micrometers were calculated for each group and method. Vertical misfit values were grouped as percentages according to the following values: <10 µm and >10µm. Horizontal misfit values were divided as: underextension, equally extended, and overextension of crowns fitted to the prepared finish line. The percentage for each category was calculated (Fig. 4). Statistical analysis was performed with the statistical software Sigma Plot (Systat Software Inc. version 12.0, San Jose, CA, USA). Data normality was assessed by Shapiro-Wilk test. The data of the vertical misfit when all screws were tightened for SEM and Interferometry were analyzed by Kruskal-Wallis test followed by Mann-Whitney U test ($\alpha=0.05$). The data of SEM single screw test were analyzed by one-way ANOVA test followed by Tukey test ($\alpha=0.05$). The minimum critical value of vertical misfit for definitive fit was determined to be 10 µm [34] . Therefore, the specimens were divided into groups on the basis of higher or lower values than 10 µm with a percentile.

Figure 1 – A- UCLA fully castable abutments framework; B- UCLA premachined Co-Cr overcastable framework; C - Neodent CAD/CAM; D- Amann Girrbach CAD/CAM.

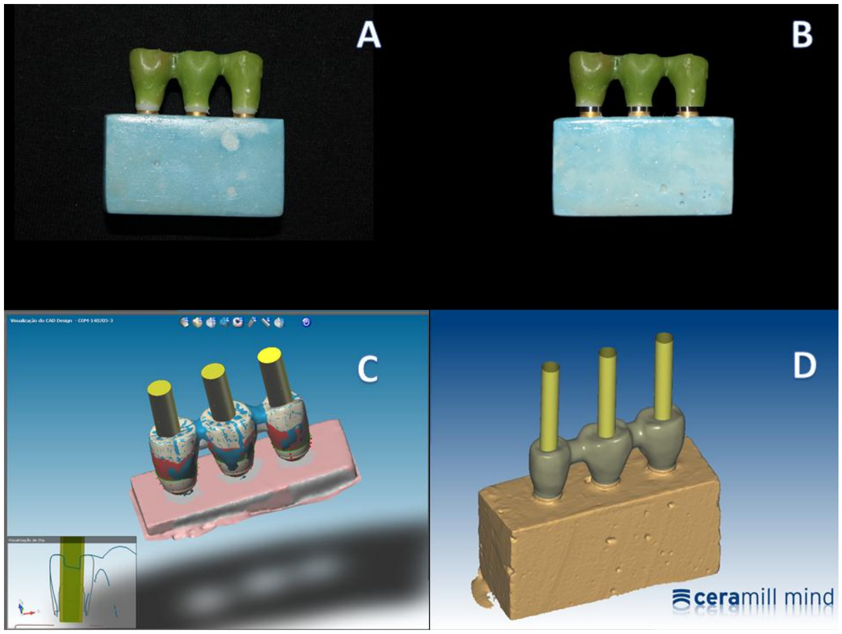


Figure 2 – Scanning electron microscope image (400x of magnification) of analysis measurement.

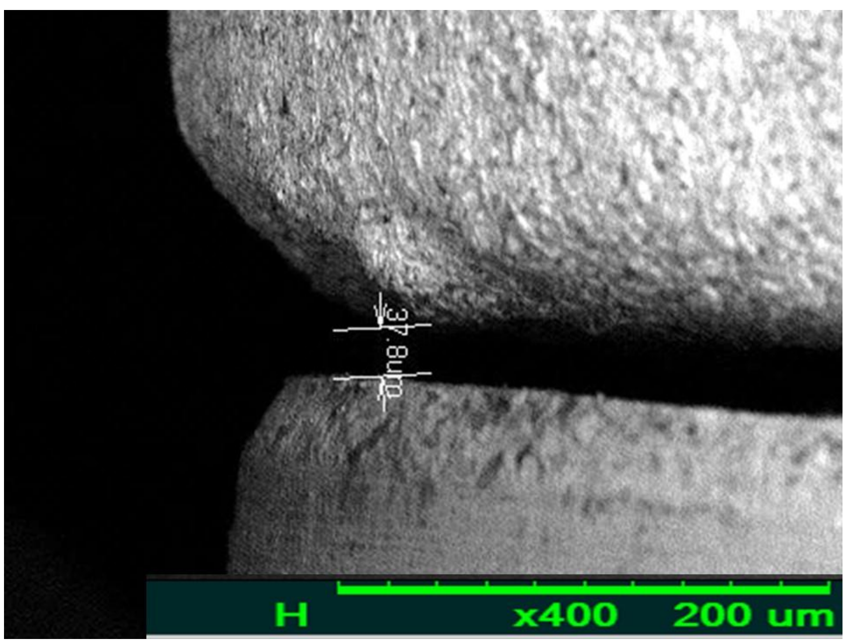
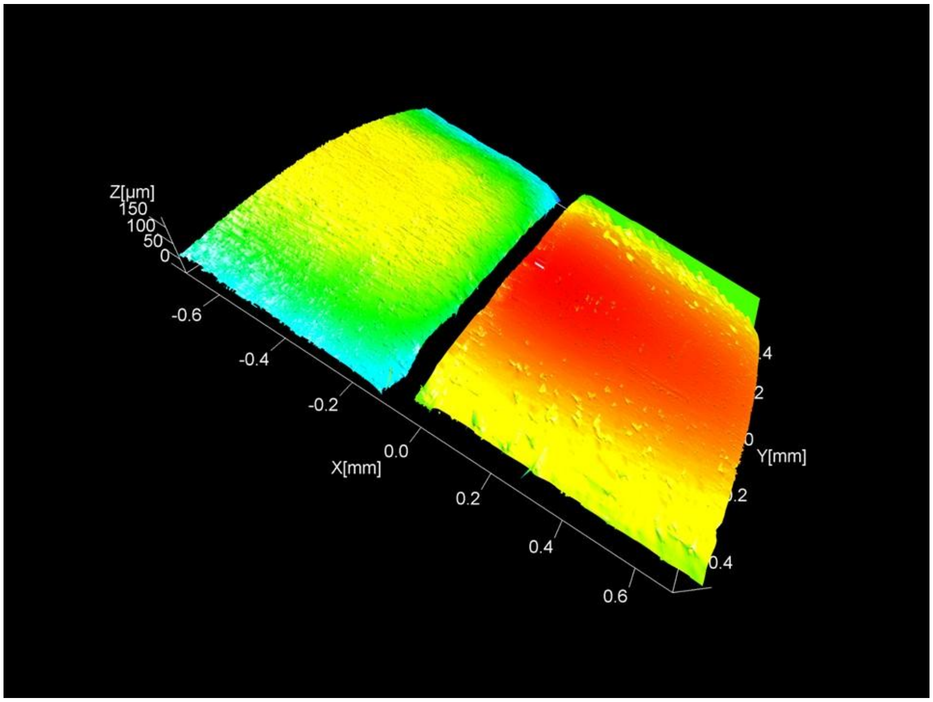


Figure 3 – Reconstructed surfaces with interferometric microscopy of the implant/framework interface.



Results

Minimum and maximum vertical misfit values (µm) are shown in Table I (SEM) and Table II (Interferometry).

The Kruskal-Wallis test demonstrated significant difference (P<.001) among the groups analyzed and Mann-Whitney U test revealed that the UCLA castable presented significantly higher values when compared with all groups. No difference was detected between the Neodent cobalt-chromium CAD/CAM group and the groups UCLA cobalt-chromium or Amann Girrbach cobalt-chromium CAD/CAM.

Vertical misfit values percentages for each group are shown in Table III (SEM) and Table IV (Interferometry). The minimum critical value of vertical misfit for definitive fit was determined to be 10 mm. Therefore, the specimens were divided into groups on the basis of higher or lower values than 10 mm with a percentile. Horizontal misfit values were also calculated for each group (Fig. 3)

Table I – SEM - Minimum and maximum of vertical misfit values (µm) and significance with all screws tightened.

Group	Min-Max	Significance
Neodent CoCr	0 – 36.1	A
UCLA Castable	0 – 52.9	B
UCLA CoCr	0 – 29.8	A
Amann CoCr	0 – 60.5	A

Values with same letter are not significantly different (*P*<.05).

Table II – Interferometry - minimum and maximum of vertical misfit values (µm) and significance with all screws tightened.

Group	Min-Max	Significance
Neodent CoCr	6 – 14	A
UCLA Castable	13 – 34	B
UCLA CoCr	9 – 15	A
Amann CoCr	8 – 14	A

Values with same letter are not significantly different (*P*<.05).

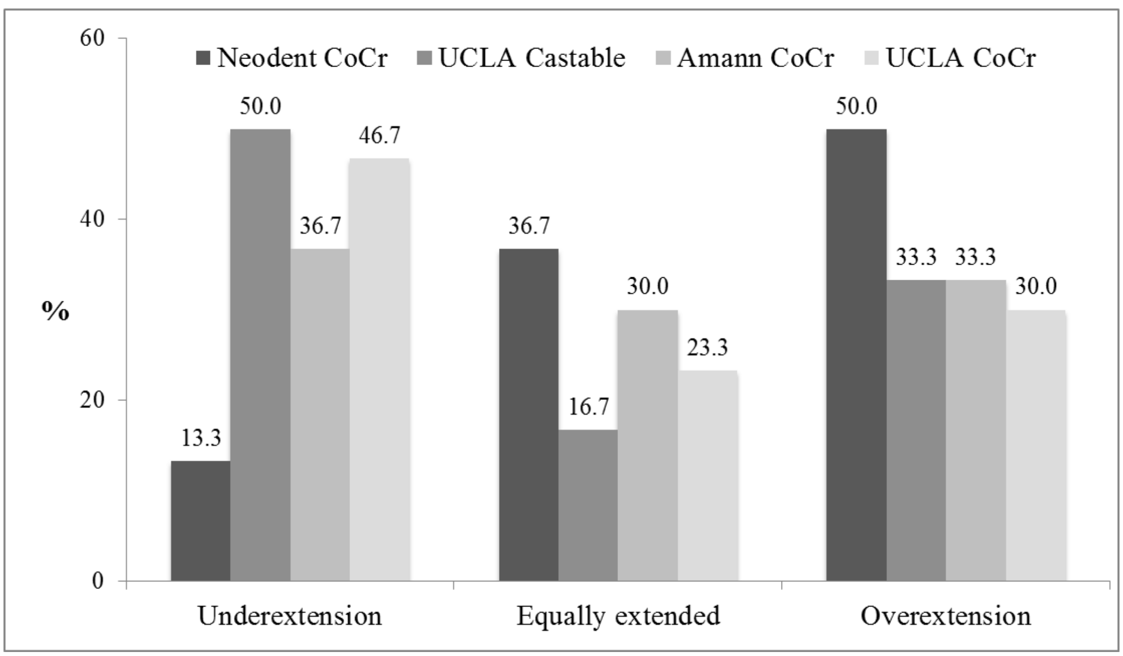
Table III – SEM – Ranges of vertical misfit for each group (%).

Group	<10µm	>10µm
Neodent CoCr	66	34
UCLA Castable	10	90
UCLA CoCr	53.3	46.7
Amann CoCr	63.3	36.7

Table IV – Interferometry - Ranges of vertical misfit for each group (%).

Group	<10µm	>10µm
Neodent CoCr	62.2	37.8
UCLA Castable	0	100
UCLA CoCr	71.2	28.8
Amann CoCr	64.4	35.6

Figure 4 – Percentile of horizontal misfit values calculated for each group.



Discussion

The null hypothesis of this study that the vertical misfit of abutment-free frameworks fabricated by CAD/CAM technology would be the same of the frameworks conventionally fabricated by casting was rejected. The UCLA castable group presented significantly higher values when compared with all groups.

Many studies tried to define the misfit numerically, but there was no agreement to quantify the acceptable level of the misfit[35]. This may be due to the fact that there is no standardizing in the research field in this issue. The implant/abutment misfit is a controversial theme. Several scanning electron microscopy researches have been published comparing the vertical and horizontal misfits between the External Hexagon implants (HE) and infrastructure made by different laboratories, materials and welding techniques[7-9,12,13,36] compared fixed prostheses three, four and five elements cast in one-piece with gold alloy, targeted and subsequently welded. With this study, the authors concluded that the distortion was a three-dimensional phenomenon, the lower the fixed prosthesis three elements and higher in fixed prostheses of five elements. Thus, problems related to the setting of castable components may be linked to the amount of soldering required points in the same structure.

In this study, the SEM was performed at 400x of magnification, what permits a very precise measurement of the junction gap. It was also used an angled device that standardize the position of the sample inside the equipment, with the plane parallel to the base. In this way, all the measurements were performed in the same position, because all of them were analyzed in the same metallic matrix. The Interferometry is very reliable method that can be used to analyze nano-surfaces end consequently a misfit between two plane pieces. In this study, the interferometry was performed for all samples with three measurements in each implant/abutment interface. It was also used in a previous study to analyze implant/abutment interface accuracy[37]. The Interferometry analysis confirmed the SEM results, showing the worse values to the fully castable group. Although there is no actual definition, a implant-supported framework can be considered passive if it does not generate static loads and strains within the prosthesis or in the surrounding bone[34,38-40]. The passive fit was defined as a clinical situation that will not produce or cause any long-term clinical harm[38].

Branemark[34] preconized that the acceptable misfit limit of implant frameworks was should be smaller than 10 microns. On the other hand, another study stated that a 30µm gap at the implant–abutment interface could be acceptable[41]. An absolute and passive fit of the abutment or framework to the implant has been considered vital for long-term clinical success. The detection of misfits at the interface is a clinical challenge in prosthodontics. Various methods have been suggested to evaluate the fit[35]. These methods include probing with dental probes, direct vision and alternating finger pressure in the framework to check the passivity. The Sheffield test (the single screw test) one screw will be tightened at one the end of the framework and then the discrepancies observed at the other terminal screw. Screw resistance during tightening procedure - if that screw needed more than extra half a turn to achieve the optimum screw seating, the framework is considered misfit. Intraoral radiography is the most popular method for the verification of the gap at the implant–abutment interface. Intraoral radiography, however, shows certain limitations and false diagnosis of the image exam[42-44]. None of these methods is truly reliable on its own, using them in combinations seems to be a good clinical way to achieve good results.

The implant impression technique itself depends on several facts. Kim et al.[45] studied the machining tolerance of implant components and found that the combined values found can give more than 60 microns of machining tolerance for single pre-machined abutment, the technique and material can also produce distortion. All this variation can affect the working model and consequently the final fit.

The horizontal misfit is also a very delicate issue. The presence of overextension of the framework over the platform can cause bacterial colonization and peri-implant complications. Due to large mismatches occurring during the casting procedure and the risk of allergy to Nickel[46], present in non-noble alloys (e.g. Ni-Cr alloy), the use of implant-level structures (directly in the implant platform without the use of any abutment has been discouraged. Titanium veneering is always a challenge and depends on several technical skills, so it is not very common in dental laboratories. The cobalt-chromium (Co-Cr) pre-machined bases for over-castings were developed to minimize these misfits. However, little information has been published on the marginal adaptation of these kind of abutment-free frameworks. The CAD/CAM companies and the software developers must try their best to improve the overextensions problem. These parameters seem to be calibrated to fit the implant platform limit, the authors believe that the settings should always provide an underextension, avoiding overhangs and consequently, the problems that it can lead.

The CAD/CAM frameworks has gained more and more space in the dental labs and clinics in the last few years. Production and milling centers are producing frameworks all over the world for so many years and has proven your success[24,32,33]. Although, many other companies are investing in smaller equipment for dental labs and clinics, showing a new concept in CAD/CAM solutions. The Amann Girrbach – Sintron frameworks are one example of this new concept. This smaller equipment was compared to a production center (Neodent Digital) and has showed similar results as shown in the results of this study.

The measurement of the microgap is an aspect currently questioned, about its influence on mechanical and biological aspects[19-23,47]. The existence of mismatches between the implant/abutment junction can favor the development of microorganisms, contributing to the marginal bone loss and also the failure of osseointegration. The presence of a vertical misfit can reduce mechanical stability of the assembly and act as a space for the accumulation of bacteria, influencing the flow of the bacterial level in this region[19-23,47]. The CAD/CAM structures showed a very accurate and passive fit and were obtained in a short period of time when compared to the other techniques. It also avoided the welding process, that is necessary and mandatory in multiple structures in the way to obtain a passive fit with less misalignments. The pre-machined based structures also exhibited a very accurate fit, but the time to obtain them and the technical dependence are disadvantages in this technique. The surfaces of the castable structures analyzed in this study showed more roughness and the presence of more imperfections when compared to the machined surfaces. The mismatch values obtained on casting UCLA abutments can be influenced when processed by different laboratories and also the conventional welding process itself enhances the degree of the infrastructure mismatch independent laboratory that carried[6]. Although the results were also presented by the conventional statistic, the authors believe that the right way to quantify misfits in any kind of restoration is the percentile, because of the heterogeneous values inside the same sample. The percentile is capable to give a very clear idea about the accuracy of the tested materials or techniques[12,13, 28,29,31].

The use of abutment-free resolutions appears to be necessary and effective in several clinical situations, such as the lack of prosthetic space, the presence of very shallow sulcus, besides having a more affordable price and superior workability to the segmented prosthesis. However, the indiscriminate use induced by economic factors should be noted with caution. The results of this and other studies shows that the mismatches present in such components may represent prone areas to bacterial colonization, which can be harmful to the peri-implant tissues. In this way, abutment-free resolutions, with a very close relationship with the adjacent bone should be performed by CAD/CAM or with a pre-machined junction, minimizing the implant/framework misfit.

Conclusion

Within the limitations of this in vitro study, it can be concluded that CAD/CAM-fabricated CoCr frameworks and premachined Co-Cr base castable abutments casted, sectioned and welded exhibit a very passive fit and are clinically acceptable. As expected, fully castable abutments conventionally fabricated frameworks (negative control) exhibited the highest vertical misfit values when compared to premachined Co-Cr base castable abutments and CAD/CAM-fabricated frameworks. Furthermore, CAD/CAM fabricated Co-Cr frameworks can be obtained by smaller milling units and achieve similar fit accuracy as industrial milling units of huge production centers (positive control) in implant-supported FDPs.

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Capítulo 6

COMPARATIVE ANALYSIS OF CAD/CAM ZIRCONIA IMPLANT-SUPPORTED FRAMEWORKS

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ABSTRACT

Statement of problem. Little information is available on the accuracy of the computer-aided design and computer-aided manufacturing (CAD/CAM) fabricated zirconia frameworks.

Objective: This in-vitro study was performed to compare the marginal fit accuracy of 3-unit screw-retained abutment-free frameworks, fabricated with zirconia in a milling center (positive control), fabricated with two different tabletop CAD/CAM systems (test groups), compared to conventionally fabricated by casting with Co-Cr the UCLA fully castable abutments (negative control).

Materials and Methods: Two different methods were used to measure the misfit: Scanning Electron Microscopy (SEM) and Interferometry. Vertical misfit values were grouped as percentages and horizontal misfit values were divided as under, equal and overextensions. The data of the vertical misfit for SEM and Interferometry were analyzed by Kruskal-Wallis test followed by Mann-Whitney U test (α=0.05).

Results: The group UCLA fully castable presented significantly higher values when compared with all groups. No difference was detected between the Neodent Zirconia CAD/CAM group and the groups Amann Girrbach Zirconia or Zirkonzahn. ***Conclusion:*** Within the limitations of this in vitro study, it can be concluded that CAD/CAM-fabricated zirconia frameworks exhibit a very passive fit and are clinically acceptable. Conventionally fabricated frameworks with UCLA fully castable abutments exhibited the highest vertical misfit values when compared to CAD/CAM-

fabricated frameworks. All the groups evaluated in this study presented a significant percentile of overhangs in the analysis of horizontal misfit. Furthermore, CAD/CAM-fabricated zirconia frameworks can be obtained by smaller milling units and achieve similar fit accuracy as industrial milling units of huge production centers in implant-supported fixed dental prosthesis.

Keywords: Implant/Abutment Interface, Scanning Electron Microscope, Vertical and Horizontal Misfit, Interferometry, Implant-supported frameworks, Zirconia.

Clinical Implications: CAD/CAM zirconia structures may be considered as an alternative for fabricating 3-unit, screw-retained implant-supported frameworks.

INTRODUCTION

Metal-ceramic crowns have been used in dentistry for many years with satisfactory and long term clinical performance[1,2]. The result of a successful implant treatment depends on the balance between biological and mechanical factors. Mechanical problems are directly associated to the stability of the components[3]. Depending on the degree of the mismatch between the implant and the restoration, complications may occur including adverse biological reaction of the surrounding tissues, pain, peri-implant bone resorption and also the loose of the osseointegration[4,5]. The most related mechanical complications are fracture of the prosthetic screw, fracture of the structure and also the implant fracture[6-8]. To avoid such complications, the perfect fit of implanted structures is always a challenge.

A good passivity is difficult to be achieved in the conventional processes used by many dental laboratories. Cast frameworks for implant-supported prostheses are associated with misfit problems due to unavoidable casting distortions, especially in multiple frameworks. In the way to minimalize these problems, several techniques as different types of casting and welding were evolved to minimize the implant abutment misfit and consequently the mechanical and biological complications. Several procedures have been proposed to improve the fit of implant frameworks. It can vary from addition of fit refinement steps or elimination of fabrication steps. The refinement steps include sectioning and soldering/laser welding, spark erosion with an electric discharge machine (EDM), and bonding the structure to prefabricated base cylinders[9]. The second category includes computer-aided design/computer-aided manufacturing (CAD/CAM) and other prototyping technologies. The computer-aided design/computer-aided manufacturing technology (CAD/CAM) was present in different areas of engineering and in the last few years has gained so much popularity in dental practice. The development of CAD/CAM technology in the manufacture of prosthetic dental structures has revolutionized the dental practice, providing adjustment with higher accuracy and lower seating mismatch values when compared to conventional methods[10-13]. It also permits the structures obtaining in a short time and in different materials. The potential for CAD/CAM to enhance the precision is based on eliminating some fabrication steps, such as waxing, investing, and casting[9].

Recently, metal-free solutions have gained popularity in dental practice too and one of the most popular materials to obtain implant-supported frameworks is the zirconia, due to its high fracture strength[14-16]. Production and milling centers are producing frameworks all over the world for so many years and had proven their[17-19]. Although, many other companies are investing in smaller tabletop equipment for dental labs and clinics, showing a new concept in CAD/CAM solutions, turning it to a versatile way to obtain implant-supported frameworks.

This in-vitro study was performed to compare the marginal fit accuracy of 3-unit screw-retained abutment-free frameworks, fabricated with zirconia in a milling center (positive control), fabricated with two different tabletop CAD/CAM systems (test groups), compared to conventionally fabricated by casting with Co-Cr the UCLA fully castable abutments (negative control). . For this, two different methods were used to measure the misfit: Scanning Electron Microscopy (SEM) and Interferometry. The null hypotheses of this study is that the vertical misfit of abutment-free frameworks fabricated by CAD/CAM technology would be better than the frameworks conventionally fabricated by casting.

MATERIAL AND METHODS

Milling Center CAD/CAM (positive control)[13], Laboratorial CAD/CAM and conventional casting techniques (negative control) were evaluated in this study. Twenty frameworks were fabricated, five for each group by:

- CAD/CAM-fabricated zirconia frameworks obtained in an industrial milling unit of a Milling Center (Neodent Digital - Neodent, Paraná, Brazil);
- CAD/CAM-fabricated zirconia frameworks obtained in a laboratorial smaller equipment (Amann Girrbach , Koblach, Austria)
- CAD/CAM-fabricated zirconia frameworks obtained in a laboratorial smaller equipment (Zirkonzahn GmbH; Gais, Italy);
- Conventionally fabricated Co-Cr frameworks with UCLA fully castable abutments (UCLA castable; Neodent, Paraná, Brazil).

The conventional casting group was set as negative control and the industrial CAD/CAM group was set as the positive control. Three external hexagon (EH) implants with regular platforms (4.1 mm diameter × 10 mm, Implant Titamax Cortical Ti; Neodent, Paraná, Brazil) were inserted in an aluminum matrix. Three external hexagon implant transfer copings (antirotational, ⌀4.1 mm, EH, open tray; Implant transfer; Neodent, Paraná, Brazil) were used for implant impression to replicate the matrix into twenty master dyes. The transfer copings were tightened with 10Ncm and splinted with metallic bars fixed with red autopolymerized acrylic resin (Dencrilay; Dencril; São Paulo, Brazil). Then were splinted to the replication device, designed to stabilize the transfers and avoid any displacement during the replication. Implant analogs were attached and Type IV dental stone (Durone IV; Dentsply Intl; Rio de Janeiro, Brazil) was used to obtain the working casts.

For the Neodent CAD/CAM group, the plastic abutments (rotational, ⌀4.1 mm, EH, UCLA Abutment; Neodent) were attached to the analogs for framework waxing. The waxed frameworks were sent to a milling center (Neodent Digital; Neodent, Paraná, Brazil) to standardize the dimensions of the CAD/CAM structures. Initial scanning of the set was performed in a digital, 3-dimensional (3D) laser scanner (3series - Dental Wings Inc. Montreal, Canada) to standardize the dimension of the frameworks. After that, each one of the five master casts was scanned. The images obtained by scanning were managed and the frameworks were developed with a 3D software (DWOS - Dental Wings Open Software). After obtaining the CAD file, the information was conducted to mill the frameworks with a high-speed 5-axis simultaneous motion milling unit. Five frameworks were fabricated from Zirconia blocks (Neodent Digital; Neodent, Paraná, Brazil). (Fig. 1)

For the Amann Girrbach CAD/CAM group, the working casts were also scanned using scan bodies to determine the implants position during the scanning procedure. But in this group, the casts were scanned in another system, ideal for laboratories and much smaller than the industrial equipment of the milling center. The casts were scanned with the Amann Girrbach light scanner (Amann Girrbach, Koblach, Austria) and the virtual models were obtained. The frameworks were designed on the software Ceramill Mind (Amann Girrbach, Koblach, Austria) and after obtaining the CAD file, the information was conducted to the high-speed 5-axis simultaneous motion laboratorial milling unit CeraMill Motion (Amann Girrbach, Koblach, Austria). Five frameworks were fabricated from zirconia blanks (Amann Girrbach, Koblach, Austria); After milling, the zirconia frameworks were sintered using the Ceramill Therm sinter furnace (Amann Girrbach, Koblach, Austria), which was specially developed for this indication. (Fig. 1)

For the Zirkonzahn group, the casts were scanned with the Zirkonzahn Optical scanner (S600 ARTI, Zirkonzahn, Gais, Italy) and the virtual models were obtained. The frameworks were designed on the software (Zirkonzahn.Modellier, Zirkonzahn, Gais, Italy). After obtaining the CAD file, the information was conducted to the high-speed 5-axis simultaneous motion laboratorial milling unit. The Zirconia blocks were milled with M5 milling machine (Zirkonzahn GmbH; Gais, Italy). Five frameworks were fabricated from zirconia blocks (Prettau Zircon; Zirkonzahn, Gais, Italy), respecting the standardized dimensions of all the other samples. After milling, the obtained frameworks were sintered in Zirkonofen 600/V2 furnace (Zirkonzahn, Gais, Italy). All frameworks were simultaneously milled, sintered in the respective system and left unfinished and unpolished for both CAD/CAM groups, each one in its respective system. (Fig. 1)

For the castable group, a total of five three-unit frameworks were waxed with UCLA fully castable abutments (rotational, ⌀4.1 mm, EH, UCLA abutment; Neodent, Paraná, Brazil). An index was used to standardize the wax dimensions. The structures were polished using sculpture wax (Sculpture Wax, Kota Ind e Com Ltd., São Paulo, Brazil). During the waxing, all the connectors were separated with a blade (Surgical Blade 12 R0304; Swann-Morton Ltd, Sheffield, United Kingdom) and were invested for casting separately. It was then performed the casting by the lost wax technique. For this, the connectors were sectioned to cast separately and avoid severe deformations due to expansion and contraction involved in the casting process. (Fig. 1)

The segments were then included in phosphate coating for high-temperature fast-setting (heat shock, Polidental, São Paulo, Brazil) provided and mixed mechanically in the presence of vacuum, according to the manufacturer's recommendations. After casting, all the frameworks were carefully cleaned by airborne-particle blasting with aluminum oxide particles of 100µm under pressure of 5.08Kg / cm (Jetpro, EDG, Brazil), protecting the cervical of UCLAs and implant analogs. After cleaning, all Co-Cr frameworks were soldered in the master casts and were left unfinished and unpolished. The vertical gap between the framework platform and implant shoulder was evaluated after tightening all retaining screws according to manufacturer’s instructions (definitive fit), with two measurements in each implant, one mesial and one distal, totaling 30 measurements per group, n=30.

Scanning electron microscopy (SEM) was performed at 400x of magnification by the Hitachi Analytical Table Top Microscope TM3000 (Hitachi, Ltd. Japan) for the topographical analysis and measurement of the microgap in the interface. The SEM was regulated under acceleration voltage 20KV, WD = 25mm and spotsize ranging from 25pA to 100pA. An angle controller device was used to standardize the position of the metallic matrix inside the microscope. For definitive fit, the frameworks were tightened to 20 Ncm with a torquemeter (Neodent, Paraná, Brazil). One mesial and one distal image were obtained for each element; a total of 30 images were obtained per group (n=30). The same operator made all vertical and horizontal misfit measurements in the SEM software. The distance from the implant platform and abutment base was measured (Fig. 2). The final fit and one screw fit values were compared among groups.

After the SEM evaluation, the samples were also analyzed by interferometry. The implant/abutment interface was analyzed after final fit with all the screws tightened in 20Ncm as recommended by the manufacturer. The interface was examined in three points on each implant using a white-light interferometer, totaling 45 measurements - NewView™ 7300 (Zygo NewView™ 7300, Zygo Corp., USA). The scanning interferometry mode was set with optical resolutions of 5x of magnification. The measurements were performed by the same trained operator in the equipment’s software. The measurements were performed from the implant platform to the abutment base as done prior on the SEM test, permitting a comparison between both methods (Fig. 3).

The minimum and maximum values in micrometers were calculated for each group and for each method. Vertical misfit values were grouped as percentages according to the following values: <10 µm and >10µm[13,20].

Horizontal misfit values were divided as: underextension, equally extended, and overextension of crowns fitted to the prepared finish line. The percentage for each category was calculated (Fig 4). Statistical analysis was performed with the statistical software Sigma Plot (Systat Software Inc. version 12.0, San Jose, CA, USA). Data normality was assessed by Shapiro-Wilk test. The data of the vertical misfit for SEM and Interferometry were analyzed by Kruskal-Wallis test followed by Mann-Whitney U test (α=0.05). The minimum critical value of vertical misfit for definitive fit was determined to be 10 µm[21]. Therefore, the specimens were divided into groups on the basis of higher or lower values than 10 mm with a percentile.

Figure 1 – A - UCLA fully castable abutments framework; B - Neodent CAD/CAM;   C - Amann Girrbach CAD/CAM. D – Zirkonzahn CAD/CAM.

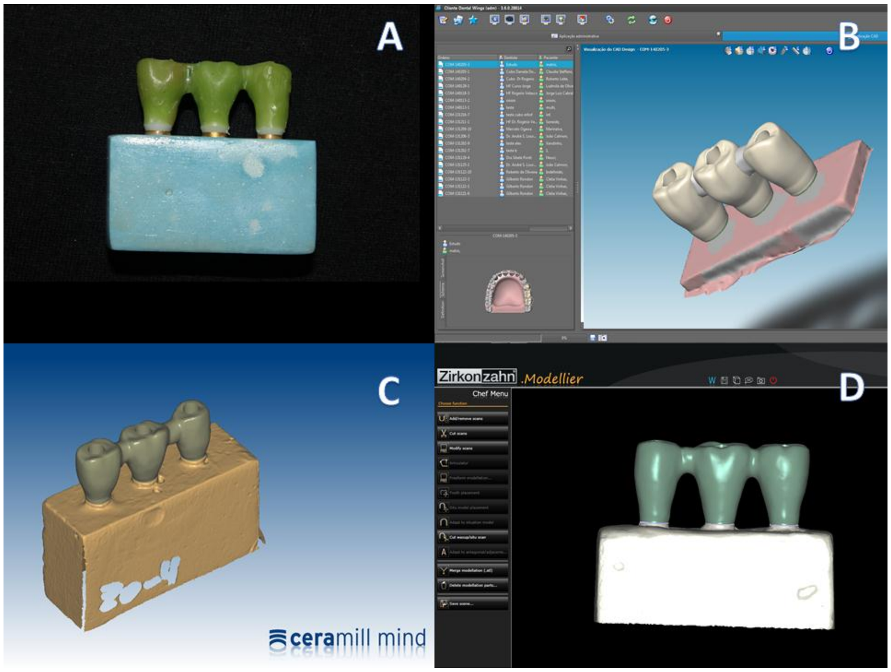


Figure 2 – Scanning electron microscope image (400x of magnification) of analysis measurement.

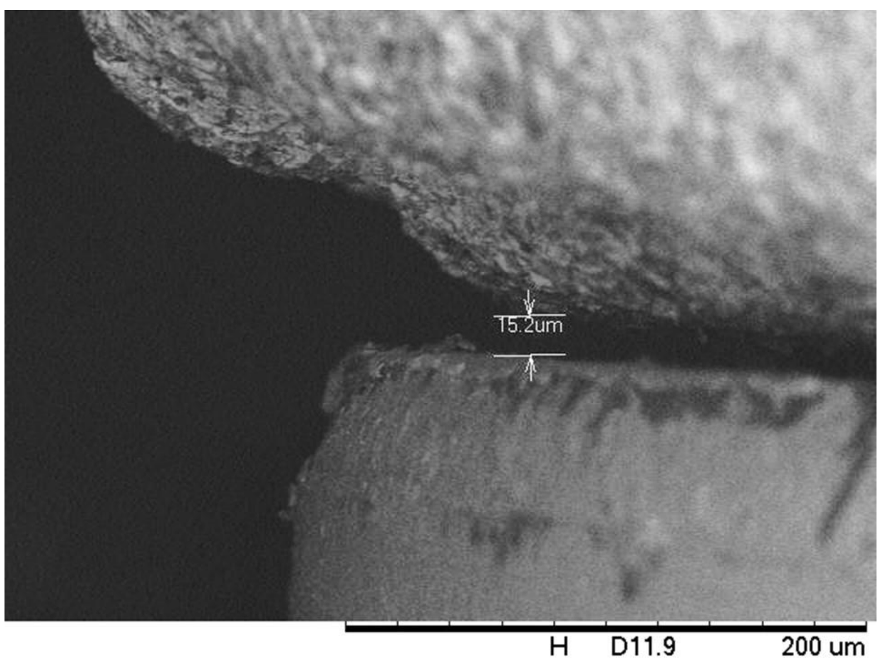
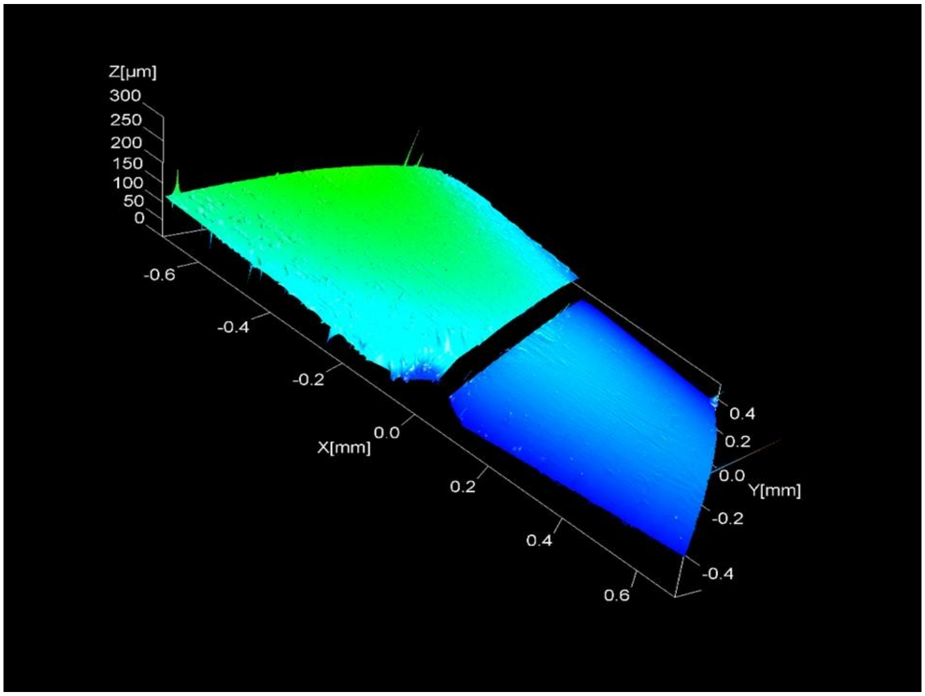


Figure 3 – Reconstructed surfaces with interferometric microscopy of the implant/framework interface.



RESULTS

Minimum and maximum vertical misfit values (µm) are shown in Table I (SEM) and Table II (Interferometry). The Kruskal-Wallis test demonstrated significant difference (P<.001) among the groups analyzed and Mann-Whitney U test revealed that the UCLA castable presented significantly higher values when compared with all groups. No difference was detected between the Neodent Zirconia CAD/CAM group and the groups Amann Girrbach Zirconia or Zirkonzahn. Vertical misfit values percentages for each group are shown in Table III (SEM) and Table IV (Interferometry). The SEM single screw test is demonstrated in Table V.

Horizontal misfit values were also calculated for each group (Fig. 4).

Table I – SEM – minimum and maximum of vertical misfit values (µm) and significance

Group	Min-Max	Significance
Neodent Zirconia	0 – 28.3	A
UCLA Castable	0 – 52.9	B
Amann Zirconia	0 – 98.0	A
Zirkonzahn	0 – 41	A

Values with same letter are not significantly different (*P*<.05).

Table II – Interferometry – minimum and maximum of vertical misfit values (µm) and significance.

Group	Min-Max	Significance
Neodent Zirconia	5 – 13	A
UCLA Castable	13 – 34	B
Amann Zirconia	5 – 12	A
Zirkonzahn	7 – 14	A

Values with same letter are not significantly different (*P*<.05).

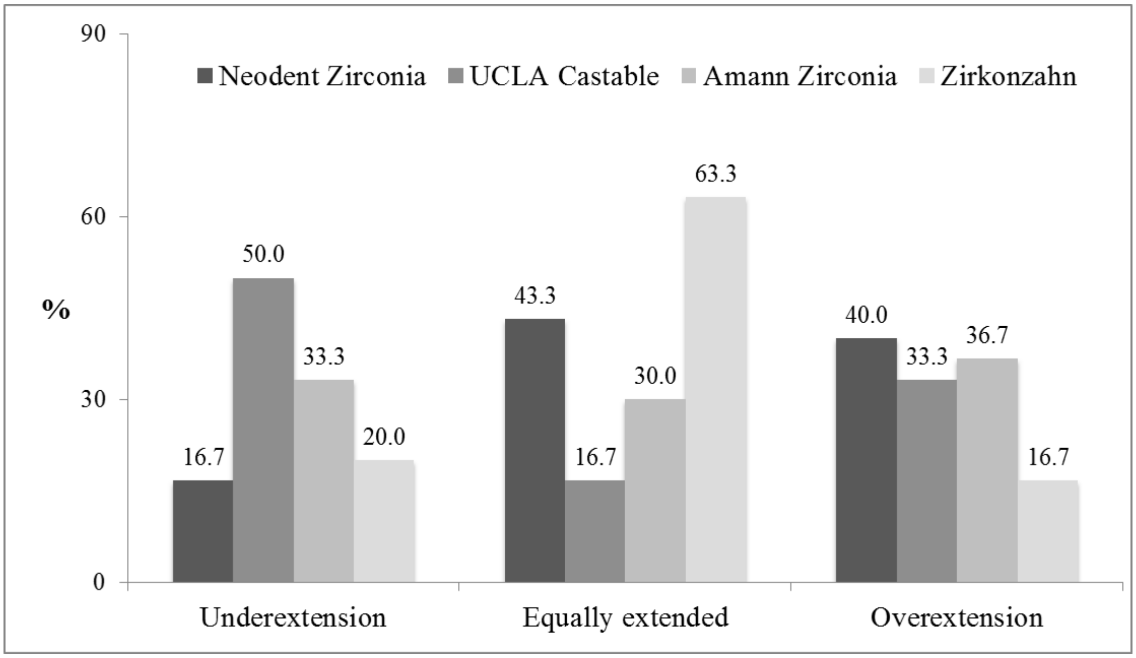
Table III – SEM – Ranges of vertical misfit for each group (%).

Group	<10µm	>10µm
Neodent Zirconia	63.4	36.6
UCLA Castable	10	90
Amann Zirconia	70	30
Zirkonzahn	86.7	13.3

Table IV – Interferometry – Ranges of vertical misfit for each group (%).

Group	<10µm	>10µm
Neodent Zirconia	88.8	11.2
UCLA Castable	0	100
Amann Zirconia	95.5	4.5
Zirkonzahn	88.8	11.2

Figure 3 – Percentile of horizontal misfit values calculated for each group.



DISCUSSION

The null hypothesis of this study that the vertical misfit of abutment-free frameworks fabricated by CAD/CAM technology would be better the frameworks conventionally fabricated by casting was accepted. The UCLA castable group presented significantly higher values when compared with all groups.

The perception of misfits at the implant/abutment interface is a clinical challenge in the daily practice of implant dentistry. Several methods have been suggested to evaluate the framework's fit[22]. Radiographic images are the most popular method for the verification passivity of the implant–abutment interface. Although, intraoral radiography, however, shows certain limitations and false diagnosis. Probing with dental probes, direct vision and alternate finger pressure in the framework are other common clinical tests to check the passivity. There is also the Sheffield test (one screw test) where a screw will be tightened at the end of the framework and then the discrepancies observed at the other terminal screw. Another important issue is the screw passivity, screw resistance during tightening procedure in one of the screws may suggest some kind of misfit[23-25]. None of these methods is completely accurate and reliable on its own, using them in combinations seems to be the best way to achieve good clinical results. Showing the results by two different ways aims to present the possible differences with more clarity. Although, the authors believe that the most important way is the percentile, because it is capable to contrast the acceptable values with the critical ones.

The presence of microgaps between the implant/abutment connection can favor the development of bacteria, leading to adverse reactions of the surrounding tissues, marginal bone loss and also the failure of osseointegration.[26-28]. The presence of a vertical misfit can also reduce mechanical stability of the system and bring several mechanical problems. [3-8]. The distortion is a three-dimensional phenomenon and larger structures has more distortion than smaller ones. Thus, problems related to the setting of castable components may be linked to the amount of soldering required points in the same structure[29]. It is clear in the results of the present study that the frameworks fabricated by CAD/CAM presented better passivity. The frameworks made by casting passed through several steps to achieve the best fit as possible and still had the worst passive fit and higher variability of results. Therefore, this technique can be considered less accurate.

The misfit between implant parts is an aspect currently questioned because of its influence on mechanical and biological aspects[27,28,30-32]. Several studies tried to define what is an acceptable misfit numerically, but there was no consensus to quantify the acceptable level of the misfit[22]. This can be attributed to the lack of standardizing in the related research field. Although there is no valid definition, an implant-supported framework can be considered passive if it does not generate static loads and strains in the prosthesis or in the peri-implant tissues[21,33-35]. A passive fit of the abutment or framework to the implant has been considered vital for long-term clinical success. The accuracy of implant/abutment interface is a controversial theme. Branemark affirmed that the acceptable misalignment limit of implant frameworks should be lower than 10 microns[21].

Many scanning electron microscopy studies have been published in the last years comparing the vertical and horizontal misfits between the External Hexagon implants (HE) and frameworks made by different ways, materials and welding techniques[13,20,36-38]. Different results were found due to the fact that there is no standardizing in the tests. In the present study, the SEM was performed at 400x of magnification, what permits a very accurate measurement of the junction mismatch. An angle controller device was also used that standardize the position of the sample inside the equipment. Therefore, all the samples were measured in the same position. The complementary test was the Interferometry. It is a very reliable method that is capable to analyze nano-surfaces and consequently the misalignment between the implant/abutment[39.] In the present study, the Interferometry analysis confirmed the SEM results, showing the highest misfit values to the fully castable frameworks. This method is sensible to detect the micro roughness between the junction of two pieces, independent of the presence of a gap or not.

Because of the heterogeneous values inside the same sample, in the present study, the results were presented in two different ways for both tests. Although the results are presented by the conventional statistical analyses, the results are also organized in percentile, which seems to be the best way to quantify misfits in any kind of restoration is the percentile, that is capable to give a very reliable idea about the accuracy of the tested materials or techniques[20,40-42].

The highlight of CAD/CAM systems is in avoiding several fabrication steps, including waxing, investment casting, and polishing, what can eliminate distortions present in all of this steps. An additional advantage is avoiding welding joints, which are considered weak links and probable failure zones[9]. The zirconia blocks were milled with 20% to 25% larger dimensions and were sintered to obtain the definitive framework. In the sintering process, the zirconia frameworks shrink until hit the definitive framework design dimensions with the appropriate resistance and physical properties. However, micrometric dimensional distortions can occur in different directions because shrinkage due to sintering is uncontrollable[13]. The amount of shrinkage represents a challenge for the software developers that have to calculate and accurately mill an enlarged framework that will shrink precisely to the final dimension after sintering[13] .

Here is the importance of using original zirconia blanks and sintering furnaces for each system, because the mathematical codes of shrinking, present in the software and calculated for a precise and accurate fit. This was verified in the present study, even with the shrinkage present in the sintering process, all the three CAD/CAM zirconia groups exhibited better fit than the conventionally castable obtained frameworks.

In the last few years, with the great technological revolution of the modern world, the CAD/CAM systems have gained so much popularity in the dental labs and clinics. Production and milling centers are producing frameworks all over the world for so many years and has proven their potential[17-19]. On the other hand, many other companies are investing in smaller tabletop equipment for dental labs and clinics, showing a new concept in CAD/CAM solutions. The Amann Girrbach and Zirkonzahn are examples of this new concept. This smaller equipments were compared to a production center (Neodent Digital) and have shown similar results as confirmed this study. This group was considered the positive control as it had already presented excellent results in a previous study[13].The CAD/CAM structures showed a very accurate and passive fit and were obtained in a short period of time when compared to the conventional techniques. It also avoided the welding process, that is necessary and mandatory in multiple structures in the way to obtain a passive fit with less misalignments. The surfaces of the castable structures presented more roughness and the presence of more imperfections when compared to the milled surfaces. The mismatch values obtained on casting UCLA abutments can be influenced when processed by different laboratories and also the conventional welding process itself enhances the degree of the infrastructure mismatch independent laboratory that carried[43]. The CAD/CAM process is less technically dependent and can be more easily controlled. Clinically, the micrometric misfits observed in this study encourage the use of zirconia, due to its biocompatibility, decreased bacterial adhesion, favorable chemical properties, high flexural strength, and esthetics, it can be used as an alternative material for 3-unit, implant-supported frameworks[13].

The presence of overextension of the framework over the implant platform can bring hygiene difficulties, bacterial colonization and peri-implant adverse reactions. Due to large mismatches occurring during the casting procedure and the risk of allergy to Nickel[44], present in non-noble alloys (e.g. Ni-Cr alloy), the use of implant-level structures (directly in the implant platform without the use of any abutment) has been discouraged. Some studies defend the abutment-free technique and showed great clinical results[45-48], most of them evaluated titanium abutment-free frameworks, however, titanium veneering is always a challenge and depends on several technical skills, so it is not very common in dental laboratories. The CAD/CAM companies and the software developers must try their best to improve the overextensions problem. These parameters seem to be calibrated to fit the implant platform limit, the authors believe that the settings should always provide an underextension, avoiding overhangs and consequently, the problems that it can lead.

The search for acceptable esthetic and low-cost solutions in implant dentistry has intensified in the last years. When frameworks are connected directly to the implants, in abutment-free situations, higher preload forces can be expected on the screws, because the tightening torque recommended this screws is much higher[13]. The use of abutment-free resolutions seems to be necessary and effective in several clinical situations, besides having a more affordable price when compared to the abutment-level prosthesis. However, the indiscriminate use induced just by economic factors should be noted with caution. The results of this and other studies shows that the mismatches present in fully castable components may lead to bacterial colonization, which can be harmful to the peri-implant tissues. In this way, abutment-free situations, should be performed by CAD/CAM or with a pre-machined junction, minimizing the implant/framework misfit. It is important to mention that veneering of zirconia frameworks can deteriorate the marginal fit[49-50]. In this way, technicians should be aware to control the stratification during the veneering procedure to minimize the modifications on the marginal area, to preserve the machined fit. Clinical trials would be helpful to understand better the clinical behavior of zirconia frameworks.

CONCLUSION

Within the limitations of this in vitro study, it can be concluded CAD/CAM-fabricated zirconia frameworks exhibit a very passive fit and are clinically acceptable. As expected, fully castable abutments conventionally fabricated frameworks (negative control) exhibited the worse vertical misfit values when compared to CAD/CAM-fabricated frameworks. Furthermore, CAD/CAM fabricated zirconia frameworks can be obtained by smaller milling units and achieve similar fit accuracy as industrial milling units of huge production centers (positive control) in implant-supported FDPs.

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Considerações Finais

3- CONSIDERAÇÕES FINAIS

Diante dos resultados obtidos e apresentados nos capítulos desta tese, pôde-se constatar que o desenvolvimento da tecnologia CAD/CAM na fabricação de coroas, copings e/ou estruturas de próteses sobre implantes revolucionou a odontologia, proporcionando adaptação com boa precisão de assentamento em um espaço de tempo muito menor quando comparados aos métodos convencionais. Além de ser muito menos sensitiva do que as técnicas convencionais, deixando de ser exclusivamente dependente da habilidade e técnica individual.

Embora na literatura não haja um consenso sobre o limite aceitável de desadaptação em coroas, copings e estruturas implantadas, o presente estudo sugere padronizações para os testes de avaliação de desadaptação marginal em diferentes metodologias, buscando sempre comparações justas e confiáveis. Para ter a real noção do impacto destas informações no ponto de vista clínico/funcional, estudos prospectivos controlados devem ser realizados no intuito de conhecer melhor e acompanhar clinicamente todas estas metodologias e materiais, que são extremamente inovadores porém ainda não possuem comprovação clínica a longo prazo.

Conclusões

4- CONCLUSÕES

De acordo com os resultados obtidos no presente estudo, pode-se concluir que:

1 - Coroas fabricadas pelo sistema CAD / CAM chairside E4D exibiram desajuste vertical significativamente menor quando uma fina camada de pó foi aplicada sobre o preparo antes do escaneamento.

2 - Não houve diferença na adaptação marginal de coroas produzidas "*in office*" a partir de blocos de cerâmica feldspática ou resina nano-cerâmica em diferentes sistemas CAD / CAM chairside (CEREC e E4D).

3 - Embora diferenças estatisticamente significativas foram encontradas antes e após a cimentação definitiva, o uso de PVS como um material de fixação de ensaio para avaliacao das fendas marginais parece ser aceitável. Além disso , os métodos parecem ser muito mais influentes sobre os resultados quando comparados ao material de fixação.

4 - Dentro das limitações deste estudo in vitro, pode-se concluir que estruturas convencionalmente fabricadas com UCLAs totalmente calcinaveis em CoCr apresentaram os maiores valores verticais de desajuste quando comparados ao UCLA com bases pré-usinadas em Co- Cr e estruturas de CoCr obtidas por CAD/CAM. Além disso, estruturas implanto-suportadas podem ser obtidas por sistemas CAD/CAM laboratoriais, de menor porte e atingir precisão de encaixe similar a oferecida por unidades de usinagem industriais de grandes centros de produção.

5 - Dentro das limitações deste estudo in vitro, pode-se concluir que estruturas convencionalmente fabricadas com UCLAs totalmente calcinaveis em CoCr apresentaram os maiores valores verticais de desajuste quando comparados as estruturas de Zirconia obtidas por CAD/CAM. Além disso, infra-estruturas implanto suportadas em zirconia podem ser obtidas por sistemas CAD/CAM laboratoriais, de menor porte e atingir precisão de encaixe similar a oferecida por unidades de usinagem industriais de grandes centros de produção.

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