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

GUILHERME FARIA MOURA

ODONTOLOGIA DIGITAL APLICADA AO PROCESSO DE ENSINO-APRENDIZAGEM E ACURÁCIA DO ESCANEAMENTO INTRAORAL EM DIFERENTES SUBSTRATOS DENTÁRIOS.

Digital dentistry applied on the teach-learning process and the accuracy of intraoral scanner on different dental substrates.

Tese apresentada à Faculdade de Odontologia da Universidade Federal de Uberlândia, como requisito parcial para obtenção do Título de Doutor em Odontologia na Área de Concentração de Clínica Odontológica Integrada.

GUILHERME FARIA MOURA

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M929
2020

Moura, Guilherme Faria, 1991-
USO DA ODONTOLOGIA DIGITAL APLICADO AO PROCESSO ENSINO APRENDIZAGEM E SUA ACURÁCIA NO ESCANEAMENTO DE DIFERENTES SUBSTRATOS DENTÁRIOS. [recurso eletrônico] / Guilherme Faria Moura. - 2020.

Orientadora: Flavio Domingues das Neves.
Tese (Doutorado) - Universidade Federal de Uberlândia, Pós-graduação em Odontologia.
Modo de acesso: Internet.
Disponível em: http://doi.org/10.14393/ufu.te.2020.660
Inclui bibliografia.
Inclui ilustrações.

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

CDU: 616.314

Bibliotecários responsáveis pela estrutura de acordo com o AACR2:

Gizele Cristine Nunes do Couto - CRB6/2091

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ATA DE DEFESA - PÓS-GRADUAÇÃO

Programa de Pós-Graduação em:	Odontologia				
Defesa de:	Doutorado, número 50, PPGODONTO				
Data:	Vinte e Um de Setembro de Dois Mil e Vinte	Hora de início:	14:00	Hora de encerramento:	17:33
Matrícula do Discente:	11613ODO007				
Nome do Discente:	Guilherme Faria Moura				
Título do Trabalho:	Uso da odontologia digital aplicado a processo ensino aprendizagem e sua acurácia no escaneamento de diferentes substratos dentários				
Área de concentração:	Clínica Odontológica Integrada				
Linha de pesquisa:	Propriedades Físicas e Biológicas dos materiais Odontológicos e das estruturas dentais				
Projeto de Pesquisa de vinculação:	Propriedades Físicas e Biológicas dos materiais Odontológicos e das estruturas dentais				

Reuniu-se em Web Conferência pela plataforma MConf - RNP, em conformidade com a PORTARIA Nº 36, DE 19 DE MARÇO DE 2020 da COORDENAÇÃO DE APERFEIÇOAMENTO DE PESSOAL DE NÍVEL SUPERIOR - CAPES, pela Universidade Federal de Uberlândia, a Banca Examinadora, designada pelo Colegiado do Programa de Pós-graduação em Odontologia, assim composta: Professores Doutores: Paulo Vinícius Soares (UFU); Luís Henrique Araújo Raposo (UFU), Gustavo Mendonça (Universidade de Michigan), Raphael Vieira Monte Alto (UFF) e Flávio Domingues das Neves orientador(a) do(a) candidato(a).

Iniciando os trabalhos o(a) presidente da mesa, Dr(a). 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 arguição e resposta foram conforme as normas do Programa.

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Documento assinado eletronicamente por **Raphael Vieira Monte Alto**, **Usuário Externo**, em 21/09/2020, às 17:34, conforme horário oficial de Brasília, com fundamento no art. 6º, § 1º, do Decreto nº 8.539, de 8 de outubro de 2015.

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Referência: Processo nº 23117.051488/2020-83 SEI nº 2234988

DEDICATÓRIA

À *Deus*,

Primeiramente pela vida, agradeço também por minha saúde e condição de buscar meu objetivo. Creio que quando se tem Deus ao nosso lado, todos nossos objetivos se tornam possíveis de serem alcançados. E particularmente comigo ele sempre foi muito presente, segurou em minhas mãos e me ajudou em mais essa caminhada. E que além de tudo me deu minha família, a Georgia, meus amigos e todas as pessoas ao meu redor que sempre foram meu suporte. Obrigado meu Deus por me tornar quem eu sou.

Aos meus queridos pais Cécia e Clécio,

Aqui eu poderia escrever outra tese só de agradecimentos.

Mãe qualquer palavra escrita aqui é insuficiente para expressar todo o agradecimento e gratidão que eu tenho por ser seu filho. Que desde de sempre nunca impôs dificuldade, dentre várias que sempre existiram, para que eu pudesse seguir meu caminho. Sempre com amor, dedicação, mesmo nas divergências de pensamentos e atitudes nunca me faltou suporte, carinho, amor.

Pai, sou muito grato por seu filho e por ter herdado várias caraterísticas suas, não só físicas, hahahhaha, mas de maneira de ser também. Muito obrigado por todos os esforços e todo o suporte que até você me dá. E agradeço também a Mayenne e ao Joao Guilherme por cuidarem de você e fazer tão bem a você como eles fazem.

Amo muito vocês.

À Georgia,

Eu não tenho palavras para escrever aqui tudo que eu sinto e o que você representa para mim. Nada e nem ninguém consegue entender e explicar o que foi esse doutorado em nossa vida. Muito obrigado, mesmo com todas as dificuldades, por me apoiar nas minhas escolhas e obrigado mais ainda por me receber de volta e acreditar em nós dois. Pode ter certeza que você não se arrependerá de sua escolha. Te amo. E obrigado a Fatinha por cuidar tão bem de você e te transformar nessa pessoa maravilhosa, e por gostar mais de mim do que da própria filha.

Ao Paulo,

Você sabe Paulo, que mesmo não tendo influenciado em nada na minha escolha pela profissão, depois que eu entrei na faculdade você influenciou em tudo. Cada oportunidade dada, cada conselho, cada dica, cada ensinamento, cada parceria que fazemos até hoje, é motivo de muita gratidão para, tanto por poder aprender quanto por ter certeza que tudo isso só acontece por você acreditar e confiar em mim. Muito obrigado profissional e pessoalmente por fazer parte da minha trajetória.

Ao Gabriel e a Yasmin,

Gordinho, você sabe que se nós nascêssemos de novo da mesma mãe e do mesmo pai, não seria possível nós essa relação de amizade que nós temos. Não tem palavras para agradecer por passar e crescer ao seu lado. Sou muito seu fã. Te amo muito. Yaya, muito obrigado por casar com meu irmão e me aceitar como um cunhado maravilho que eu sou. Gosto muito de você e obrigado por cuidar tão bem do meu irmão.

As minhas irmãs,

Laurinha, que começamos juntos a ser gente grande, a Lala e a Marcelinha, que está começando agora os passos na odontologia. Eu sei que muitas vezes a vidas e os afazeres nos afastam um pouco, mais sou muito grato por ter vocês na minha. Muito obrigado.

Aos meus avós,

Agradeço de forma especial, aos meus queridos avós, que são exemplos para mim. Queria chegar na idade de vocês podendo ser uma mistura de todos juntos. Tenho muito orgulho de tê-los como exemplo de vida. Muito obrigado por tudo, amo vocês. Vô Deó, Vó Didi, Vó Nedina e Vô Carlito.

Aos meus familiares,

Tios e tias, madrinhas e padrinhos muito obrigado por fazerem parte da minha vida por serem exemplos, por me ajudarem, por me darem suporte e amor de família. Sem essa estrutura de família e apoio tudo seria bem mais difícil do que foi. Aos meus primos e primas, muito obrigado, ao mais velhos por sempre estarem do meu lado, como família, como amigos, presentes em os momentos. Ao mais novos, que além de ser amigos que eu possa conseguir de alguma forma ser exemplo de coisas boas para vocês que ainda estão crescendo, traçando seus caminhos.

AGRADECIMENTOS ESPECIAIS

Ao professor **Dr. Paulo Vinicius Soares**, por um dia sentado em sua casa e tomando cerveja, ter me dado oportunidade de ser seu aluno de mestrado e depois de doutorado. Paulo muito obrigado pela confiança, e pelas oportunidades que até você me dá. Sou grato a você por minha formação na pós-graduação, pela amizade que nós construímos e por todos conselhos, dicas, sugestões, ralas, todos me fazem aprender muito. Me desculpe se durante esses 6 anos deixei a desejar em algum quesito, se não sou tão pesquisador quanto poderia ser, acho que você conhece meu perfil, e sempre estarei à disposição para tudo que precisar de mim.

Ao professor **Dr. Gustavo Mendonça,** não tem palavras que possam te agradecer Gustavo, primeiro que sem me conhecer confiou em mim, e na Jessica, ahahahahha, e me aceitou como aluno de doutorado sanduiche. Não só aceitou, mas me tratou como filho e amigo. Sou muito grato pela oportunidade que eu tive de te conhecer e trabalhar com você. Falo e falarei em todos lugares que eu posso, o quão exemplo eu aprendi com você, uma das pessoas mais inteligentes e influentes e respeitadas, por todos, e ao mesmo tempo mais humilde, atenciosa e prestativa, quem dera o mundo tivesse vários Gustavos.

A **Profª. Dra. Daniela Mendonça,** agradeço com muito carinho, pela oportunidade de trabalhar com você, poder participar de suas pesquisas, dividir pré-clínicos, espero ter contribuído da melhor forma possível com tudo. Parabéns por ser esse exemplo de mulher bem sucedida na profissão e dentro de casa, tenho sua família como exemplo pra mim. E quero te parabenizar também pelos meninos, Breno e Enzo são duas crianças maravilhosas fruto de uma criação impar que você e o Gustavo sempre deram a eles. Tio Guilherme tem um carinho muito especial pelos dois.

Ao professor Luiz Meirelles, um grande amigo que tive a oportunidade fazer. Luiz te agradeço muito por cada dia que trabalhamos juntos, cada ensinamento que aprendi com você, cada conversa jogada fora, cada besteira que falamos, e foram muitas. Cada cerveja que tomamos juntos no Wolverine. Saiba que sou seu fã e te admiro, espero que possamos nos encontrar em breve. Muito obrigado a você, a Cris e as meninas, Alice e Stella.

Ao meu recém aceito orientador, **Prof. Dr. Flavio Domingues das Neves,** obrigado por aceitar esse desafio de me orientar após minha volta do exterior, e me desculpe todo o trabalho de ultima hora. Me inspiro muito em você e te admiro muito profissionalmente e como pessoa. Muito obrigado por todo o conhecimento que aprendi com você, espera aprender muito ainda.

Aos professores da banca, por toda contribuição nas etapas desse trabalho. **Prof. Dr. Raphael Monte Alto,** primeiramente agradecer por aceitar participar desse momento tão importante na minha carreira, e te falar que foi com muito carinho que sugeri seu nome a essa banca. Tenho uma admiração muito grande pelo seu trabalho. **Prof. Dr. Luís Henrique Araújo Raposo** por todo o conhecimento compartilhado e contribuição desde a época de mestrado. Raposão, te admiro muito, tenho você como uma referência profissional além de ser uma pessoa fantástica. Obrigado!

Agradecer também aos membros suplentes professores, Prof. Dr. Paulo Cesar Simamoto Junior, um grande professor, competente, profissional, que me ensinou muito na graduação, especialização, mestrado e doutorado, e quem tem uma família sensacional, que puder conviver mais próximo no período em que estivemos juntos nos EUA, pena você e o Pedrinho serem flamenguistas. Prof. Dr. Adriano Gondim Almeida, meu “chefe”, admiro muito seu trabalho e fico grato por ter a honra de poder dividir sala de aula com você. Obrigado por aceitarem o convite e estarem dispostos a ajudar.

Aos professores da FOUFU, meus eternos e sábios mestres, pessoas a quem eu devo meus primeiros passos nesta jornada profissional, agradeço por cada momento compartilhado, pelas aulas, clínicas, experiências divididas na Graduação e Pós-Graduação. Obrigado por todos os conhecimentos técnicos e de vida compartilhados por vocês durante esses 11 anos de Universidade Federal de Uberlândia.

A escola de pós-graduação, **HD Ensinos Odontológicos, extensivo aos professores Dr. Denildo de Magalhaes e Dr. Helder de Menezes** onde cursei minha especialização em Implantodontia, por ser um lugar onde me sinto em casa e por ter sido fundamental em minha formação clínica e onde hoje trabalhos e temos grande parceria.

Ao **Papai (Juninho) e mamãe (Jessica)**, não tenho nem palavras para agradecer a confiança que tiveram em mim e me indicar dentro da universidade de Michigan para o meu doutorado sanduiche. Amigos, colega de graduação, mestrado, dupla da especialização, e agora Doutorado Sanduiche, compadres, obrigado por me acolherem como família quando eu estava mais sozinho e longe de tudo, foram momento bons, momentos de dificuldade, muito trabalho, porco, rato, finais de semana, curso voluntario de veterinária e recuperação de porcos pós anestesias, momentos de free-food, pobre é pobre até em inglês. Contem comigo para o que vocês precisarem na vida.

Aos meus amigos de sempre (RSL), Bebeto, Digay, Bruno, Zé, Jader, Oreia, Coró, Junão e Herói e suas respectivas companheiras por desde de sempre estarem comigo nas horas fáceis e difíceis de todo o meu percurso

Aos amigos de doutorado, que entre seminários, e dificuldades, aprendemos uns com os ostros, nos ajudamos, tornamos amigos e tenho certeza que todos nós iremos colher muitos frutos desta linda jornada. Sucesso a todos!

Aos amigos de Michigan, **Rafa, Renata, Diogo, Giovana, Fábio, Rafeka, Ananda, Lucas, Maria, Lore, Marcelo, Taina, Didi, Angélica Ben.** Foi um prazer ter a oportunidade de conhecer cada um, tenho a certeza que a distância e a falta de convivência que temos hoje não vai diminuir o carinho e a amizade que construí com cada um.

Aos amigos da Universidade de Michigan, colegas da perio, da prótese, da endo, da orto, da restauradora, e aos amigos pesquisadores que fiz, pela oportunidade de poder conviver e trabalhar com vocês no meu dia a dia.

Ao departamento de periodontia da Universidade de Michgan e seu professores e funcionários, em especial aos professores Hom-lay Wang por me dar a oportunidade de trabalhar com seus residentes, ao professor Albert Chan, por dividirmos pesquisas, casos clínicos e aprender com seus conhecimentos, a professora Erin pela convivência diária ao dividirmos sala. E a todos os residentes em especial ao Bart, Sajjad, Lorenzo, Khal, Andrea, Islam, Jayden e Michelle por todo o convívio diário e troca de conhecimentos.

Ao departamento BMS e seus professores, por me receberem como colegas de trabalho, principalmente aos professore com os quais tive a oportunidade de dividir disciplina. Ao professor Furat Geroge por toda a disponilidade e acessibilidade de compartilhar suas experiências e metodologias de pesquisa.

À **Faculdade de Odontologia da Universidade Federal de Uberlândia,** por tudo que vivi e aprendi nesses corredores. Se hoje tenho a possibilidade de me tornar um doutor, isso deve a todo conhecimento técnico e todo o aprendizado para minha vida que aprendi aqui. Tenho orgulho de ter me formado nesta casa.

As secretárias do PPGO, **Brenda, Graça e Laís,** por estarem sempre dispostas capazes de fornecerem todo o suporte necessário aos alunos, além de excelentes profissionais e de ótimo convívio.

E a todas as pessoas que, de alguma forma, contribuíram para que essa etapa fosse vencida!

EPÍGRAFE

“A utopia está lá no horizonte. Me aproximo dois passos, ela se afasta dois passos. Caminho dez passos e o horizonte corre dez passos. Por mais que eu caminhe, jamais alcançarei. Para que serve a utopia? Serve para isso: para que eu não deixe de caminhar.”

Eduardo Galeano

SUMÁRIO

RESUMO

RESUMO

A odontologia digital apresenta uma crescente demanda na evolução dos processos odontológicos. A busca pela melhora na acurácia das restaurações se inicia na evolução da percepção do cirurgião dentista a respeito da precisão dos preparos, entendimento que deve começar ainda durante a graduação. E se estende à medida que amadurece seu entendimento sobre inclinação de paredes, espaço para resistência e estética do material restaurador e acabamento superficial, principalmente na região de término cervical. Além disso, a relação entre a captura das imagens pelo escaneamento intraoral com o substrato escaneado pode influenciar na qualidade do arquivo digitalizado. Este estudo foi dividido em três objetivos específicos: **Objetivo 1:** avaliar e comparar a pontuação dos alunos durante o preparo para coroa total no curso de prótese fixa de forma manual e digital. **Objetivo 2:** correlacionar a avaliação realizada pelo aluno de forma manual, pelo professor de forma manual e utilizando um software 3D para aumentar a concordância entre professor e aluno. **Objetivo 3:** avaliar se o uso de um instrumento de acabamento na margem de preparos para coroa total, assim como as condições do meio bucal, influencia a precisão do arquivo digital gerado pelo escâner intraoral. A avalição das diferentes formas de pontuar os preparos realizados pelos alunos mostrou que para critérios mensuráveis como redução axial e oclusão houve diferença estatística para as avalições manuais e digitais, nas quais a digital foi mais precisa. Em relação a concordância entre a avaliação do professor e dos alunos utilizando métodos de avaliação digitais e manuais, houve níveis de correlação de moderado para baixo entre os mesmos. Ao avaliar a acurácia dos escaneamentos em diferentes substratos dentais, a presença da saliva diminuiu a acurácia do escaneamento independente do substrato e do refinamento do preparo. Para o substrato esmalte, não houve diferença estatística entre o uso de brocas e pontas de acabamento pré-escaneamento. Quando o preparo é realizado em dentina, o refinamento do preparo melhora a eficácia do escaneamento.

Palavras chave: ensino, escâner intraoral, odontologia digital, prótese dentária.

ABSTRACT

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Digital dentistry presents an increasing demand in the development of dental processes. The search for improvement in the accuracy of restorations begins when the practitioner perception about the precision of dental preparations evolves. This understanding should initiate even during the training process of undergraduate students and involves recognizing the relationship between image acquisition through intraoral scanning and the substrate to be scanned. This study was divided into three specific objectives: **Objective** 1: to evaluate and compare the student scores during a full crown preparation process in the fixed prosthodontics course using manual and digital tools; O**bjective 2**: correlate the assessment of the full crown preparation carried out by the student manually, by the teacher manually and using 3D software, to increase the agreement between teacher and student; O**bjective 3**: to assess whether the use of a second finishing instrument on the cervical margin of a full crown preparation, as well as the conditions of the oral environment, influence the accuracy of the digital file generated by the intraoral scanner. The evaluation of the different techniques for scoring dental preparations made by the students showed that for measurable criteria such as axial reduction and occlusion, there was statistical difference for the manual and digital evaluations, in which the digital technique was more accurate. Regarding the agreement between teacher and students using digital methods for assessment, there was moderate to low correlation level among them. When evaluating the accuracy of the scans on different dental substrates, the presence of saliva decreased the accuracy of scanning, regardless the substrate and the refinement of the preparation. For the enamel substrate, there was no statistical difference between the use of refining instruments to finish the preparation before scanning; for dentin substrate, the refinement of the preparation improved the scanning efficiency.

Key words: digital dentistry, education, intraoral scanner, prosthodontics.

INTRODUÇÃO E REFERENCIAL TEÓRICO

1. INTRODUÇÃO E REFERENCIAL TEÓRICO

Atualmente, a crescente demanda por restaurações estéticas exige cada vez mais precisão e confiabilidade das técnicas. Materiais restauradores inovadores e diferentes métodos de produção de restaurações indiretas foram desenvolvidos para a obtenção de melhores propriedades mecânicas e estéticas com o objetivo de permitir preparos dentários com maior preservação e tecido sadio, mantendo a resistência das restaurações. (1)

Restaurações indiretas podem ser confeccionadas de duas maneiras diferentes, utilizando métodos convencionais ou sistemas CAD/CAM. Antes do advento da tecnologia CAD/CAM na Odontologia, o único método disponível para confecção de restaurações indiretas consistia em moldar o dente preparado, e após obtenção dos modelos, as restaurações eram produzidas em laboratório de prótese anexo ao consultório ou terceirizado. Atualmente, a produção de restaurações indiretas utilizando o sistema de design assistido por computador e manufatura auxiliada por computador (CAD/CAM), permite que os dentistas possam planejar a restauração e a produção seja realizada por meio de uma máquina. Essa tecnologia pode ser usada de maneira *chairside*, na qual o profissional tem o controle de todas etapas sem assistência de um técnico em prótese, ainda de forma que o profissional possa escanear o paciente e a restauração ser fabricada em laboratório de prótese dentária ou com a moldagem não digital. (2)

Essa nova maneira de produzir restaurações com planejamento e fabricação baseados em ambientes virtuais assistidos por computador podem reduzir custos, riscos de contaminação durante a fase de restauração provisória em alguns casos, reduzir o tempo de cadeira e do laboratório em comparação com o processo não digital.(2, 3) Alguns estudos, apresentam vantagens da técnica CAD/CAM comparada a técnica laboratorial não digital realizada de forma manual. Os autores demonstraram que a obtenção de restaurações indiretas empregando equipamentos eletrônicos resulta em desajustes internos e marginais semelhantes aos da técnica tradicional, porém esse processo é realizado em menor tempo. (3, 4).

A literatura demonstra que um bom ajuste marginal é um fator-chave no sucesso de restaurações indiretas a longo prazo. Um desajuste marginal considerável pode promover acúmulo de placa dentária, a dissolução do material de cimentação e / ou a inflamação do periodonto marginal. (1, 4, 5) Uma relação entre a qualidade da adaptação do material restaurador indireto e a saúde periodontal foi apresentada em estudo prévio, o qual demostrou que as restaurações inadequadas apresentaram significativamente mais placa, gengivite e formação de bolsa periodontal do que as consideradas adequadas. (6) Além dos problemas periodontais, a necessidade de ajustes internos diminuir a resistência da restauração indireta, pois a espessura aumentada da camada de cimento pode influenciar a resistência de união do mesmo além de afetar a resistência das coroas de cerâmicas. (5) Essa relação foi demonstrada por Tuntiprawon and Wilson (7), que relataram o efeito da espessura da camada de cimento na diminuição da resistência à fratura de coroas totalmente cerâmicas e relacionando esse fato às diferentes propriedades físicas existentes entre cimento e cerâmica. (7)

A literatura ainda é inconclusiva sobre o desajuste marginal aceitável (75-120 µm), mas o mesmo precisa ser pequeno o suficiente para evitar a presença de saliva e/ou ácido lático, um subproduto do metabolismo bacteriano. Um desajuste marginal menor que as bactérias é extremamente difícil de se obter, considerando que a espécie mais comum na boca, os *Streptococcus mutans*, têm diâmetro em torno de 0,75 µm. (8) No entanto, alguns autores propuseram 100 µm ou menos como um desajuste marginal aceitável (3, 9-11), e estudos in vitro encontraram valores inferiores a esse. (12-16)

O término do preparo é uma área crítica em relação aos desajustes marginais das restaurações indiretas, portanto, os instrumentos rotatórios usados para preparar as margens podem criar diferentes níveis de rugosidade devido à maneira como cada broca ou ponta diamantada remove a estrutura do dente. Para pontas diamantadas, partículas abrasivas em contato com a estrutura removem o tecido e criam ranhuras de acordo com o tamanho do diamante, sendo que quanto maior o diamante, mais áspera é a superfície obtida. (17) A rugosidade do preparo realizado com brocas laminadas é dependente do número de lâminas do design da broca. (17) O uso de uma broca para polir a superfície do preparo influencia a rugosidade de superfície, que varia de 10 µm (broca de preparo) a 1-7 µm (brocas de acabamento de diamante e carboneto de silício) nos parâmetros de rugosidade Ra e Rq. (18) O mesmo resultado é relatado para a rugosidade da dentina e do esmalte.(19) Outro ponto importante é a *smear-layer* criada por diferentes instrumentos rotatórios, pois uma ponta diamantada grossa cria uma camada mais espessa em comparação com as brocas laminadas e isso pode influenciar a permeabilidade da dentina, resultando em uma resistência adesiva reduzida da restauração.(20) Foi demonstrado em estudo que uma ponta mais fina resulta em superfície de preparo mais lisa, além de um melhor ajuste interno, porém essas diferenças não afetaram a retenção da coroa ao dente preparado.(21)

A obtenção de moldes sem distorções é passo importante no processo de obtenção de restaurações indiretas. O processo de moldagem é extremamente dependente da qualidade do material empregado e também da habilidade do operador, sendo que quaisquer falhas ocorridas durante essa etapa, podem levar a erros de manufatura nas etapas laboratoriais subsequentes. As restaurações resultantes podem ser produzidas com sobre ou sub contorno ou podem ter margens defeituosas que levam à cárie, gengivite e outros problemas. (4)

O uso de escâneres intraorais tem aumentado consideravelmente recentemente, pois com o surgimento de várias marcas diferentes no mercado, essa tecnologia tem se tornado mais acessível. Os escâneres são capazes de obter um modelo virtual com precisão, evitando vários problemas inerentes ao processo de moldagem não digital como o reflexo de vômito, desconforto do paciente e espaço necessário para armazenamento de modelos de gesso. Além disso, vantagens como eficiência de tempo, procedimentos clínicos simplificados, capacidade de capturar e armazenar informações altamente precisas e a possibilidade de transferir facilmente dados digitais para o técnico em prótese, via internet, evitando ainda a contaminação com o envio de moldes convencionais para o laboratório.(23) No desenvolvimento dos sistemas CAD/CAM, foi feita a transição de sistemas fechados para sistemas abertos, a partir dai uma série de possibilidades técnicas tornaram-se possíveis, como por exemplo uma marca de scanner com esse acesso aberto fornecer arquivos digitais para serem impressos ou fresados em outra marca de equipamento.(22)

Para criar um arquivo digital com dados tridimensionais, a primeira etapa é a captura da imagem, que depende do escâner e é feita por laser, ou por gravação de vídeos em cores ou ainda por captura de fotografias sobrepostas.(2) Após a aquisição das imagens, o software converte os dados em um modelo digital que pode ser exportado e em seguida, o design da restauração indireta pode ser realizado empregando diferentes opções de softwares. Assim, com esta técnica, o potencial de imprecisões dimensionais é eliminado ou pelo menos reduzido quando comparado à técnica de moldagem não digital. (4)

Além disso, o uso da tecnologia CAD/CAM tem avançado e conquistado espaço dentro nas instituições de ensino, visto que as ferramentas digitais podem ser utilizadas como ferramentas auxiliares no processo de ensino-aprendizagem. Os estudantes de Odontologia tendem a preferir informações visuais, imediatas, consistentes e objetivas como as obtidas por esses sistemas, (24) que são relacionadas ao desenvolvimento de uma avaliação de auto-feedback mais confiável, maximizando as capacidades de aprendizado. (24-26) Além disso, os sistemas de feedback digital podem estar disponíveis a qualquer momento, reduzindo a necessidade da presença integral de um tutor/instrutor e contribuindo para o tempo de treinamento dos alunos e a experiência de aprendizado personalizada. (24, 25, 27)

Durante o treinamento pré-clínico, os alunos costumam se frustrar com as dificuldades técnicas que começam a enfrentar. Nesse contexto, a autoavaliação tornou-se um requisito para a Comissão de Credenciamento Odontológico (CODA), (28, 29) e é reivindicada como crucial para um rápido desenvolvimento profissional, tanto da perspectiva do estudo autoguiado, quanto para poder entender o feedback dos instrutores. (29-35) No entanto, muitas vezes há falta de concordância entre os alunos e a classificação/avaliação dos professores, (29, 31, 35-37) bem como entre os próprios instrutores. (37-39) Este fato pode comprometer o processo de aprendizagem se os alunos começam a perceber diferenças como preconceito ou discriminação e/ou classificarem os instrutores como graduadores fáceis ou difíceis. (25, 29, 31, 40, 41)

Tais fatos podem ocorrer devido à falta de calibração, subjetividade das avaliações e limitações da avaliação. (30) Como exemplo, determinar a conicidade adequada (em torno de 6°) e comunicá-la a um aluno para o preparo da coroa pode ser muito desafiador nas percepção pré-clínica e clínica, especialmente ao usar apenas métodos visuais auxiliados ou não por um espelho clínico. (42) Considerando que na odontologia diferenças mínimas nos preparos podem afetar a longevidade das restaurações, (26, 39, 43-45) a prática com feedback tem sido considerada crucial para a aprendizagem, utilizando um método objetivo de avaliação capaz de avaliar preparos de maneira mais consistente e abrangente, bem como fornecer esse feedback de forma mais clara. (31, 39)

As tecnologias digitais, baseadas em sistemas CAD, permitem que alunos e instrutores criem modelos digitais e, dependendo do sistema, analisem objetivamente o preparo realizado. Os principais benefícios dessa abordagem podem consistir na possibilidade de identificar com precisão erros, incluindo a possibilidade de girar e aumentar a imagem, (30) além de fornecer feedback instantâneo, objetivo e visual para o estudo. (25, 30, 36, 39, 40, 46) Além disso, também poderia consistir em uma abordagem para reduzir a falta de calibração/concordância entre os instrutores, (29, 38, 39, 46-48) permitindo que os alunos determinassem se as diferenças de classificação provinham falta de habilidades manuais ou deficiências no conhecimento didático, e não no viés durante o feedback do instrutor. (29, 49)

Assim sendo, os métodos digitais podem ajudar a superar esses cenários, fornecendo um método mais objetivo e abrangente, (27, 29, 39, 46, 49) estimulando o aluno a se concentrar no processo de aprendizagem, e não apenas nas notas. (25) Diante dessa evolução, a literatura ainda não é conclusiva se os sistemas digitais podem melhorar o processo de ensino-aprendizagem para os procedimentos restauradores e nenhuma padronização foi proposta para esse método nos critérios comumente avaliados, além de não existirem estudos na literatura que comprovem a influência da rugosidade de superfície com a acurácia dos escâneres intraorais. Dessa forma essa tese tem como objetivo a proposição um método de avaliação digital, assim como avaliar a relação entre a rugosidade de superfície do substrato com a acurácia do escâner intraoral.

OBJETIVOS

2. OBJETIVOS

Objetivo Geral

Avaliar a viabilidade, a acurácia, o método e o entendimento na introdução da tecnologia digital no processo de ensino-aprendizagem de alunos de graduação em odontologia na disciplina de prótese fixa, assim como avaliar a acurácia dessa tecnologia no escaneamento de diferentes substratos dentais.

Objetivos específicos

Objetivo 1

Capítulo 1 - ***3D software technology applied on undergraduate student evaluation in prosthodontics course.***

O objetivo deste estudo foi avaliar e comparar a pontuação dos alunos durante preparo para coroa total na disciplina de prótese fixa em 5 diferentes critérios (margem, conicidade do preparo, acabamento de margens e paredes axiais, redução axial e oclusal) de forma manual (técnica convencional) e digital (técnica experimental).

Objetivo 2

Capítulo 2 - ***Agreement evaluation between professor and undergraduate students using manual and digital assessment to score crown preparation.***

O objetivo desse estudo foi correlacionar a concordância na avaliação dos preparos protéticos realizada pelo aluno e pelo professor de forma manual (técnica convencional) e digital utilizando software 3D (técnica experimental).

Objetivo 3

Capítulo 3 – **Influence of enamel and dentin roughness on the trueness of a intraoral scanner.**

O objetivo desta pesquisa foi avaliar se o uso de um segundo instrumento de acabamento na margem de preparos para coroa total, assim como as condições do meio bucal influenciariam a precisão do arquivo digital gerado por um scanner intraoral.

CAPÍTULOS

3. CAPÍTULOS

3.1 CAPÍTULO 1

Artigo submetido para publicação ao periódico Journal of Prosthetic Dentistry.

3D software technology applied on undergraduate student evaluation in prosthodontics course.

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ABSTRACT

Statement of the problem: Use of digital tools and tridimensional (3D) technologies in dental school has increased in recent years. Advantage of using these devices is that faculty can provide more accurate and standardized feedback of students work such as crown preparations in preclinical and clinical situations.

Purpose: The objective of this study was to evaluate and compare the score in 5 different criteria (margin placement, taper, finishing at margins and walls, axial and occlusion reduction) obtained by students in preclinical fixed prosthodontics course.

Material and methods: 102 students prepared one tooth for a porcelain fused metal (PFM) crown and another one for a full gold (FG) crown. After preparing the teeth, each student did a self-evaluation (without 3D software support) of their own preparation. Faculty also evaluated the preparation, at first without 3D software support and then with the support of computed aided manufacture (CAD) software (digitally). All the three evaluations were analyzed and compared using two-way ANOVA followed by Tukey's test between the groups.

Results: Results showed that for margins, finishing and taper parameters there is no statistically significant difference between faculty and students and when faculty used digital tools to evaluate. On the other hand, for parameters that can be measured (axial and occlusal reduction) there were statistically significant difference from the manual to the digital evaluation. The two-different crown preparations had similar scores when compared to the other separately on each different evaluation mode for all the criteria.

Conclusion: The digital evaluation was more accurate than the manual for the axial and occlusal reduction parameters.

Key words: prosthodontics, tooth preparation, school dentistry, digital dentistry.

CLINICAL IMPLICATION: The evaluation criteria for the prosthodontic course during dental school is kind of inaccurate and difficult to understand by the students. Therefore, the possibility of using digital tools to elucidate the evaluation make the score process faster and more accurate, simplifying the learning process.

Introduction

The use of digital technology in dentistry has been spread in the last years. Scanners, milling machines, and tridimensional (3D) printers allow professionals to treat their patients with increased accuracy, quality, and reliability, at the same time it decreases the length of the treatment. [1-5] The use of intraoral scanners can substitute the traditional impression techniques with a good accuracy and comfort for the patient, also avoiding possible distortions from impression and/or pouring techniques.[6, 7] In addition, digital impressions also reduce costs with impression materials and time and cost with transport to and from the laboratory. In addition to that, intraoral scanners allow immediate feedback when doing crown preparations (either visual or using specific software's).[8] Using this technology students and clinicians might be able to evaluate their preparations before proceeding to manufacturing processes, which can reduces time and cost with eventual repetitions.

Another increasing use for digital tools as a feedback tool, consist in its use in an educational setting (i.e. dental schools) as some of those software allow faculty/student to precisely analyze the preparation (based on the antagonist and/or final restoration), as well as areas presenting roughness which could interfere with proper seat/fit of restorations, areas with sharp corners/angles, and presence of undercuts. Digital tools and 3D technologies use as an educational tool are crucial since small variations in preparation design can represent the difference between the clinical success and failure. These can be very helpful tools to use in teaching as dental students sometimes would struggle in understand concepts of tooth preparation and non-ideal using pictures (2D representation), power point presentations, videos, and live demonstrations on typodonts (due to its reduced size).[9-13] Considering the preclinical setting, the students usually provide their self-evaluation and faculty provide a final grade based on a checklist.[14] Having the same method of evaluation (aided by computer and avoiding human variance) is desirable. Two of the most common preparations, porcelain fused to metal (PFM) and full gold crowns (FGC) performed during fixed prosthodontics courses present clearly different requirements. Occlusal (OR) and axial (AR) reduction corresponds, respectively to 2.0 (PFM) and 1.5 mm (FGC), and 1.2 (PFM) and 0.5 mm

(FGC).[15] And for these two specific crown preparation designs, it is clear that 0.5 mm variations, which might represent a clinical failure, are difficult to be evaluated precisely by visual analysis. Another important factor is the previous experience of the faculty when performing these measurements and calibration of all faculty that provide feedback to the students [9-13]. Within the context of the need for development of a more reliable and accurate feedback tool, using of intraoral scanners may contribute to a more comprehensive understanding by the student during the course. This is corroborated by previous studies reporting the preference and better performance of students exposed to the use of 3D technology.[16]

A few studies, [14, 17-19] showed the use of the digital technology in dental schools. In this study we attempt to establish a protocol and a checklist to be used during a fixed prosthodontics preclinical course. Based on the possibility of including such technologies at different dental schools, the aim of the present investigation was to compare self-evaluation, provided by the second-year DDS-program students, with manual and digital score evaluations provided by a calibrated evaluator, considering two different preparations (PFM and FGC). The first null hypothesis was that no difference would be detected between the scores of manual and digital evaluations, in other words, the evaluation performed by the scanner presents equal scores compared to the manual performed by the students and by the evaluator. The second null hypothesis was that no difference would be found between the scores in both types of preparations, this way the full gold crow and the porcelain fused to metal acquire the same learning curve from the students.

Materials and methods

The present study followed a 3x5 factorial design having as study factors: 1) evaluation mode in three levels (manual self-evaluation – performed by the undergrad student; manual evaluation – performed by a calibrated evaluator; and digital evaluation performed by a calibrated evaluator); and 2) score criteria in five levels (margin placement, taper, finishing margin and walls, axial and occlusal reduction), having as response variables the scores assessed using manual evaluation and 3D analysis software program (PrepAnalisys – Cerec Sirona).

The research was previously approved by the local ethics committee number

(HUM00144152). The sample consisted of PFM and FGC crowns prepared by 102 second-year DDS-program students attending to the Fixed Prosthodontics preclinical courses at the University Of Michigan School Of Dentistry (in a total of 204 preparations). The PFM crowns were performed on the left mandibular first pre-molar (#21) and the FGC were prepared on the left mandibular first molar (#19) on a typodont (R 862 – Columbia Dentoform) according with the preparation checklist (Tables 1 and 2).[15] All the preparations were self-evaluated by the respective student and evaluated manually by a calibrated evaluator. During manual evaluation, each preparation was assessed based on the following criteria: 1- margin placement, 2 – margins and walls finish surfaces, 3 – taper, 4- axial reduction, and 5-occlusal reduction (Fig. 1 and Tables 1 and 2).

Following the manual evaluations, all the preparations, adjacent teeth (from second molar to canine), opposing teeth and bite registration were scanned and aligned using the intraoral scanner (Omnicam, Cerec Sirona, Bensheim, Germany). All the preparations were evaluated by a calibrated evaluator using PrepAnalysis function of Cerec software version 4.5 (Cerec Sirona). The criteria to perform the digital evaluation (Fig. 2) was adapted from the manual criteria sheet (Fig. 1) and based on the same parameters used for the manual evaluation. To evaluate: 1 – margin placement was evaluated using the margins tool; 2 – margins and walls finish surfaces was evaluated with the surface tool; 3 – taper was evaluated using the undercut tool; 4 – axial reduction was evaluated with the slice and distance tools after simulating the crown design; 5 – occlusal reduction was evaluated using the distance tool, having the opposing tooth as reference.

Margin evaluation using the digital software was based on yellow spots along the margins (Fig. 3A), which represents areas in which the milling machine would not be able to mill accurately due to indentations, roughness, closeness or overlaps with the soft tissue. The surface evaluation was based on the same “yellow-spots” principle (Fig. 3B), which represents convex or sharp areas. For analysis of taper, the software does not provide the total angle of convergence, so the evaluations were performed based on the presence of undercuts (Fig. 4A) which represent preparations that did not respected the minimum degree of taper. Evaluation of axial reduction was based on a crown that was automatically designed by the software on each preparation and modified as necessary by the operator. Cross-sections were obtained using the slice tool and the thinnest or thickest area of the crown in the axial wall was measured (using the distance tool) and considered as axial reduction (Fig. 4B). Occlusal reduction parameter was quantified based on the opposing tooth using the distance tool (between occlusal surfaces). This tool provides a color map scale based on the distances (in millimeters) and allows the instructor to evaluate the least/most reduced areas (Fig. 4C).

To compare the scores in all situations the R/S/T/V grading system, used ate the University of Michigan, was converted to numbers 1/2/3/4, respectively, to perform the statistical analysis. The letter "R" represents 100% (excellent) in the specific criteria, "S" represents 80% (good), T represents "60%" (not ideal but clinically acceptable) and V represents less than 60% (unacceptable or fail). Subsequently, the different set of results, for each preparation, were collected and the data were submitted to Levene's test to evaluate normality and equality of variance, followed by Two-Way ANOVA and Tukey's HSD test. All statistical analyses were performed adopting 5% significance level.

Results

Results showed significant difference for evaluation mode ($p<.001$), as well as considering the interactions between crown type (PFM or FGC) and evaluation methods (manual or digital) ($p=.007$) (Fig 5 a and b). Crown type by itself did not present significant difference ($p=.071$) (Fig. 6 a-c). Self-evaluation performed by the students and evaluation by the instructor showed similar results. Higher grades were given when preparations were assessed manually compared to digital evaluations, regardless of the crown type.

Among the evaluated criteria, it showed that the margin placement corresponds to the highest/best grades, and occlusal reduction corresponds to the lowest/worst grades. When considering criteria and evaluation methods, a significant difference was also observed ($p<.001$), with occlusal reduction showing the highest discrepancy in grades among digital (3.11), manual (1.48), and self (1.27) evaluations. Axial reduction also showed different values among the evaluation methods (2.28, 1.25, and 1.33 for digital, manual and self-evaluation, respectively). All the other criteria also presented statistical difference in the results, regardless of the evaluation method, except for taper, in which digital, self, and manual evaluation did not present statistical difference.

Comparing criteria, evaluation method, and preparation type ($p<.001$), the only results showing a difference in the above-mentioned trends were observed for occlusal reduction considering the digital evaluation for FGC and PFM, in which preparations for FGC showed lower grades (3.40) than those for PFM (2.83).

Discussion

The first null hypothesis was rejected. There was significant difference between the distinct methods used to evaluate the different preparations according to the defined criteria, except for taper. The second null hypothesis was accepted since there was no difference between the two types of crown preparations. Nevertheless, it is important to mention that there was significant interaction between crown type and evaluation methods. Success in prosthodontics requires an integration between diagnosis, treatment plan, sequence of treatment, material manipulation, tooth preparation and maintenance.[14] The use of typodonts in a preclinical setting represents the most commonly-used method for students to develop the clinical skills necessary for tooth preparation. After preparation, students usually provide and receive feedback based on manual and/or visual analysis with the aid of reduction matrices and instruments with sizes similar to the proposed reductions, consisting in a fairly subjective and often imprecise technique.[20] and they usually struggle with visualization of proper reduction in areas that are harder to reach or get direct view, such as distal lingual cusps and distal lingual walls/planes. The American college of Prosthodontics (ACP) published a guideline about the impact of 3D technologies (such as intraoral scanners) in prosthodontics exploring the diagnosis, treatment benefits and barriers, as well as the importance of integration of digital technologies within the dental school curriculum, allowing the students to graduate having at least a basic expertise in the use of such technologies. This is crucial especially in the context that it is very likely that their future practices (or employers) will require some sort of expertise in digital dentistry.[21]

It is well known that the use of an intraoral scanner allows a digital impression of the patient with at least a similar quality compared with the conventional impression techniques. [22-26] Among the advantages of digital impressions, such as comfort to the patient, avoidance of distortions with impression materials and stones, time saving, etc, [22-26] it also allows a real-time evaluation of the tooth reduction prior to fabricating the restorations, as well as corrections and re-impressions with a very efficient workflow when necessary. The evaluation process of dental preparations developed based on the tools available in the software is a reliable alternative to the manual assessment process currently in use. The major benefits from the proposed process are: (1) standardized analysis less dependent on the evaluator’s judgment, (2) real-time feedback for faculty, student and clinician during crown preparation, and (3) more intuitive analysis resulting in faster evaluation, as observed by the present results and supported by the literature. [17, 21] Among the parameters evaluated, the axial and occlusal wall reductions are the most critical quantitative measurable values during a crown preparation, since an insufficient reduction could increase the failure risk of restorations due to reduced resistance, [27] and it can also jeopardize the final esthetic outcomes [28, 29]. On the other hand, an excessive reduction represents an unnecessarily removal of sound tooth structures, which will reduce the resistance of the dental reminiscent, [30-32] what can also increase the fracture risk for porcelain veneering. [30, 33]

In the present study, the method for digital analysis used the same software that came with the intraoral scanner as a tool for feedback. It allowed us to introduce only one software to students and faculty. There is available software in the market that has specific purpose for evaluation of crown preparation but that would add additional cost and installation demands. The proposed method for digital analysis also focused in keeping the same criteria used by the manual evaluation. The use of the margins tool to evaluate the margin placement can be a useful tool, although there are some limitations related to the method used to scan in the clinic, as well as to the margins position. If the margins are positioned subgingivally (or at gingival level) and scanned without a retraction cord, the relationship between the tooth structure and the soft tissue will not be clear in the software and it will be virtually impossible to correctly draw the margins in the software, which may recognize as irregular areas to be milled. Finishing margins and walls consist in a more subjective evaluation, although the software present with a color code that demonstrate areas of convexity/concavity and sharp corners that was used to qualitatively assess the preparations. Based on that, the authors of the present study do consider the number of spots present in the surface as a reliable evaluation to be used. Nevertheless, it is noteworthy that bigger spots, corresponding to more than 50% of the surface, should be counted as two spots. Otherwise, a sample with a single big spot would, by an error/limitation, be considered better than a sample showing two small spots at the surface. The convexity/concavity feature of the software was especially useful to demonstrate to the students' areas of unsupported enamel at the margin ("J" shaped margins) that can affect longevity of restorations and represents a crucial mistake during crown preparation according to the criteria adopted.

Undercut tool and axial reduction evaluation can be considered as complementary to each other. Evaluating the taper using the undercut tools consist in an incomplete evaluation (as it does not allow measurements of over-taper). Nonetheless, checking the axial reduction allows detection of such mistakes and the score would be adjusted. Axial reduction tool is based on the ideal design of the final crown (which can be determined using a "biogeneric copy" – software copies the crown which was scanned before preparation or a "biogereric individual" – software uses a tooth library), following the tooth anatomy, without compensating for thickness increasing or modifying the contour of the crown. The amount of reduction can be quantified using the tools "slice" and "distances". Evaluating occlusal reduction using the digital method allows a very precise quantification based on the distances between the occlusal surfaces of the crown preparation and the antagonist. This method is a lot more reliable and precise than manual evaluation using an instrument with size similar to the proposed reduction, as observed in the present study. Nevertheless, the digital method presented a difficult related with the presence of some over-reduced areas on the sulcus region (which are not supposed to present contact points during normal occlusion. In order to avoid this limitation, if no under-reduction was observed in the sulcus area, the occlusal reduction was assessed based only on the reductions at the cusp areas.

Based on the evaluated criteria, it was clear that axial and occlusal reduction consisted a very sensitive and subjective measurements, which might benefit from a more reliable (digital) assessment method. This would allow a more comprehensive evaluation of the entire preparation, without limitations that faculties (and students) currently face regarding calibration. This fact may occur especially when dealing with more conservative preparations (FG crown in the present study), and also to extrapolate for more complex anatomy-driven preparations for reinforced ceramics, which also allow more conservative preparations.[34] In this cases, small variations in the reduction could result in clinical failures. In the ideal scenario students should be able to scan their preparations and perform their self-evaluation using the same software used in this investigation. A proper student/scanner ratio need to be established to allow students to have proper time to use this technology, especially with timed proficiency exams. Students would then make the decision to modify the preparation if necessary or turn it in for faculty evaluation. This would streamline the process and allow for a truly digital workflow. In the present study, students did not have access to the scanners during these preparations. In our study one examiner scanned all typodonts and during an evaluation process that would require an extensive amount of time due to software processing times. Considering the limitations of the present study, it seems important to create and integrate a digital analysis of tooth preparations, allowing students to have a standardized self-feedback and feedback from their instructors. The results showed that a digital evaluation method can be reliable and feasible. Future studies should focus in testing the reproducibility of the proposed method in different dental schools/research centers.

Conclusion

The use of a digital evaluation method provided more accurate results compared to manual and self-evaluation of teeth prepared for crowns for all the criteria assessed, except for taper. The highest difference was shown in axial and occlusal reduction parameters.

Conflict of Interest

Authors disclose any financial, economic or professional interests that may have influenced the design, execution or presentation of the presented research.

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Tables

Table 1: Represents the parameters for the criteria sheet score used for porcelain fused to metal evaluation.

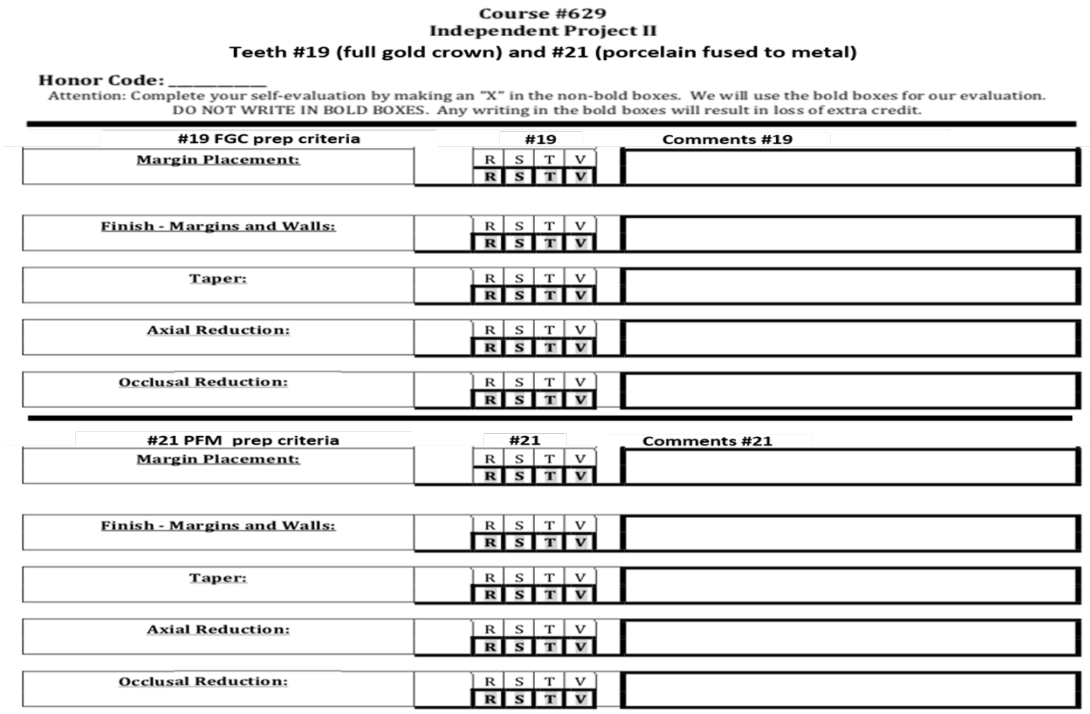
PFM retainer preparation #21					
Rating	**Margin placement**	**Finish, margins and walls**	**Taper (draw)**	**Axial reduction**	**Occlusal reduction**
R	• Even with or 0.5 mm occlusal to FGM or CEJ	• Margins and walls are smooth • Margins are continuous, well defined,	• Taper fully visible (8^{o} with line of draw) • Ideal path of draw with the other abutment preparation	• Sufficient tissue removal for convenience, retention and resistance form • Rounded line and point angles • Smooth curves	• 2.0 mm • Maintain general occlusal anatomy with identifiable triangular ridges and grooves
S	• Moderately overextended, not more than 0.5 mm below the FGM or CEJ • Moderately underextended, not more than 1 mm above the FGM or CEJ	• Moderate roughness of margins and walls • Margins are moderately non-continuous • Moderate lack of definition	• Taper present, but near parallel • Overtapered on mesial or distal ($>8^{o}$ $<16^{o}$) • Path of draw is not ideal or near parallel with the other abutment prep.	• Moderate over or under removal of tooth tissue • Moderate lack of rounded line or point angles • Moderate lack of smooth curves • **Minor damage to adjacent teeth / tissue**	• Max. = 2.0-2.5 mm • Min. = 1.5-2 mm • Lack of general occlusal anatomy and identifiable triangular ridges and grooves
T	• Significantly overextended, not more than 1.0 mm below the FGM or CEJ • Significantly underextended, not more than 1.5 above the FGM or CEJ	• Significant roughness of margins and walls • Margins are non-continuous • Significant lack of definition	• Undercuts visually present • Overtapered on buccal or lingual ($>8^{o}$ $<16^{o}$) • Slight lack of draw but retainers would seat given normal mobility of abutment teeth	• Significant over or under reduction • Significant lack of rounded line or point angles • Significant lack of smooth curves • **Significant damage to adjacent teeth / tissue**	• Max. = 2.5 - 3.0 mm • Min. = 1.0-1.5 mm • Absence of identifiable buccal/lingual groove, but presence of mesial/distal central groove
V	• Severely overextended, more than 1.0 mm below the FGM or CEJ • Severely underextended, more than 1.5 mm above the FGM or CEJ	• Severe roughness of margins and walls • Unsupported enamel • Severe lack of definition	• Severe undercuts present • Severe overtapered on any axial surface ($>16^{o}$) • Severe lack of draw, impossible to seat without additional modification of the prep	• Severe over or under reduction • Severe lack of rounded line or point angles • Severe lack of smooth curves • **Major damage to adjacent teeth**	• Max. >3.0 mm or • Min. <1.0 mm • Absence of identifiable buccal/lingual groove and mesial/distal central groove

Table 2: Represents the parameters for the criteria sheet score used for full gold crown evaluation.

FGC retainer preparation #19					
Rating	**Margin placement**	**Finish, margins and walls**	**Taper (draw)**	**Axial reduction**	**Occlusal reduction**
R	• Even with or 0.5 mm occlusal to FGM or CEJ	• Margins and walls are smooth • Margins are continuous, well defined • Functional cusp bevel is well defined	• Taper fully visible (8^o with line of draw) • Ideal path of draw with the other abutment preparation	• Sufficient tissue removal for convenience, retention, resistance form • Rounded line and point angles • Smooth curves	• 1.5 mm • Maintain general occlusal anatomy with identifiable triangular ridges and grooves
S	• Moderately overextended, not more than 0.5 mm below the FGM or CEJ • Moderately under-extended, not more than 1 mm above the FGM or CEJ	• Moderate roughness of margins and walls • Margins are moderately non-continuous. • Moderate lack of definition • **NO functional cusp bevel.**	• Taper present, but near parallel • Overtapered on mesial or distal ($>8^o <16^o$) • Path of draw is not ideal or near parallel with the other abutment prep.	• Moderate over or under removal of tooth tissue • Moderate lack of rounded line or point angles • Moderate lack of smooth curves • **Minor damage to adjacent teeth / tissue**	• Max. = 2.0-2.5mm • Min. = 1.0-1.5 mm • Lack of general occlusal anatomy and identifiable triangular ridges and grooves
T	• Significantly overextended, not more than 1.0 mm below the FGM or CEJ • Significantly underextended, not more than 1.5 above the FGM or CEJ	• Significant roughness of margins and walls • Margins are non-continuous • Significant lack of definition	• Undercuts visually present • Overtapered on buccal or lingual ($>8^o <16^o$) • Moderate lack of draw but retainers would seat given normal mobility of abutment teeth	• Significant over or under reduction • Significant lack of rounded line or point angles • Significant lack of smooth curves • **Significant damage to adjacent teeth / tissue**	• Max. = 2.5-3.0mm • Min. = 0.5-1.0 mm • Absence of identifiable buccal/lingual groove, but presence of mesial/distal central groove
V	• Severely overextended, more than 1.0 mm below the FGM or CEJ • Severely underextended, more than 1.5 above the FGM or CEJ	• Severe roughness of margins and walls • Unsupported enamel • Sever lack of definition	• Severe undercuts present • Severe overtapered on any axial surface ($>16^o$) • Severe lack of draw, impossible to seat without additional modification of the prep	• Severe over or under reduction • Severe lack of rounded line or point angles • Severe lack of smooth curves • **Major damage to adjacent teeth / tissue**	• Max. >3.0 mm or • Min. <0.5 • Absence of identifiable buccal/lingual groove and mesial/distal central groove

Figures

Figure 1: Score criteria sheet based on the parameters represented in Tables 1 and 2 to perform the manual and self-evaluations of the PFM and FGC preparations.



Course #629
Independent Project II
Teeth #19 (full gold crown) and #21 (porcelain fused to metal)

Honor Code: __________

Attention: Complete your self-evaluation by making an "X" in the non-bold boxes. We will use the bold boxes for our evaluation. DO NOT WRITE IN BOLD BOXES. Any writing in the bold boxes will result in loss of extra credit.

#19 FGC prep criteria	#19	Comments #19
Margin Placement:	R S T V / **R S T V**	
Finish - Margins and Walls:	R S T V / **R S T V**	
Taper:	R S T V / **R S T V**	
Axial Reduction:	R S T V / **R S T V**	
Occlusal Reduction:	R S T V / **R S T V**	

#21 PFM prep criteria	#21	Comments #21
Margin Placement:	R S T V / **R S T V**	
Finish - Margins and Walls:	R S T V / **R S T V**	
Taper:	R S T V / **R S T V**	
Axial Reduction:	R S T V / **R S T V**	
Occlusal Reduction:	R S T V / **R S T V**	

Figure 2: Score criteria sheet adapted from the manual criteria sheet and score parameters table to perform the PFM and FGC digital evaluation.

To evalute the preparation conditions, the evaluators are using Analisys tools from Cerec/Sirona program

Student Code: ______ Tooth Number: ______

Full Gold Crown		
Margim Placement Criteria	**Finishin Margins and Walls**	**Taper**
Using Margin R - None areas in yellow S - Until 2 areas in yellow T - 3 – 5 areas in yellow V - more than 5 areas in yellow	Using Surface R - None areas in yellow S - Until 2 areas in yellow T - 3 – 5 areas in yellow V - more than 5 areas in yellow	Using Undercut R - No Undercut S - Undercut until 0.20 mm T - 0.21 – 0.39 mm undercut V - more than 0.40 mm undercut
Axial Reduction (mm) Optimal 1.0 mm		**Occlusal Reduction (mm) Optimal 1.5 mm**
Using slice/ distance R - 0.9 < X < 1.1 mm S - 0.6 - 0.89 / 1.1 – 1.4 T - 0.30 - 0.59 / 1.41 -1.70 mm V - less than 0.29 / more than 1.70 mm		Using Distance to Antagonist R - 1.4 < x < 1.6 mm S - 1.0 – 1.4 / 1.6 – 2.0 mm T – 0.5 – 0.99 / 2.1 – 2.5 mm V – < 0.49 / > 2.51 mm
Porcelain Fused to Metal		
Margim Placement Criteria	**Finishin Margins and Walls**	**Taper**
Using Margin R - None areas in yellow S - Until 2 areas in yellow T - 3 – 5 areas in yellow V - more than 5 areas in yellow	Using Surface R - None areas in yellow S - Until 2 areas in yellow T - 3 – 5 areas in yellow V - more than 5 areas in yellow	Using Undercut R - No Undercut S - Undercut until 0.20 mm T - 0.21 – 0.39 mm undercut V - more than 0.40 mm undercut
Axial Reduction (mm) Optimal 1.2 mm		**Occlusal Reduction (mm) Optimal 2 mm**
Using slice/ distance R - 1.2 < X < 1.5 mm S - 0.90 - 1.19 / 1.51 – 1.80 T - 0.50 - 0.89 / 1.91 -2.20 mm V - less than 0.49 / more than 2.20 mm		Using Distance to Antagonist R - 2 mm S - 1.5 – 2.0 / 2.0 – 2.5 mm T – 1.0 – 1.5 / 2.5 – 3.0 mm V – > 1.0 / < 3.0 mm

Margin Placement:	R S T V **R S T V**	
Finish - Margins and Walls:	R S T V **R S T V**	
Taper:	R S T V **R S T V**	
Axial Reduction:	R S T V **R S T V**	
Occlusal Reduction:	R S T V **R S T V**	

Figure 3A: Cerec/Sirona PrepAnalizys tools used to perform the digital evaluation for the PFM and FGC evaluations. Margins tool used to evaluate the margin placement.

Figure 3B: Cerec/Sirona PrepAnalizys tools used to perform the digital evaluation for the PFM and FGC evaluations. Surface tool used to evaluate the finishing margins and walls.

Figure 4A: Cerec/Sirona PrepAnalizys tools used to perform the digital evaluation for the PFM and FGC evaluations. Undercut tool used to evaluate the taper of the preparation.

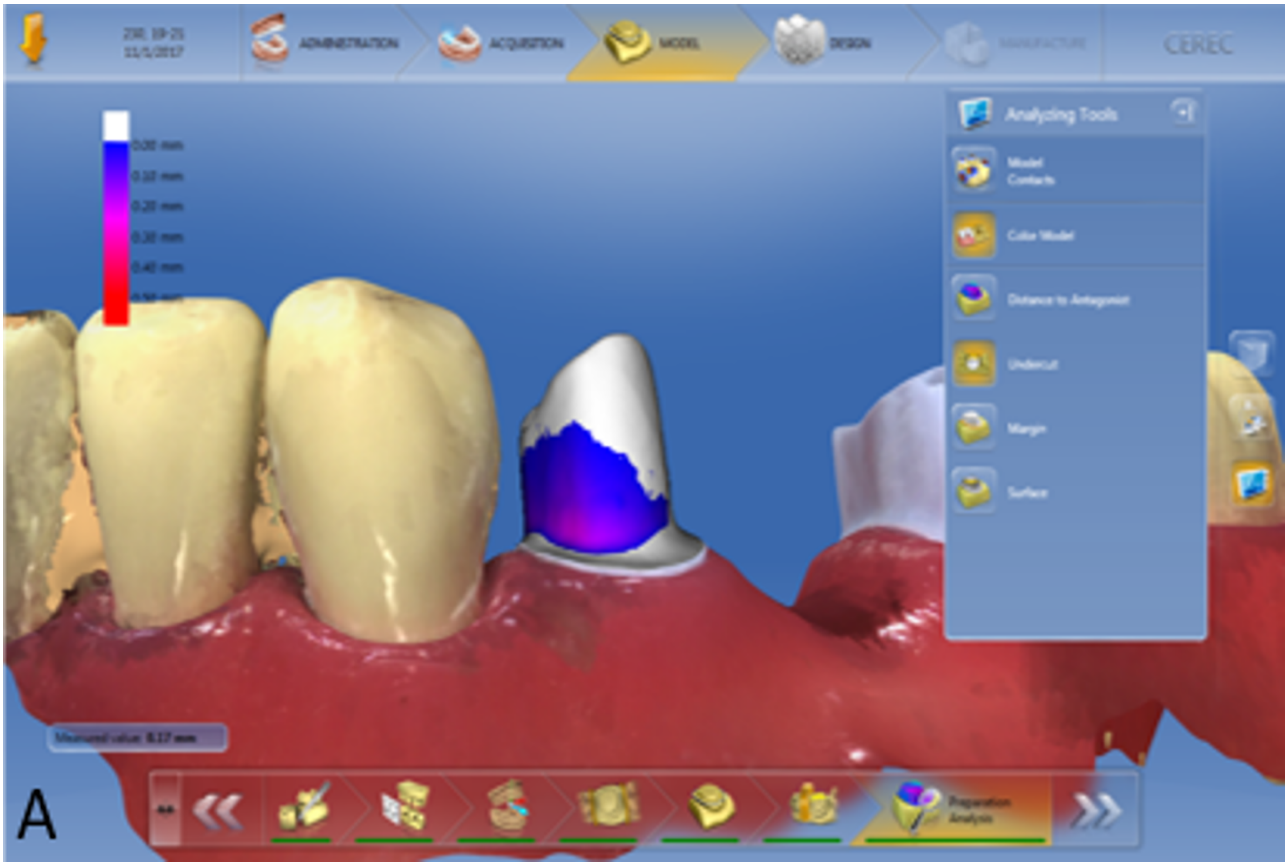


Figure 4B: Cerec/Sirona PrepAnalizys tools used to perform the digital evaluation for the PFM and FGC evaluations. Slice and Distance tools used after designing the crown to evaluate the axial reduction.

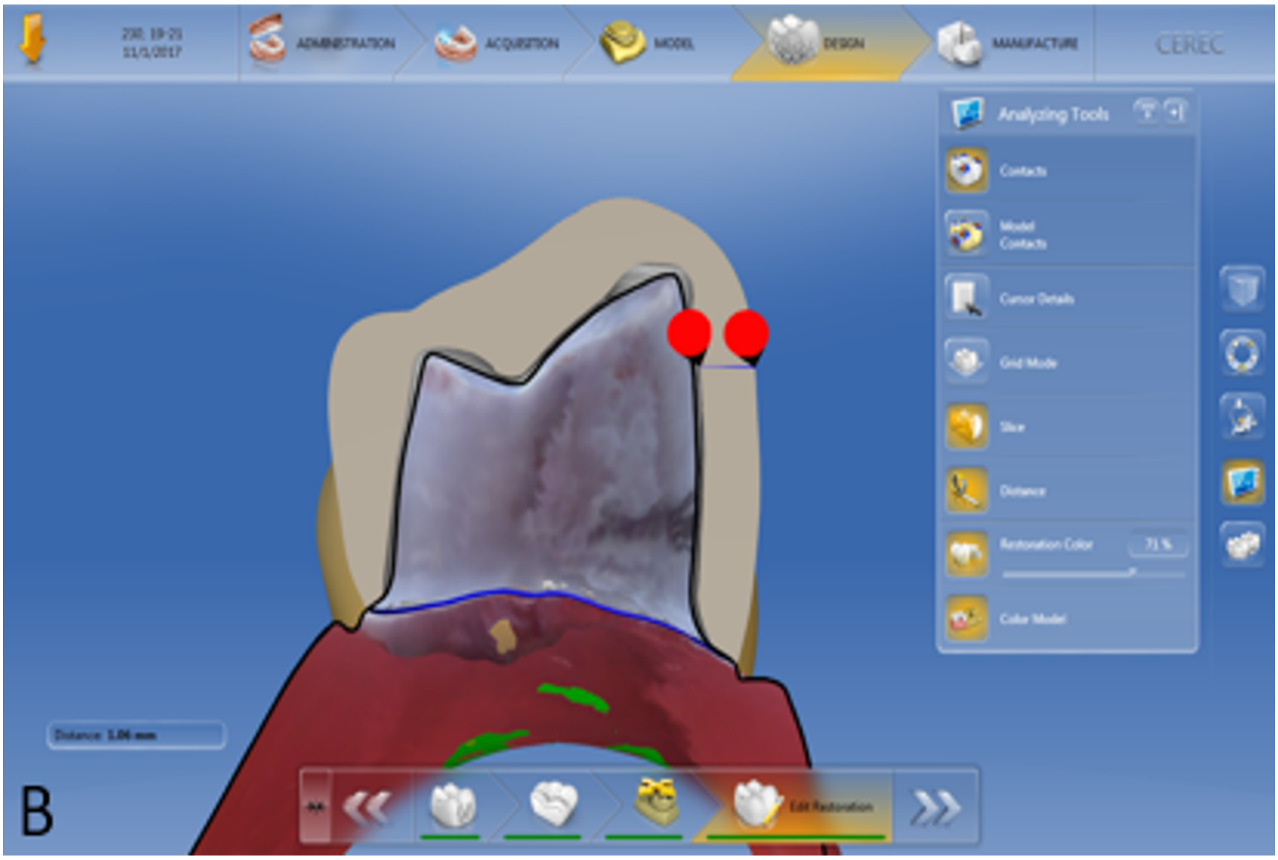


Figure 4C: Cerec/Sirona PrepAnalizys tools used to perform the digital evaluation for the PFM and FGC evaluations. Distance to antagonist tool used to evaluate the occlusal reduction.

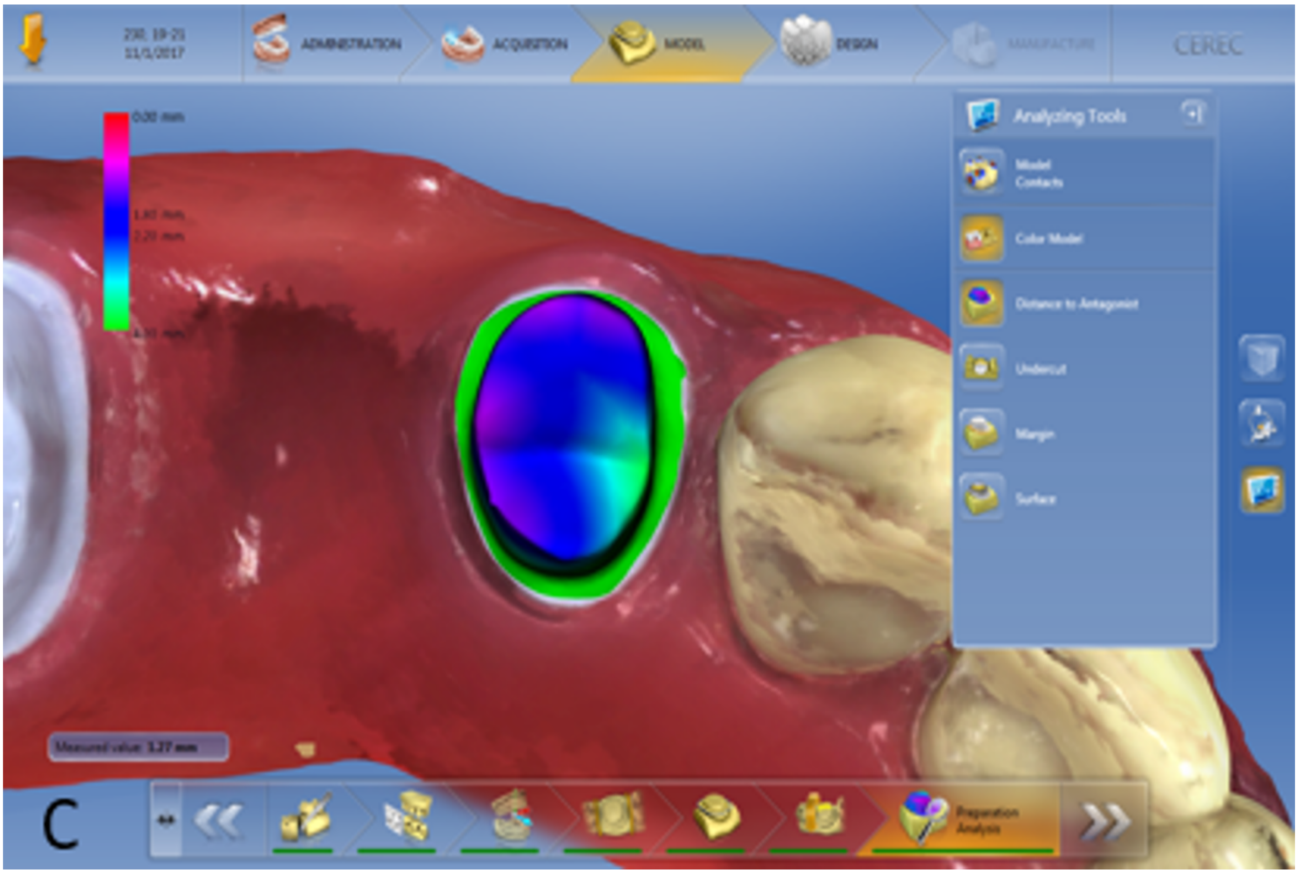
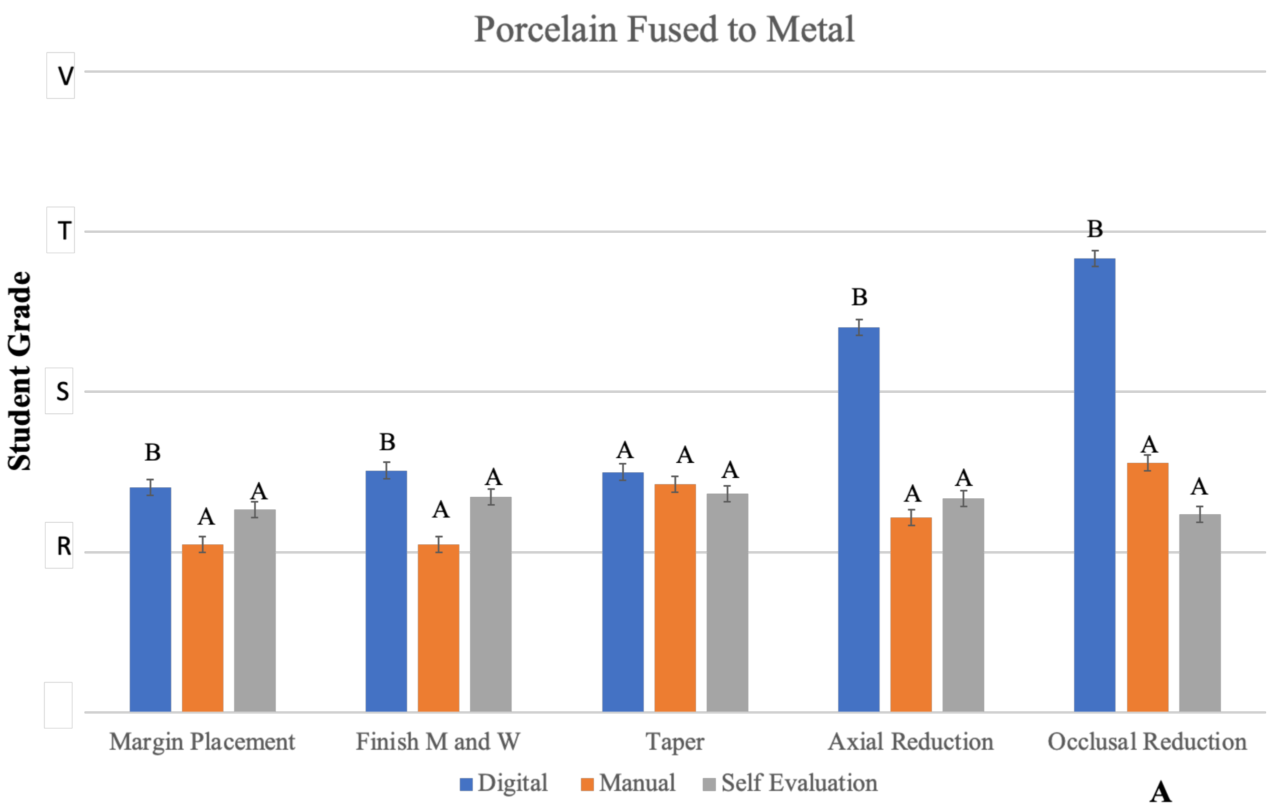
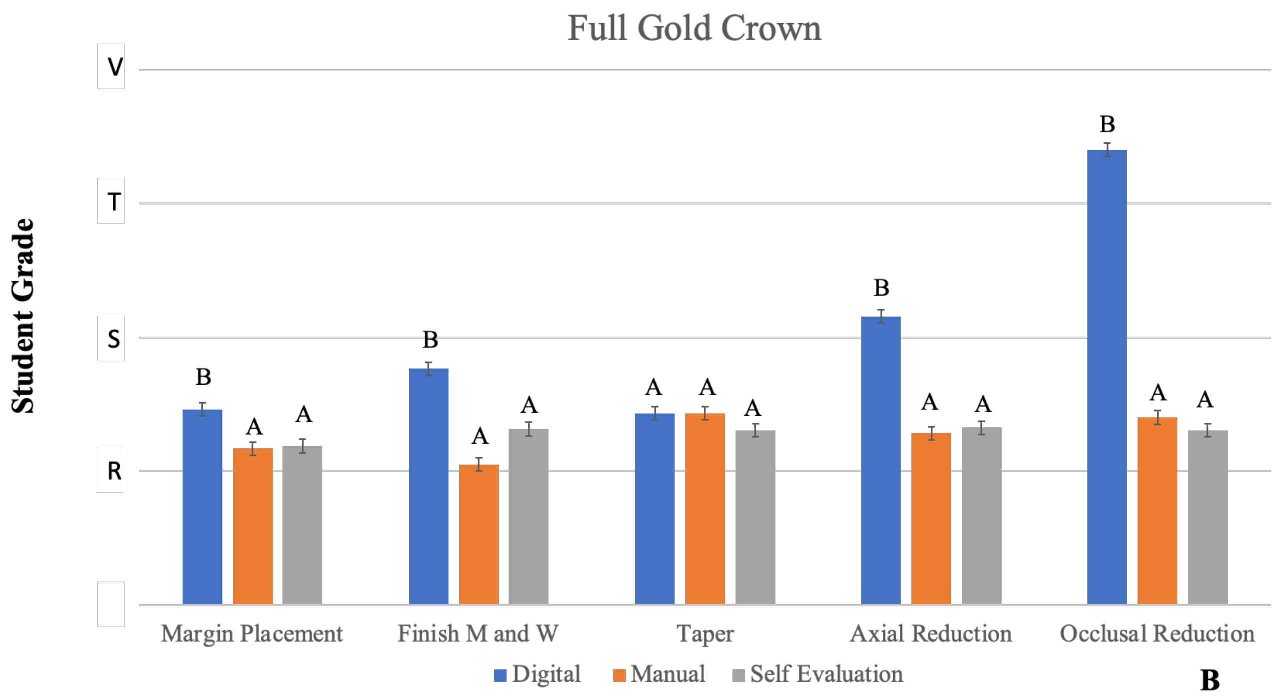


Figure 5A: Represents the comparison of the three evaluation modes for the PFM crown preparation.



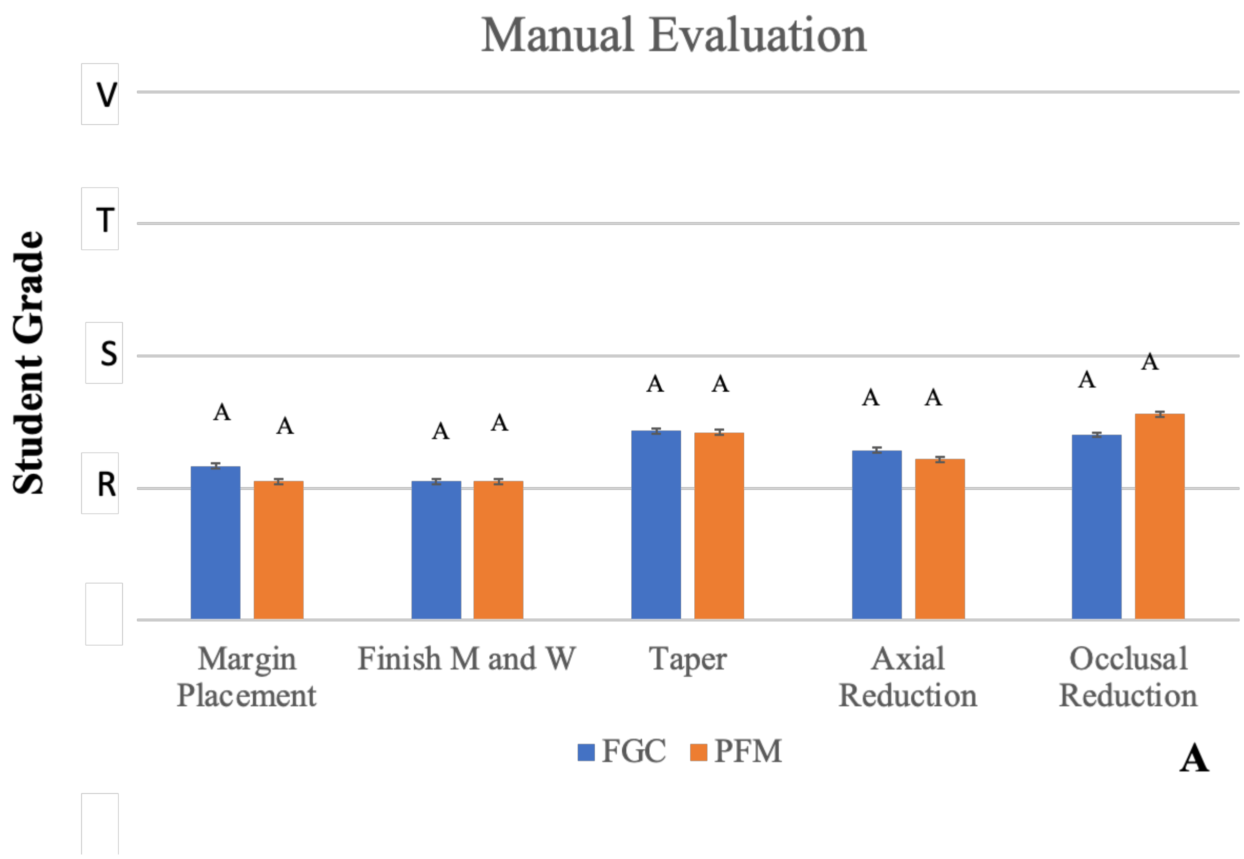
Different letters represent statistical difference between the groups (p<0.001)

Figure 5B: Represents the comparison of the three-correction mode for the FGC crown preparation.



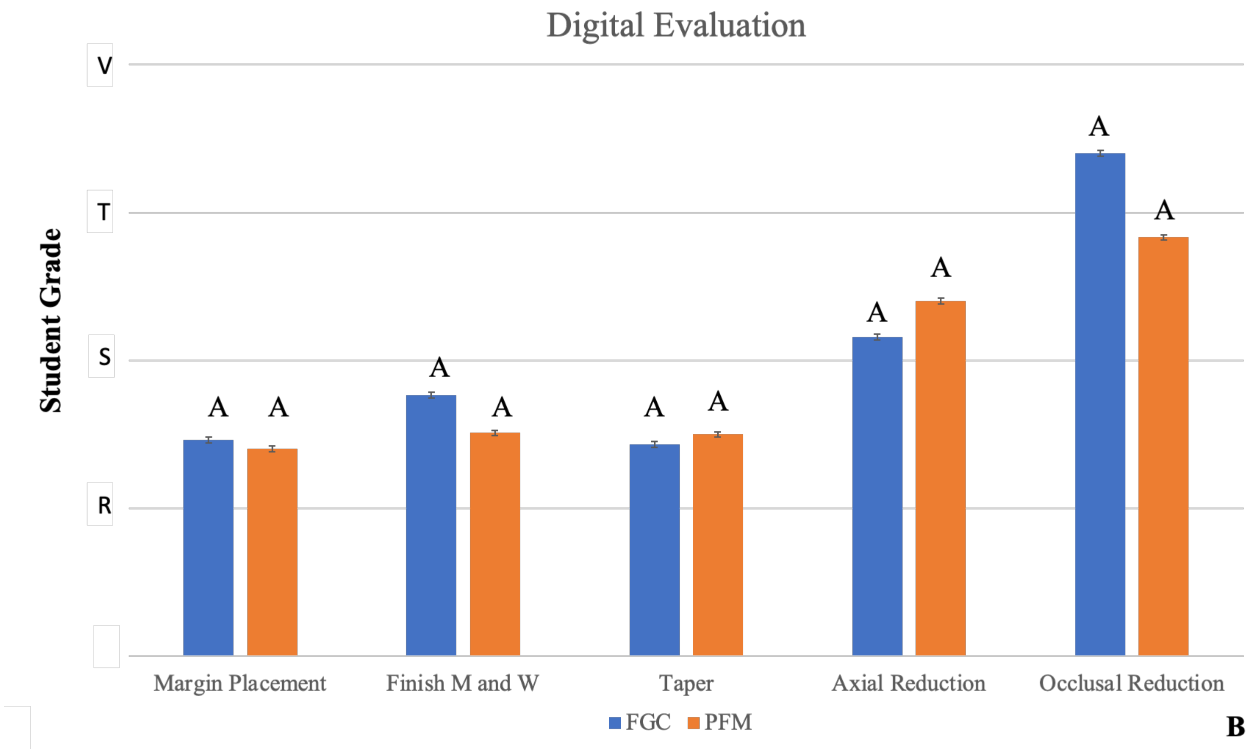
Different letters represent statistical difference between the groups (p<0.001)

Figure 6A: Graphics comparing the three different evaluation modes for PFM and FGC (Manual evaluation graph).



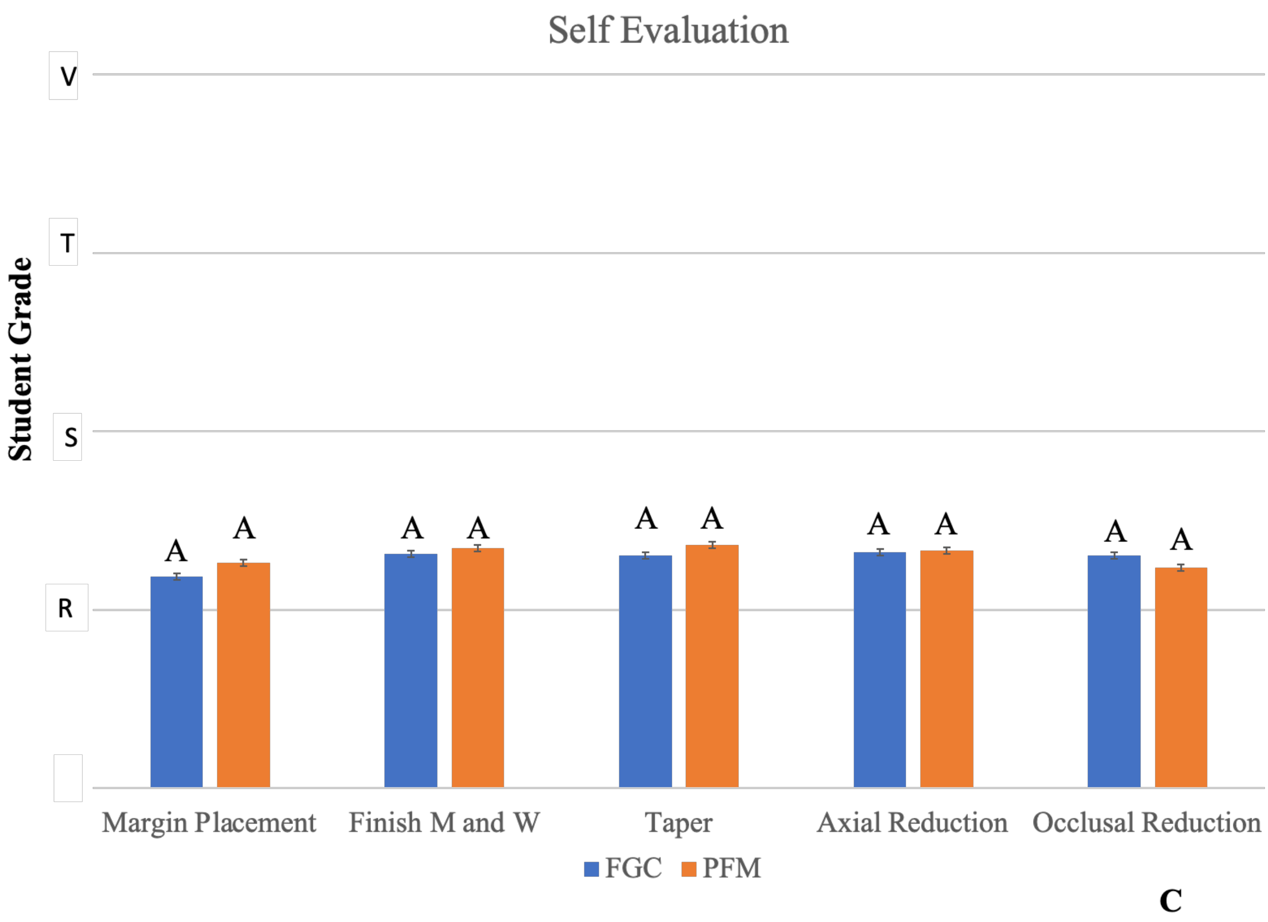
Different letters represent statistical difference between the groups (p<0.001)

Figure 6B: Graphics comparing the three different evaluation modes for PFM and FGC (Digital evaluation).



Different letters represent statistical difference between the groups (p<0.001)

Figure 6C: Graphics comparing the three different evaluation modes for PFM and FGC (Manual self-evaluation).



Different letters represent statistical difference between the groups (p<0.001)

CAPÍTULOS

3.2 CAPÍTULO 2

Artigo a ser enviado para publicação no periódico Journal of Dental Education

Agreement evaluation between professor and undergraduate students using manual and digital assessments to score crown preparation.

Moura GF, Rizzante FAP, Soares Pv, Mendonca G.

Abstract

Statement of the problem: The practical teaching and learning process commonly used by the dental school is based on performing crown preparation techniques on typodonts. Most of the times, the agreement between students and professor are deficient. Based on it, the purpose of this research is to correlate this agreement using a 3D software to make the process more reliable.

Methods: 75 typodonts were prepared, for a porcelain fused to metal and a full gold crown, by the second-year students from the DDS program of the university of Michigan. After preparations, the professor manually graded all the preparations and them, the typodont were scanned and evaluated by each student using a manual and a digital workflow. Data were tabulated and the agreement between the different datasets considering the different criteria was assessed via descriptive analysis and Gamma Coefficient correlation.

Results: The gamma correlation evaluation method presented a low to moderate agreement between the groups. Independent of the method used to evaluate, the range of the agreement was 50% to 72% and the gamma correlation -0.005 to 0.759.

Conclusion: Different assessment methods showed a low-moderate agreement between professor and students. The use of a digital evaluation method could improve the understanding, consolidating a more reliable tool that can contribute to better learning process.

Introduction

Preclinical training using typodonts consists in the gold standard during dental education, aiming in the capability of students to apply technical concepts acquired during didactic courses in a “hands-on” scenario. Such training is characterized by the need of quickly refining psychomotor skills in order to fulfill each courses’ requirements.[1,2] Moreover, it will determine the transition to real human patients.

During the preclinical training, students are often stressed out by the technical difficulties they start to face. Within this context, self-assessment has become a requirement for Commission on Dental Accreditation (CODA)[3,4] and is claimed as crucial for a quick professional development, both from the perspective of self-guided study, as well as to be able to understand instructors’ feedback.[4-10] Nevertheless, there is often a frustrating lack of agreement between students and faculty grading,[4, 7, 10-12] as well as between the instructors themselves,[12-14] which can jeopardize the learning process if students start to perceive such differences as bias or discrimination and/or rank instructors as easy or hard graders.[4,7,15-17] Such occurrences may happen due to a lack of calibration, subjectivity of the assessments, as well as the limitations of a regular typodont (limited view and space during work and during assessment with an instructor; and can contribute for a very stressful scenario, especially when previous feedbacks were received.[5]

As an example, determining the proper taper (and communicating it to a student) for a crown preparation (around 6°), can be very challenging, both in the preclinical and clinical environments, especially when using only visual methods aided or not by a mirror from the occlusal view. [18] Considering that in dentistry, narrow differences in preparations can impact the longevity of the restorations,[1,2,13,19-20] and that practice with feedback has been considered crucial for learning.[7] Using an objective evaluation/assessment method, capable of evaluate a preparation more consistently and comprehensively, as well as to provide a clearer feedback/assessment seems desirable.[7,13]

Digital technologies, based on CAD systems, allow students and instructors to create digital models and, depending on the system, to objectively analyze the preparation. The main benefits of such approach can consist in the possibility of precisely identify errors (including option of rotating and augmenting the image),[5] as well as to provide instant, objective, and visual feedback for self-guided study. [5,11,13,15,21] In addition, it also could consist in an approach for reducing the lack of calibration between instructors/lack of agreement between instructors,[4,13,14,21-23] allowing students to determine if the grading differences come from (lack of) hand skills or deficiencies in didactic knowledge rather than bias during instructor’s feedback.[4, 24]

This said, digital methods could help to overcome such scenarios providing a more objective and comprehensive method of analysis, [4,13,21,24,25] stimulating student to focus in the learning process rather than on the grades only.[15] In addition, digital/technological tools consist in a very powerful teaching instrument as students tend to prefer visual, immediate, consistent and objective information,[26] which is reported to contribute for the development of a more reliable self-feedback assessment, maximizing learning capabilities.[15,19,26] Moreover, digital feedback systems can be available at any time, reducing the requirement for a tutor/instructor and contributing for students' training time and customized learning experience.[15,19,25]

Currently, there is a lack of data about self-assessment performed by the students using visual/manual and objective/3D methods, and how they correlate with the instructor's manual/visual feedback. Thus, the objective of the present study was to assess the outcomes of a students' manual and 3D methods of evaluation when compared with instructor's feedback using manual method, considering two different preparations for Porcelain fused to metal (PFM) and FGC (Full Gold Crown).

Material and Methods

After approved by the local ethics committee (process #HUM00144152), the results from exams applied to second-year dental students during the Fixed Prosthodontics course during 2018 and 2019 were assessed, tabulated and analyzed.

The sample consisted of PFM and FG crown preparations carried out by 75 second-year DDS-program students attending to the Fixed Prosthodontics preclinical courses at the University of Michigan School of Dentistry (in a total of 150 preparations). The PFM crowns were performed on the left maxillary second pre-molar (#21) and the FG crowns were prepared on the right maxillary first molar (#19) on a typodont (R 862 – Columbia Dentoform) according to Goodacre, Campagni and Aquilino [27].

Three sets of data/grades (Professor's correction, student self-assessment, and student self-assessment using a digital tool) were analyzed for each exam based on the course's rubric (Table 1a and 1b). For each dataset, there were 150 samples (75 crown preparations for Full Gold Crown/FGC and 75 preparations for Porcelain Fused to Metal/PFM crown). Professor's correction was performed by the course director (G.M.) and the students' self-assessments were performed by the respective 75 students.

Professor's correction and student self-assessment were performed via manual inspection of the typodonts/preparations using 2x magnifying loupes (Orascoptic, WI, USA), clinical mirror and probe. For the student self-assessment using a digital tool, the prepared typodonts and their respective antagonists were scanned by a trained operator using a CEREC Omnicam (Sirona) and imported to the PrepAnalysis software (version 4.5, Sirona) and analyzed based on the course rubric.

For the manual evaluation, the preparations were evaluated according to the criteria sheet: 1- margin placement; 2 – margins and walls finish surfaces; 3 – taper; 4- axial reduction; and 5- occlusal reduction (Fig. 1a)

The criteria sheet used to digital evaluation (Fig. 1b) was adapted from the manual criteria (Fig. 1a), following the same parameters used for manual evaluation. Each tool provided by the software was used for an specific criteria: 1 – margins tool was used to evaluate margin placement; 2 – the surface tool to evaluate margins and walls finish surfaces; 3 – undercut tool to evaluate taper; 4 – the slice and distance tools after simulating the crown design were used to evaluate axial reduction; 5 – occlusal reduction was evaluated using the distance tool, having the opposing tooth as reference.

Based on the digital software, margin evaluation was graded according to yellow spots along the margins (Fig. 2a), which represents areas that the milling machine would not be able to mill accurately due to indentations, roughness, closeness or overlaps with the soft tissue. The surface was evaluated following the same "yellow-spots" principle (Fig. 2b), which represents convex or sharp areas. As software does not provide the total angle of convergence, the taper was evaluated based on the presence of undercuts (Fig. 2c), which represent preparations that did not respected the minimum degree of taper. Evaluation of axial reduction was based on a standard crown designed by the software, based on the typodont arch, up on each preparation and if necessary, modified by the operator. By using the slice tool cross-sections view were obtained and the thinnest or thickest area of the crown in the axial wall was measured, provided by the distance tool, and considered as axial reduction (Fig. 2d). Occlusal reduction parameter was quantified based on the opposing tooth using the distance tool (between occlusal surfaces). This tool provides a color map scale based on the distances (in millimeters) and allows the instructor to evaluate the least/most reduced areas (Fig. 2e).

To score the typodonts in all situations the R/S/T/V grading system was used. The letter "R" represents 100% (excellent) in the specific criteria, "S" represents 80% (good), T represents "60%" (not ideal but clinically acceptable) and V represents less than 60% (unacceptable or fail). To perform the statistical analysis the R/S/T/V were converted to numbers 1/2/3/4, respectively. Data were tabulated and the agreement between the different datasets considering the different criteria was assessed via descriptive analysis and Gamma Coefficient correlation (with $p<0.05$).

Results

The results corresponding to gamma correlation and percentage of agreement are described on Table 2, 3a and 3b and Fig. 3.

For margin placement on FGC, professor's and student's digital evaluations agreed only in 55.2% of the cases. In another 36.4% of the analysis, the grades using the digital assessment were lower than for the professor's manual analysis. Students' digital and manual evaluations corresponded only in 53.8% of the analyses with the digital feedback resulting in lower grades in about 40.6% of the remaining cases. Comparing students' and professor's manual feedback, there was 70.6% of agreement, while in around 18.2% of the cases, the faculty provided grades were worse than the students' grades. Gamma correlation showed a moderate association between the tested variables

Considering margin placement on PFM, professor's manual assessments and students' digital analyses agreed in 68.6% of the cases, while in 22.5% of the cases the digital-based analysis resulted in lower grades. Students' digital and manual methods agreed in 70.6% of the cases, with digital method providing lower scores in 19.6% of the cases. Students' and professor's manual feedback were similar in 72.5% of the cases, with 15.7% of the cases with lower grades provided by the students' self-feedback. Gamma correlation showed a substantial association between the tested variables.

For finishing margins and walls on FGC, professor's manual and students' digital assessments agreed only in 65.7% of the cases. The different grades were equally divided between the different evaluation methods (15.7% higher grades for students' digital, and 17.6% better grades for professor's manual method). Students' digital and manual methods corresponded only in 59.8% of the analyses, again with the digital method resulting in lower grades in about 26.5% of the cases. Comparing students' and professor's manual feedback, there was 62.7% of agreement, while in around 24.5% of the cases, the faculty's grades were worse than the student's grades. Gamma correlation showed a moderate to substantial (student digital versus professor's manual) association between the tested variables.

The same pattern was observed for finishing margins and walls on PFM, in which professor's manual and students' digital assessment methods agreed in 68.6% of the cases, while in 17.7% of the cases, the digital method provided worse results. Students' digital and manual agreed in 61.8% of the cases, while digital provided lower scores in 26.6% of the cases. Students' and professor's manual feedback were similar in 56.9% of the cases, with 24.5% of the cases with lower scores provided by the professors. Gamma correlation showed a low (professor's versus students' manual method) to moderate (students' digital versus manual) to substantial (students' digital versus professor's manual) association between the tested variables.

For taper on FGC, professor's manual and students' digital agreed only in 59.8% of the cases. For the analyses that did not have agreement, the grades from the digital workflow were smaller than the ones provided by the professor in 26.5% of the time. Students' digital and manual analyses corresponded only in 62.7% of the analyses, again with the digital method resulting in lower grades in about 24.5% of the cases. Comparing students' and professor's manual feedback, there was 67.6% of agreement. The different grades were equally divided between the different evaluation methods (16.7% higher grades for professors, and 15.7% better grades for students' manual). Gamma correlation showed a moderate association between the tested variables

Considering taper on PFM, professor's manual and students' digital methods agreed in 58.8% of the cases, while in 24.5% of the cases, the digital method provided lower results. Students' digital and manual agreed in 53.9% of the cases, while digital method provided lower scores in 27.4% of the cases; and students' and professor's manual feedback were similar in 58.8% of the cases. Once more, the distribution of the different grades was equally divided between the different evaluation methods (20.6% higher grades for professor's, and 20.5% better grades for students' manual method). Gamma correlation showed a low to moderate (students' digital versus professor's manual) association between the tested variables.

For axial reduction on FGC, professor's manual and students' digital methods agreed in 71.6% of the cases. Usually, the grades from the professor's evaluation were lower than for the digital students' method – 17.6% of the time. Students' digital and manual corresponded only in 59.8%, with the digital method resulting in lower grades in about 23.5% of the cases. Comparing students' and professor's manual feedback, there was 64.7% of agreement with 24.5% of the cases with lower scores provided by the professor's manual method. Gamma correlation showed a moderate (students' digital versus manual) to substantial (professor's versus students' manual) to strong (students' digital versus professor's manual) association between the tested variables.

Considering axial reduction on PFM, professor's manual and students' digital methods agreed in 52.9% of the cases, while in 28.4% of the cases, the professor gave a lower score than the students' digital method. Students' digital and manual methods agreed in 65.7% of the cases, and the distribution of the different grades were equally divided between the different evaluation methods (16.7% for each). Students' and professor's manual feedback were similar in 53.9% of the cases. The professor's evaluation resulted in lower grades in 29.4% of the cases. Gamma correlation showed a low or substantial (students' digital versus manual) association between the tested variables.

For occlusal reduction on FGC, professor's manual and students' digital methods agreed in 56.9% of the cases. The grades for the digital workflow were smaller in 29.4% of the cases without agreement. Student's digital and manual corresponded only in 55.9% of the analyses, with the digital method resulting in lower grades in about 33.4% of the cases. Comparing students' and professor's manual feedback, there was 64.7% of agreement with 20.6% of the cases with lower scores provided by the professor. Gamma correlation showed a moderate association between the tested variables

Considering occlusal reduction on PFM, professor's manual and students' digital methods agreed in 52% of the cases, while in 35.3% of the cases, the students' digital method gave a lower score than professors. Students' digital and manual methods agreed in 50% of the cases, with the digital method resulting in lower grades in 39.2% of the remaining cases. Students' and professor's manual feedback were similar in 61.8% of the cases. The professor's evaluation resulted in lower grades in 20.6% of the cases.

Gamma correlation showed a low association between the tested variables. This said, the overall agreement between the different assessment methods was lower than 70% and, in cases of disagreement, there was a tendency of lower resulting grades for professor's and students' digital evaluations.

Discussion

The lack of agreement between students and instructors feedback has been subject of innumerous discussions and is inherent of the association between the subjectivity of the analysis, limited communication quality between students and faculty members, as well as a challenging calibration process (between instructors), jeopardizing the students' learning process and development of adequate self-assessment skills. [4, 7, 415-17]

The use of digital technologies in dentistry could possibly help to overcome such limitations due to the versatility of the software enhancing comprehensive and objective assessment with the students. [4, 13, 21, 24, 25] In addition, machines can be available at any time, stimulating further training.[15, 19, 25] Nevertheless, there is a lack of information about the outcomes of manual and digital evaluation methods performed by students and their correlation with instructor's feedback using manual methods.

In general, it can be observed that for Margin placement, manual and digital evaluations resulted in the lowest percentages of agreement, especially for FGC. The feedback from the students (manual) and professors showed a relatively higher agreement, although still low (70.6% and 72.5% for FGC and PFM respectively). Considering PFMs, all analyses resulted in similar agreement. It is noteworthy that, when the methods did not provide the same feedback for both FGC and PFM, the digital method resulted in lower grades when compared with both manual assessments (from professor and students), indicating that the digital tool could provide a more sensitive evaluation.

Comparing PFM and FGC, the lower level of agreement for FGC may happen due to the smaller and more precise preparation required by this design, which is technically more complex at the cervical margin, while for PFM, the higher results probably correspond to acceptable variations existing for PFM as the reduction is a little more pronounced. The higher agreement between manual methods can indicate that the human eye can be more forgiving than the 3D model/computer. This becomes even more clear with the significantly lower results for FGC when compared with the PFM results, as FGC consist in a more conservative preparation.

Considering finish margins and walls, professor's manual evaluation and the students' digital feedback resulted in the highest agreement (65.7%) for FGC and PFM (68.6%). The students' manual feedback showed lower agreement with either the students' digital or professor's feedback for both preparations. Once more, when the methods did not provide the same feedback, the digital method resulted in lower grades for both FGC and PFM, showing that the digital tool could be more sensitive.

Comparing PFM and FGC, the lower values for PFM might have happened because of a an increased chance of marked roughness and creation of sharp angles due to the more pronounced reduction of tooth structure necessary. It is also evident the necessity of a more reliable method or more experienced operator (professor in this case) to provide a reliable evaluation of the crown preparation. In addition, the higher agreement between students' digital method and the professor's feedback for both FGC and PFM can indicate that the students cannot identify this criterion as easily and a more objective evaluation method is required.

Considering taper, while for FGC the highest agreement was observed between the students' manual evaluation and the professor's feedback, for PFM, professor's manual feedback resulted in similar values when compared with either students' digital and manual methods (58.8%). For FGC, the decrease in agreement when the digital method is used provides evidence that this preparation can be very challenging to grade as the reduction is not readily observable. For the PFM, the lower values of agreement show that probably due to the increased reduction, different evaluators might perceive the preparation in different ways. This said, although the experience of the operator (professor) can play an important role during the identification of the taper, it seems complicated to identify the angle of reduction especially in less conservative preparations (PFM), requiring a more standardized evaluation as widely discussed on the literature.[13, 21]

Considering axial reduction, for FGC it could be observed a higher agreement between the students' digital method and the professor's manual method (71.6%), while the comparison with the students' manual self-feedback resulted in the lowest agreement values. For PFM, students' digital and manual methods showed the highest agreement (65.7%). Interestingly, for axial reduction, mostly of the time the results were not in agreement, the professor graded the preparations with lower values, meaning that the instructor seems to be more conservative when a more pronounced preparation is needed (PFM). In addition, the bigger reduction further jeopardizes a manual analysis as there is a significant loss of reference points for analysis, explaining the lower agreements when the digital feedback was involved. For FGC, the results suggest that it is easier to evaluate the axial reduction as it is not as pronounced as for the PFM.

Such results can be explained by the recent push towards conservative procedures.[28,29] The impacts of such philosophy in the clinical evaluations became clear as it is possible to observe the highest agreement between the digital/objective method and the professor for the more conservative preparation (FGC). Nevertheless, once the preparation starts to be less conservative, the professor's grades start to be lower when compared with the other analyses, indicating it tends to be too conservative about the required reduction.

Considering occlusal reduction, both FGC and PFM showed the same trend, with the feedback from professor and students (manual) showing the highest agreement, while both analysis involving the digital instrument resulted in significantly lower agreement. Such results reflect a common clinical finding: how to reliably analyze occlusal reduction without an impression or 3D model? The present results reinforce that manual/visual methods tend not to be reliable enough when compared with the digital/objective method.

Although a direct comparison with the literature is prevented by the lack of itemized analysis, the authors of the present study believe it is important to individually analyze each criterion, with different preparations, to provide a more comprehensive understanding of the results. Nonetheless, it was possible to observe a general low-moderate correlation between the different assessment methods as previously reported. In addition, when discrepancies were observed, there was a tendency for students to overestimate their grades when compared with the professor's assessment and/or digital assessment, probably because they did not fully understand the used criteria or lack the ability for self-assessment. Such results are consistent with previous studies.[3, 10, 11, 13, 29]

In order to test the digital tool free of any bias, the same students who performed the manual analysis, assessed their own preparations using the software, using the exactly same criteria. The results showed a tendency for lower grades when disagreements happened compared with students' or professor's manual methods. Such results indicate that hand grading are not as precise as the computer grading and even experienced operators still lack the desired level of precision as previously reported.[4, 5, 7, 10, 13, 14, 17, 21, 25, 26] In addition, such results reinforce the perception that digital tools are able to provide a more comprehensive assessment, even for less experienced users (students).[7, 17, 25, 26]

Based on the results of the present study, it is clear the need for a more standardized, objective, and reliable method for assessment of different tooth preparations. It is noteworthy that mostly of the analysis resulted in 50-70% of agreement, which is rather low, especially considering a learning environment. Future studies should continue to focus in the evaluation of digital methods of feedback, especially related to the calibration between faculty members and even between teaching institutions.

The present study was performed as part of a regular fixed prosthodontics course, having as advantages the big sample size (entire classroom) and the standardization of the grader (one experienced instructor) and setting as every student wanted to perform as their best as it was part of their final competency. In addition, the present study assessed two different preparations (for PFM and FGC) providing more comprehensive information about the limitations of self- and instructor- based assessments.

Conclusion

The agreement between the different assessment methods was low to moderate, emphasizing the need of more reliable and objective feedback/assessment tools to contribute with a better and more comprehensive learning process for the dental students.

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Tables

Table 1a – Represents the parameters for the criteria sheet score used for porcelain fused to metal evaluation.

PFM retainer preparation #13					
Rating	**Margin placement**	**Finish, margins and walls**	**Taper (draw)**	**Axial reduction**	**Occlusal reduction**
R	• Even with or 0.5 mm occlusal to FGM or CEJ	• Margins and walls are smooth • Margins are continuous, well defined,	• Taper fully visible (8^{o} with line of draw) • Ideal path of draw with the other abutment preparation	• Sufficient tissue removal for convenience, retention and resistance form • Rounded line and point angles • Smooth curves	• 2.0 mm • Maintain general occlusal anatomy with identifiable triangular ridges and grooves
S	• Moderately overextended, not more than 0.5 mm below the FGM or CEJ • Moderately underextended, not more than 1 mm above the FGM or CEJ	• Moderate roughness of margins and walls • Margins are moderately non-continuous • Moderate lack of definition	• Taper present, but near parallel • Overtapered on mesial or distal ($>8^{o}$ $<16^{o}$) • Path of draw is not ideal or near parallel with the other abutment prep.	• Moderate over or under removal of tooth tissue • Moderate lack of rounded line or point angles • Moderate lack of smooth curves • **Minor damage to adjacent teeth / tissue**	• Max. = 2.0-2.5 mm • Min. = 1.5-2 mm • Lack of general occlusal anatomy and identifiable triangular ridges and grooves
T	• Significantly overextended, not more than 1.0 mm below the FGM or CEJ • Significantly underextended, not more than 1.5 above the FGM or CEJ	• Significant roughness of margins and walls • Margins are non-continuous • Significant lack of definition	• Undercuts visually present • Overtapered on buccal or lingual ($>8^{o}$ $<16^{o}$) • Slight lack of draw but retainers would seat given normal mobility of abutment teeth	• Significant over or under reduction • Significant lack of rounded line or point angles • Significant lack of smooth curves • **Significant damage to adjacent teeth / tissue**	• Max. = 2.5 - 3.0 mm • Min. = 1.0-1.5 mm • Absence of identifiable buccal/lingual groove, but presence of mesial/distal central groove
V	• Severely overextended, more than 1.0 mm below the FGM or CEJ • Severely underextended, more than 1.5 mm above the FGM or CEJ	• Severe roughness of margins and walls • Unsupported enamel • Severe lack of definition	• Severe undercuts present • Severe overtapered on any axial surface ($>16^{o}$) • Severe lack of draw, impossible to seat without additional modification of the prep	• Severe over or under reduction • Severe lack of rounded line or point angles • Severe lack of smooth curves • **Major damage to adjacent teeth**	• Max. >3.0 mm or • Min. <1.0 mm • Absence of identifiable buccal/lingual groove and mesial/distal central groove

Table 1b: Represents the parameters for the criteria sheet score used for full gold crown evaluation.

FGC retainer preparation #3					
Rating	**Margin placement**	**Finish, margins and walls**	**Taper (draw)**	**Axial reduction**	**Occlusal reduction**
R	• Even with or 0.5 mm occlusal to FGM or CEJ	• Margins and walls are smooth • Margins are continuous, well defined • Functional cusp bevel is well defined	• Taper fully visible (8^{o} with line of draw) • Ideal path of draw with the other abutment preparation	• Sufficient tissue removal for convenience, retention, resistance form • Rounded line and point angles • Smooth curves	• 1.5 mm • Maintain general occlusal anatomy with identifiable triangular ridges and grooves
S	• Moderately overextended, not more than 0.5 mm below the FGM or CEJ • Moderately under-extended, not more than 1 mm above the FGM or CEJ	• Moderate roughness of margins and walls • Margins are moderately non-continuous. • Moderate lack of definition • **NO functional cusp bevel.**	• Taper present, but near parallel • Overtapered on mesial or distal ($>8^{o}$ $<16^{o}$) • Path of draw is not ideal or near parallel with the other abutment prep.	• Moderate over or under removal of tooth tissue • Moderate lack of rounded line or point angles • Moderate lack of smooth curves • **Minor damage to adjacent teeth / tissue**	• Max. = 2.0-2.5mm • Min. = 1.0-1.5 mm • Lack of general occlusal anatomy and identifiable triangular ridges and grooves
T	• Significantly overextended, not more than 1.0 mm below the FGM or CEJ • Significantly underextended, not more than 1.5 above the FGM or CEJ	• Significant roughness of margins and walls • Margins are non-continuous • Significant lack of definition	• Undercuts visually present • Overtapered on buccal or lingual ($>8^{o}$ $<16^{o}$) • Moderate lack of draw but retainers would seat given normal mobility of abutment teeth	• Significant over or under reduction • Significant lack of rounded line or point angles • Significant lack of smooth curves • **Significant damage to adjacent teeth / tissue**	• Max. = 2.5-3.0mm • Min. = 0.5-1.0 mm • Absence of identifiable buccal/lingual groove, but presence of mesial/distal central groove
V	• Severely overextended, more than 1.0 mm below the FGM or CEJ • Severely underextended, more than 1.5 above the FGM or CEJ	• Severe roughness of margins and walls • Unsupported enamel • Sever lack of definition	• Severe undercuts present • Severe overtapered on any axial surface ($>16^{o}$) • Severe lack of draw, impossible to seat without additional modification of the prep	• Severe over or under reduction • Severe lack of rounded line or point angles • Severe lack of smooth curves • **Major damage to adjacent teeth / tissue**	• Max. >3.0 mm or • Min. <0.5 • Absence of identifiable buccal/lingual groove and mesial/distal central groove

Table 2 – Gamma correlation between the different feedback methods considering Full Gold Crowns (FGC) and Porcelain Fused to Metal Crowns (PFM).

	FGC			*PFM*		
	Std dig x prof	*Std dig x manual*	*Prof x std manual*	*Std dig x prof*	*Std dig x manual*	*Prof x std manual*
Margin placement	*0.442*	*0.440*	*0.377*	*0.563*	*0.650*	*0.557*
Finish margins and walls	*0.592*	*0.344*	*0.484*	*0.640*	*0.365*	*0.172*
Taper	*0.306*	*0.414*	*0.479*	*0.351*	*0.188*	*0.276*
Axial reduction	*0.759*	*0.364*	*0.600*	*0.171*	*0.528*	*0.192*
Occlusal reduction	*0.356*	*0.305*	*0.357*	*0.259*	*0.199*	*-0.005*

Table 3a - Percentage of agreement and distribution of the disagreement between the different feedback methods considering Porcelain Fused to Metal Crowns (PFM).

	Porcelain Fused to Metal (PFM)			
		Professor x digital student		
		Agreement	worst grades	
			professor	digital student
(%)	Margin Placement	68	9.5	22.5
	Finish M and W	68.6	13.7	17.7
	Taper	58.8	16.7	24.5
	Axial Reduction	52.9	23.55	23.55
	Occlusal reduction	52	12.7	35.3
		Professor x manual student		
		Agreement	worst grades	
			professor	manual student
(%)	Margin Placement	72	12.3	15.7
	Finish M and W	56.9	24.5	18.6
	Taper	58.8	20.6	20.6
	Axial Reduction	53.9	29.4	16.7
	Occlusal reduction	61.8	20.6	17.6
		digital student x manual student		
		Agreement	worst grades	
			digital student	manual student
(%)	Margin Placement	70.6	19.6	9.8
	Finish M and W	61.8	26.5	11.7
	Taper	53.9	27.4	18.7
	Axial Reduction	65.7	17.15	17.15
	Occlusal reduction	50	39.2	10.8

Table 3b - Percentage of agreement and distribution of the disagreement between the different feedback methods considering Porcelain Fused to Metal Crowns (PFM).

	Full Gold Crown (FGC)			
		Professor x digital student		
		Agreement	worst grades	
			professor	digital student
(%)	Margin Placement	55.2	8.8	36
	Finish M and W	65.7	17.15	17.15
	Taper	59.8	26.5	13.7
	Axial Reduction	71.6	10.8	17.6
	Occlusal reduction	56.9	13.7	29.4
		Professor x manual student		
		Agreement	worst grades	
			professor	manual student
(%)	Margin Placement	70.6	18.2	11.2
	Finish M and W	62.7	24.5	12.8
	Taper	67.6	16.2	16.2
	Axial Reduction	64.7	24.5	10.8
	Occlusal reduction	64.7	20.6	14.7
		digital student x manual student		
		Agreement	worst grades	
			digital student	manual student
(%)	Margin Placement	53.8	40.6	5.6
	Finish M and W	59.8	26.5	13.7
	Taper	62.7	24.5	12.8
	Axial Reduction	59.8	23.5	16.7
	Occlusal reduction	55.9	33.4	10.7

Figures

Fig 1a – Criteria sheet used to grade the manual assessment for PFM and FGC.

Course #629
Independent Project II
Teeth #3 (full gold crown) and #13 (porcelain fused to metal)

Honor Code: ________

Attention: Complete your self-evaluation by making an "X" in the non-bold boxes. We will use the bold boxes for our evaluation. DO NOT WRITE IN BOLD BOXES. Any writing in the bold boxes will result in loss of extra credit.

#3 FGC prep criteria	#3	Comments #3
Margin Placement:	R S T V / **R S T V**	
Finish - Margins and Walls:	R S T V / **R S T V**	
Taper:	R S T V / **R S T V**	
Axial Reduction:	R S T V / **R S T V**	
Occlusal Reduction:	R S T V / **R S T V**	

#13 PFM prep criteria	#13	Comments #13
Margin Placement:	R S T V / **R S T V**	
Finish - Margins and Walls:	R S T V / **R S T V**	
Taper:	R S T V / **R S T V**	
Axial Reduction:	R S T V / **R S T V**	
Occlusal Reduction:	R S T V / **R S T V**	

Fig 1b - Criteria sheet used to grade the digital assessment for PFM.

To evalute the preparation conditions, the evaluators are using Analisys tools from Cerec/Sirona program

Student Code: ______ Tooth Number: ______

Full Gold Crown		
Margim Placement Criteria	**Finishin Margins and Walls**	**Taper**
Using Margin R - None areas in yellow S - Until 2 areas in yellow T - 3 – 5 areas in yellow V - more than 5 areas in yellow	Using Surface R - None areas in yellow S - Until 2 areas in yellow T - 3 – 5 areas in yellow V - more than 5 areas in yellow	Using Undercut R - No Undercut S - Undercut until 0.20 mm T - 0.21 – 0.39 mm undercut V - more than 0.40 mm undercut
Axial Reduction (mm) Optimal 1.0 mm		**Occlusal Reduction (mm) Optimal 1.5 mm**
Using slice/ distance R - 0.9 < X < 1.1 mm S - 0.6 - 0.89 / 1.1 – 1.4 T - 0.30 - 0.59 / 1.41 -1.70 mm V - less than 0.29 / more than 1.70 mm		Using Distance to Antagonist R - 1.4 < x < 1.6 mm S - 1.0 – 1.4 / 1.6 – 2.0 mm T – 0.5 – 0.99 / 2.1 – 2.5 mm V – < 0.49 / > 2.51 mm
Porcelain Fused to Metal		
Margim Placement Criteria	**Finishin Margins and Walls**	**Taper**
Using Margin R - None areas in yellow S - Until 2 areas in yellow T - 3 – 5 areas in yellow V - more than 5 areas in yellow	Using Surface R - None areas in yellow S - Until 2 areas in yellow T - 3 – 5 areas in yellow V - more than 5 areas in yellow	Using Undercut R - No Undercut S - Undercut until 0.20 mm T - 0.21 – 0.39 mm undercut V - more than 0.40 mm undercut
Axial Reduction (mm) Optimal 1.2 mm		**Occlusal Reduction (mm) Optimal 2 mm**
Using slice/ distance R - 1.2 < X < 1.5 mm S - 0.90 - 1.19 / 1.51 – 1.80 T - 0.50 - 0.89 / 1.91 -2.20 mm V - less than 0.49 / more than 2.20 mm		Using Distance to Antagonist R - 2 mm S - 1.5 – 2.0 / 2.0 – 2.5 mm T – 1.0 – 1.5 / 2.5 – 3.0 mm V – > 1.0 / < 3.0 mm

Margin Placement:	R S T V R S T V	
Finish - Margins and Walls:	R S T V R S T V	
Taper:	R S T V R S T V	
Axial Reduction:	R S T V R S T V	
Occlusal Reduction:	R S T V R S T V	

Fig 2a – Margin placement assessment for teeth number #3. Note that there is no yellow spots representing an excellent (R) preparation at the margin.

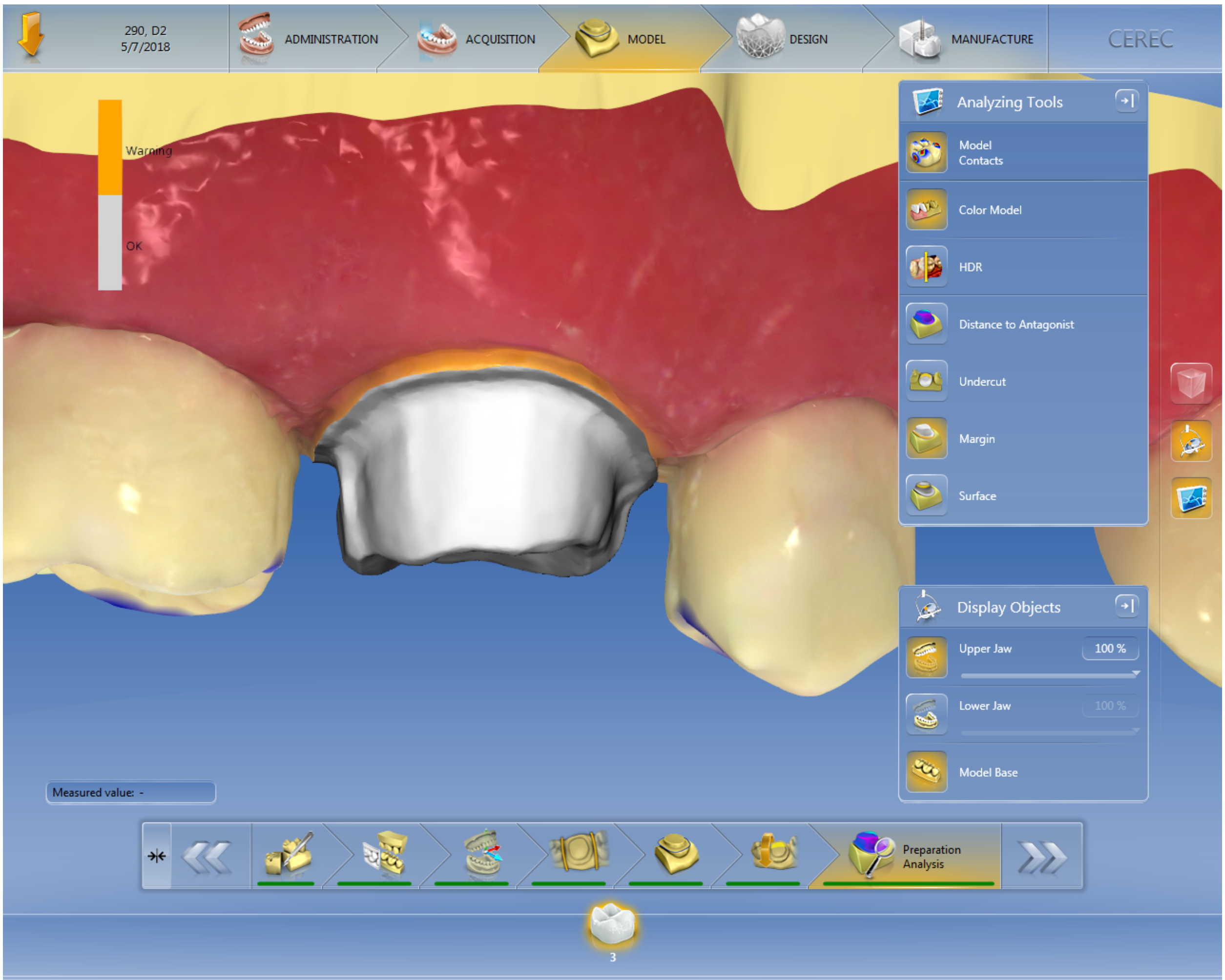


Fig 2b – Finishing margin and walls assessment for teeth number #3. Note that there is one yellow spot representing the is a good (S) finishing for the walls

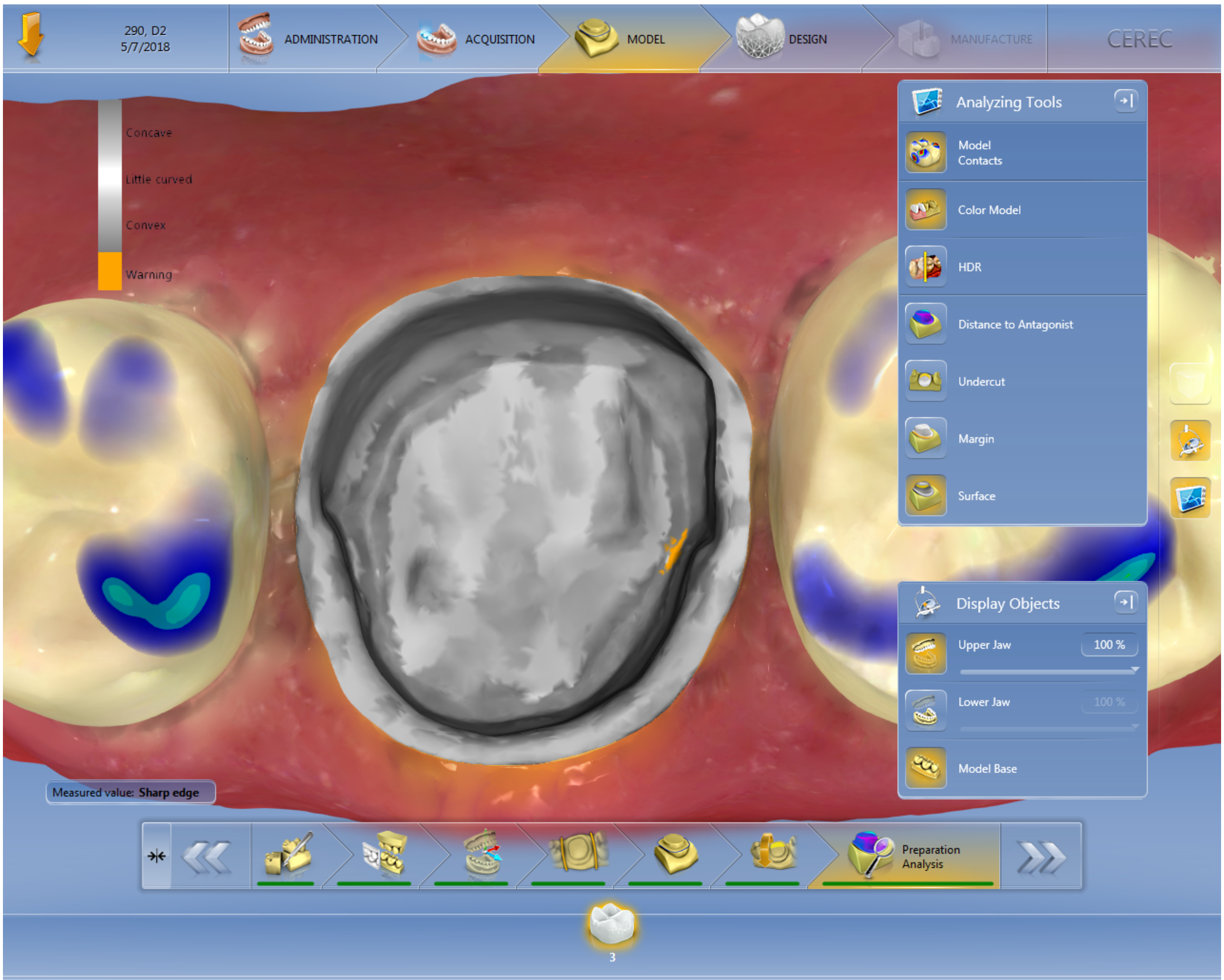


Fig 2c - Taper assessment for teeth number #3. Note that there is one color spot at the distal (0,10mm) representing the is a good (S) taper.

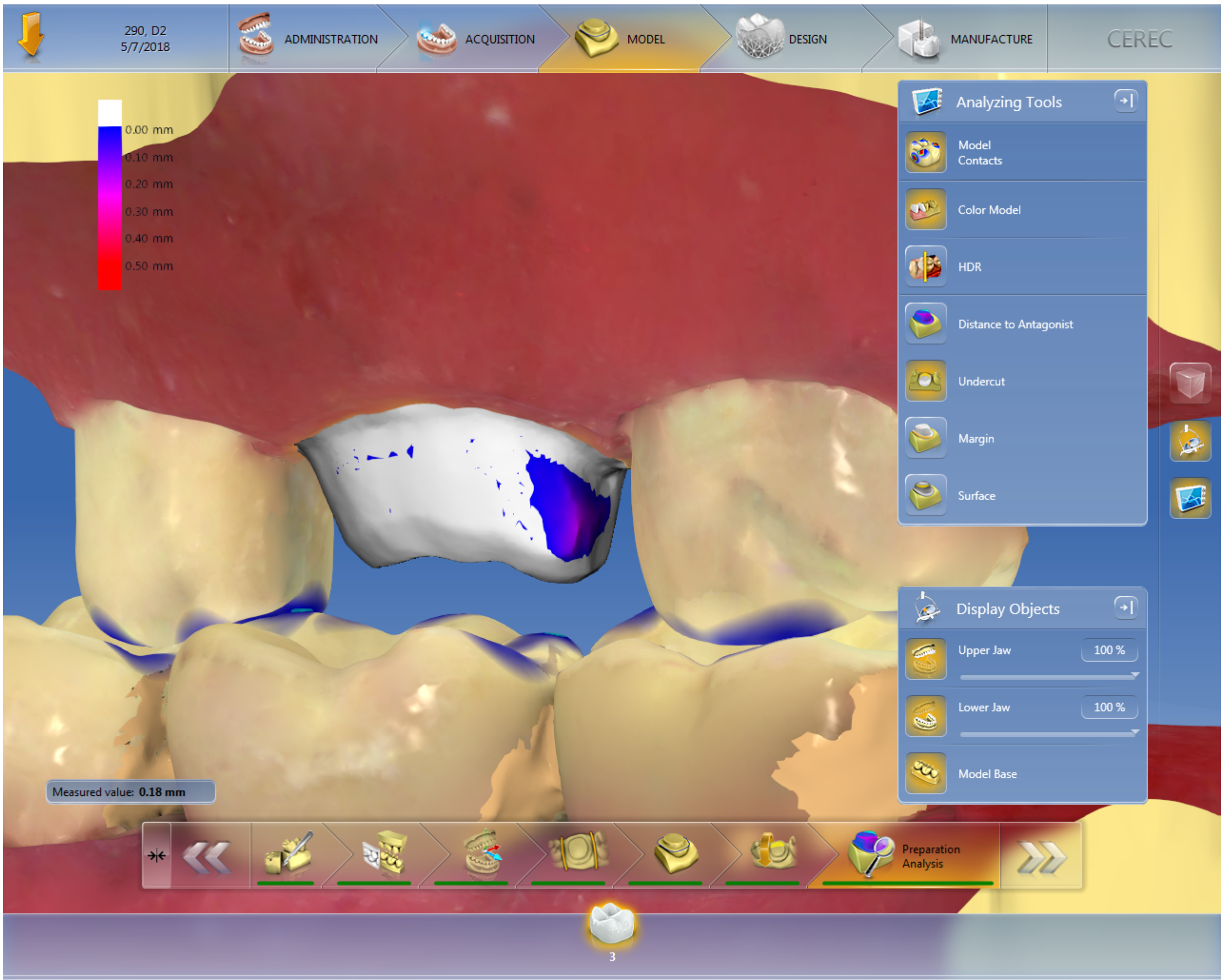


Fig 2d – Axial reduction assessment for teeth number #3. Note that the buccal reduction close to the margin is less than 1 mm representing that there is a not good a reduction but acceptable (T) finishing for the axial reduction.

Fig 2e - Occlusal reduction assessment for teeth number #3. Note that the occlusal reduction is less around 2 mm representing the is a good a reduction (T) finishing for the occlusal reduction.

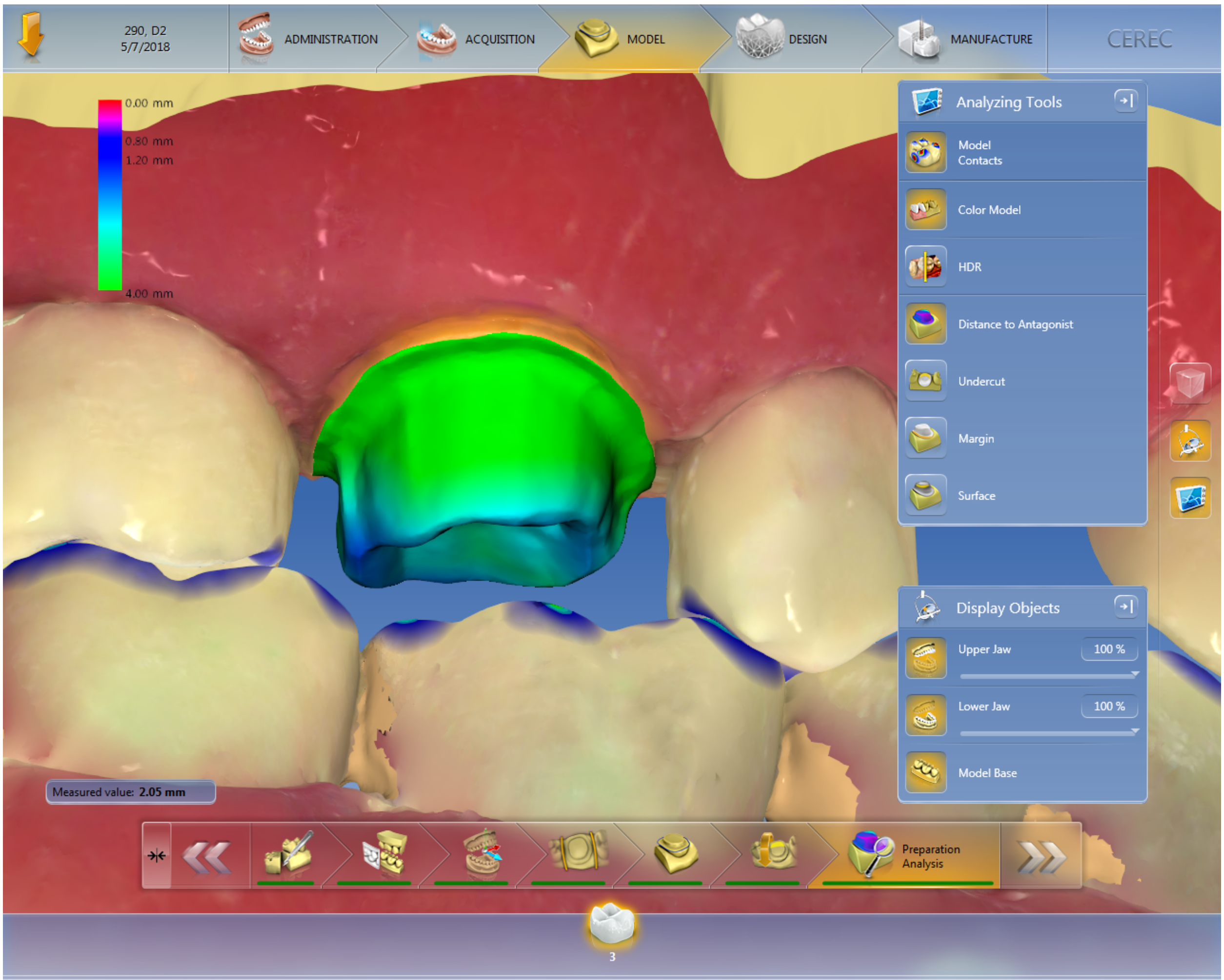
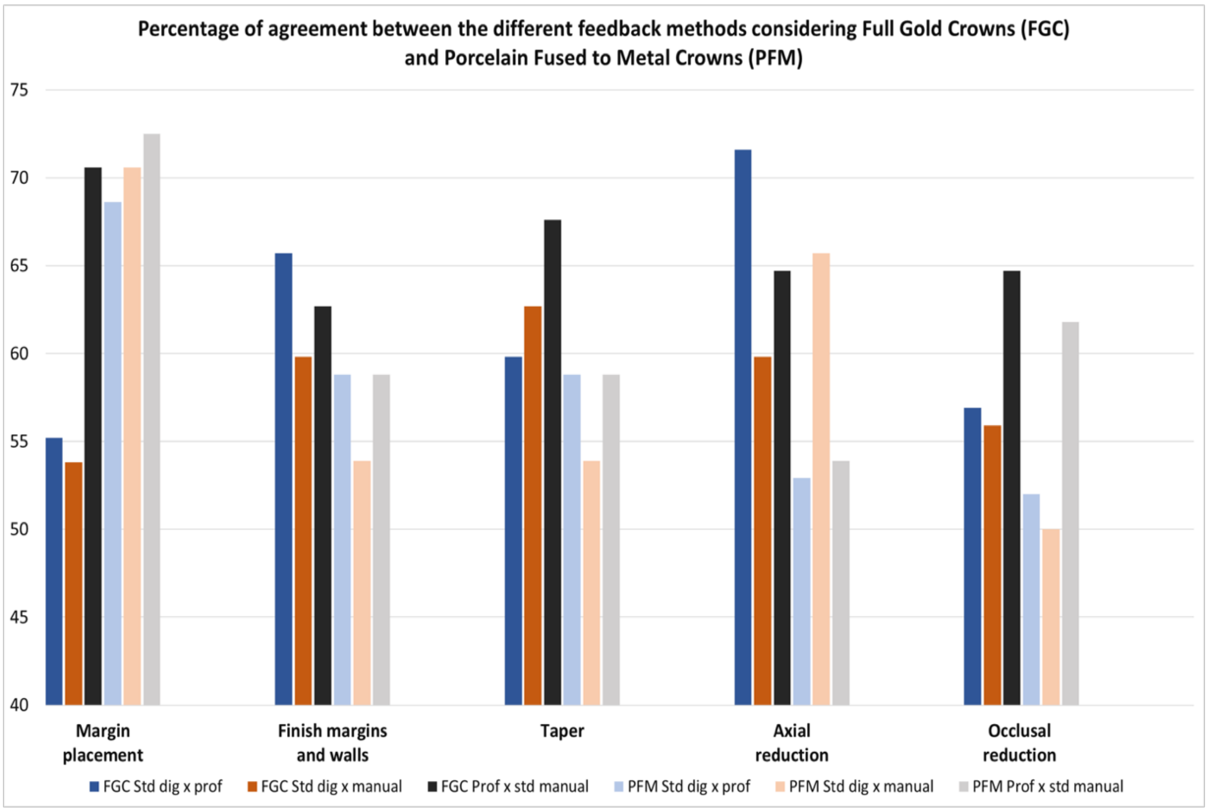


Figure 3- Percentage of agreement between the different feedback methods considering Full Gold Crowns (FGC) and Porcelain Fused to Metal Crowns (PFM).



CAPÍTULOS

Artigo a ser enviado para publicação no periódico Dental Materials

Influence of enamel and dentin roughness on the trueness of an intraoral scanner.

Moura GF, Mendonça G, das Neves FD, Soares PV, Meirelles LAD

Abstract

Objective: Secondary caries detected at the crown margin is typically associated to poor bonding observed to dentin or enamel or to misfit between the crown and tooth margin. The aim of this study was to evaluate the accuracy of margins in dentin (De) and enamel (En) with different finishing protocols of specimens stored in dry (Dr) and wet (We) environments.

Methods: Upper canines (n=8) were prepared using different burs sequence: 1) Coarse Diamond Bur; 2) 1 + Fine Diamond Bur; and 3) 1 + Carbide Fine Bur. Margins were scanned 10x using Trios (3-Shape) and compared to a D200 (3Shape) bench scanner. Accuracy was determined by precision and trueness (Geomagic Control 2015). Roughness (Sa) was measured by an interferometer (Lext, Olympus) to determine the impact of topography on accuracy.

Results: Improved precision was observed to En (15.7 μm) compared to De (24.3 μm) (p=0.000). In addition, the environment had major impact in accuracy. Higher precision and trueness (p=0.000) was observed to Dr (18.3 μm) compared to We (37.3 μm). The use of fine burs improved precision and trueness for Dr-De when comparing preparation protocols (1-2 p=0.017; 1-3 p=0.005; 2-3 p=0.999), whereas no difference was detected for Dr-En (1-2 p=0.966; 1-3 p=0.822; 2-3 p=0.519). The use of a second fine bur decreased Sa (μm) for De (1/2/3) (7.11/5.63/4.53), whereas En values were similar (7.94/8.53/9.97). Accuracy of marginal crown impressions was dependent on the tissue, roughness, and environment.

Significance: The use of finishing burs is an alternative to improve accuracy and is a safe and simple approach to optimize marginal adaptation.

Key words: Intraoral scanner, accuracy, surface roughness, enamel, dentin

1. Introduction

When intraoral scanners (IOS) first appeared in the market they required a strict finish line design and/or the use of a layer of powder on the tooth surface to achieve the recommended fit for full crown restorations.[1,2] Novel technology incorporated to IOS resulted in more flexibility regarding the finish line and overcame the need to apply surface powders. A key component independent of the IOS, is the physical properties of the scanned structures, and in particular, the surface properties. The surface properties of the substrate of interest will impact how the light is reflected to the IOS sensor determining the quality of the digital file generated. Marginal fit is a key factor for long-term success of fixed dental prosthesis (FDP). The range considered by several studies for an acceptable marginal fit is between 75 – 120 μm.[1, 3-5] Ideally, the American Dental Association (ADA) suggested between 25 – 40 μm, however this marginal fit range is clinically difficult to be obtained.[6] A misfit margin can promote dental plaque accumulation, the dissolution of the luting material, and may favor the onset of periodontal disease. [7-9] A study conducted by Grasso et. Al [10] suggested a relationship between the quality of restorative care and periodontal health. The results indicated that restorations with inadequate fit had significantly more plaque, gingivitis, and periodontal pocket formation than restorations with recommended fit. [10]

The finishing line of the tooth preparation is a critical area for the crown adaptation. The burs used to prepare the margins create different roughness due to particular configuration of the blades or particles incorporated. Actually, the rotary instruments, usually used for tooth preparation, create a highly complex surface that consists of roughness, waviness, straightness, and other similar errors of form whereas the preparation process. All these features combined is denominated as the total profile that are able to be quantified by profilometer parameters (Ra, Rq, Ry, and Rz).[11]

Since the 80's studies compared the difference in the tooth surface due to different bur preparations. Price et. al. (1988), presented that a 30-fluted bur could machine a smoother surface than a fine diamond bur.[12] Fluted burs remove tooth structure by different mechanism compared to the abrading action of a diamond rotary bur. During the fluted bur rotation, the flutes undermine dental tissue and the angle of attack determined the amount of tissue removed by the flute, a basic feature of bur design. On the other hand, the abrasive particles of diamond rotary bur, when it comes in contact with the tooth surface and plough troughs in the substrate, tooth structure is removed ahead of abrading particles and the surface become into several scratches running parallel to the direction of the movement of the bur. [13] The same result is reported for dentin and enamel roughness.[14]

Intraoral scanner is one device that allows the dentist to take a digital impression avoiding the use of impression materials.[15] It usually uses different way to capture images or videos to generate the digital standard tessellation language (.stl) files. Renne et. al. [16] comparing several scanners reported that the range for sextants scans accuracy is between 45 – 75 µm according to the technology and brand. Some optics properties of the substrate as the reflectivity, refraction index, and translucency change the amount of light received by an IOS sensor which might influence the quality of surface data captured. [17] Dutton et. al. [17], discussed about the influence of the substrate in the accuracy of different IOS and concluded that, for most of the scanner, a more translucent substrate, like enamel, lithium disilicate, translucent resins (enamel and bulk-fill) are more susceptible to be less accurate than an opaque one.[17] And also Resende et. al. [18] reported that the operator experience and the scan size influence the scan quality. A less experienced operator associated to full arch scan tends to generate more inaccurate scans.[18]

According to ISO 5725-1 accuracy of IOS consist in precision (how close different repeated measurements to each other) and trueness (how close the scanned file variate from the real surface).[15,16] The different way to capture can improve or, sometimes became a limitation of the scanning process. [15] The differences in surface characteristics and roughness of teeth might interfere in the marginal crown adaptation for conventional workflow.[19] In addition, tooth structures are commonly covered by saliva that will create a layer modifying teeth surface properties, which is suggested by some authors as one of the reasons for inaccuracy.[20,21] Since use of IOS in dental practice is becoming more and more popular, there is a lack of consistent support of the literature in the relationship between the accuracy of the scanner and the surface roughness of the preparation margin. The aim of this research was to evaluate the use of a second finishing bur during crown preparation at the finish line to understand the influence on the accuracy of the digital file generated by the IOS.

2. Materials and Methods

2.1 Specimen preparation

This research did not require ethical approval. Eight upper canines were divided in 4 groups (Fig.1) and prepared following Goodacre, et. al. [22] using 3 different finishing protocols, to create different surface roughness in the specimens, as shown in Figs. 2A and B. Each tooth had a margin preparation with the finishing line above the cement-enamel junction (CEJ) in the mesial surface comprising mainly of enamel, and in the distal below the CEJ comprising mainly of dentin (Fig. 2C and D). The groups were divided based on the protocol used to prepare the tooth finish line: G1: Prepared with coarse diamond bur (DC); G2: Initial preparation with coarse diamond bur followed by finishing with fine diamond bur (DF); G3: initial preparation with coarse diamond bur followed by finishing with carbide fine bur (CF). To evaluate the effect of saliva on the quality of the scanning, one specimen of each group was immersed in artificial saliva for 24 hours (gastric mucin 2.20g/L, NaCl 0.381g/L, CaCl2 2H2O 0.213g/L, KH2PO4 0.738g/L, KCl 1.114g/L; pH7.0) [78]. The other specimens were maintained in a dry environment.

2.2 Surface roughness analysis

The finish line of all groups was evaluated by interferometry (Lext – Olympus) with ×10 objective resulting in a standarized ROI (regions of interest) for all samples of a 500x500 µm field of view (Fig.2B). Band pass Gaussian filter was used to remove errors of form and waviness. To perform the measurements, the samples were placed on an acrylic plate held by a piece of wax, with the ROI as perpendicular as possible to the microscope lens. The roughness parameters selected were calculated using software Lext OLS 4000, Olympus (Figure 3) and included: Sa (arithmetical roughness), Sk (Core Roughness Depth), Svk (Reduced Valley Depth), Sxp (Peak extreme height) and the somatory of Sk, Spk and Svk.

2.3 Scanner data acquisition

To scan the samples, the IOS Trios 3 (3Shape) was used. Each sample from each group were scanned 10 times (n=10) in the high resolution mode (test group). The amount of 80 digital files were exported (high quality) in a standart tesselation surface (.stl) (Figure 2D) and kept saved according to the groups.

To acquire the master file (standart scan aqcquisition) each sample was scanned using the bench scanner D2000 (3Shape), a gold standart scanner (control group). The master model was later compared with the IOS scan,

2.4 Scanner assessment analysis

The obtained data from the benchtop and intraoral scanning were analyzed using a metrology software, Geomagic Control X (3D Systems, Rock Hill, South Carolina). The master files were first trimmed, using the metrology software, to eliminate excess data points on the teeth, leaving only the finish line margin to be aligned. The trimming of the master file removed data points from the reference scan which should then be excluded from comparison with the IOS .stl file. The master file was set as reference to be compared. Each IOS scan file was imported then superimposed onto the reference file using the best-fit alignment tool by using reference points, the best-fit use an iterative closest point algorithm, which has become a standard method for aligning digital 3D files (Figure 4A).[24] After alignment, the discrepancies in the margins were compared using a 3D compare tool. A color map scale represented in different colors on the images of the model showed the deviation results (Figure 4B). Deviations toward darker blue indicates a negative, or inward deviation, and toward darker red indicates a positive, or outward deviation of the test model to the reference model.[17] To evaluate the IOS precision (how close the intraoral scans are to each other), all the IOS files from each group were compared among each other (n=10). To evaluate the IOS trueness (how close the intraoral scan files are to control group (benchtop scanner), all the IOS files were compared to the file acquired from the benchtop scanner.

2.5 Statistical analyses

The data were processed and submitted to Levene test to evaluate the normality distribution and then submitted to 2- way ANOVA and to Bonferroni post-hoc analysis to identify if there was difference between the groups using SPSS software (SPSS v26). Statistical significance difference was set at $p<0.05$.

3. Results

The accuracy of the intraoral scanner is dependent on the environment variation. For precision (p=0.000) and trueness (p=0.000) the dry environment present better accuracy than the wet, independent of the preparation protocol used or the tissue prepared. Fig. 5.A represent the precision and Fig. 5.B the trueness comparing the different environments. Comparing how close one measurement is to the other in the same scanner (precision) the enamel presented less distortion than dentin (p=0.000); however, the deviation from the control group (trueness) the dentin was more precise (Figs. 6. A and B).

The enamel precision (Fig. 7.A) comparison between the three different preparation protocols did not present statically different for the groups in a wet environment (G1/G2 – p=0.109; G1/G3 – p=0.925; G2/G3 – p=0.593), neither for the dry (G1/G2 – p=0.992; G1/G3 – p=0.992; G2/G3 – p=1.000). Although, when compared in the same preparation protocol, the scan from the dry environment is more reliable (G1 – p=0.001; G2 – p=0.000; G3 – p=0.000). For the trueness (Fig 7. B), the use of a finishing carbide bur increases the reliability of the scanner in a wet environment (G1/G2 – p=0.072; G1/G3 – p=0.000; G2/G3 – p=0.188) compared to the fine diamond bur. In a dry environment for enamel trueness there is no significant different in the 3 preparation protocols (G1/G2 – p=0.996; G1/G3 – p=0.519; G2/G3 – p=0.822). However, the comparison in the same protocol, except for the G3 group (p=0.174), the scanning performed in a dry environment had more reliability for G2 and G1 groups (p=0.000).

In contrast to the enamel, the use of fine diamond or carbide bur increase the accuracy of the scanner in a dry environment. For precision (G1/G2 – p=0.017; G1/G3 – p=0.005; G2/G3– p=0.999) and trueness (G1/G2 – p=0.032; G1/G3 – p=0.011; G1/G3 – p=0.999), the use of a second bur to finish the tooth surface is better than the use of a coarse bur only (Figs. 8 A and B). Otherwise, the wet environment result in more discrepancy for precision and trueness, independent to the preparation protocol, comparing to the dry (p=0.000). There is no statistical significant difference for precision when comparing the burs (G1/G2 – p=1.000; G1/G3 – p=0.839; G1/G3 – p=0.871). For trueness, the use of a fine diamond bur (G2) is better than using the diamond coarse bur (G1) (p=0.032), the carbide bur had similar trueness comparing to the other groups (G1/G3 – p=0.383; G2/G3 – p=0.873)

Different preparation protocols create different surface roughness on the prepared tissue. For enamel roughness (Fig. 9A) using the Sa, Sk, Svk, Sk+Spk+SvK and Sxp roughness parameters the variations presented corroborate with the values obtained for accuracy in the scanning analyses. There is no variation in the surface as same as there is no statistical difference in the accuracy. For dentin roughness (Fig. 9B), the same parameters used for enamel showed that the use of a finishing bur to perform the preparations decrease the roughness creating a smoother surface. The same results were found for the scanner analysis. Comparing the values of dentin and enamel, the roughness for dentin is slightly lower than enamel as same as the trueness for dentin and enamel comparison.

4. Discussion

The null hypothesis was partially rejected or enamel in a dry environment the surface roughness does not influence the accuracy of the intraoral scanner. Otherwise, for the dentin substrate, the use of a fine bur decreases the surface roughness and increase the accuracy of the intraoral scanner. The environment does represent a discrepancy in accuracy, since when the wet surface is scanned, the accuracy was worse than the surface scanned in a dry environment.

Misfit of a crown is an important factor that could affect its longevity.[66, 68] The increased cement line in any specific area could affect quality of the restoration. The cements used for luting indirect restorations have some intrinsic limitations. The limitation with the most impact on the clinical longevity is the solubility to oral fluids. [80] The dissolution of the cement might result in recurrent caries and loss of restoration. Because of their solubility, cements, in general, have been described as the “weak link” in the relationship between the teeth and the restorations.[25]

The rate of luting cement dissolution has been related empirically to the degree of marginal opening. Thus, the larger the marginal gap and subsequent exposure of the dental luting cement to oral fluids, the more rapid is the rate of cement dissolution. [25] As the degradation of the cements is related to the thickness of the crown misfit, this cement line is an important variable in the prosthetic restorations. The evaluation of the accuracy of the manufacturing methods become an important issue to reduce as most as possible the thickness of the cement gap and avoid the dissolution of the cement.

Based on improvement of digital technologies in CAD/CAM and dentistry in general, evaluating the different possibilities of acquiring models will represent the method that will have less distortion. The intraoral scanning is most recent technology for acquiring the files required to manufacture a crown. The scanner use the light reflection of the teeth surface to rendering the 3D object.[15] Different surface roughness represents different reflection of the lights. Several studies report that the use of different burs creates different roughness for dentin and enamel surfaces. [11, 13, 14, 26] Based on these studies, the authors also found difference in the roughness of the samples prepared. For dentin, the use of a fine bur creates a decrease in the surface roughness. For enamel the use of several burs to finish the surface did not induce differences on the surface roughness. In relation to the surface roughness, the accuracy of the scan files was better for smother surfaces.

In addition to surface roughness, the environment moisture reflects the light in different ways. To reduce the distortion of the scanning files, the authors suggest that the acquirement should be done preferably on a dry surface. The data presented a more accurate acquisition result when performed on dried teeth.

The method used to compare the scanning files was based on the superimposition of the models. The models created by each scanner is a stereolithography (.stl) file. All the files were processed and superimposed in the software Geomagic Control X. This software compares the difference in the surfaces and indicate, by a color and numeric scale, the discrepancies on all the surfaces. The superimpositions were performed inside the same groups to evaluate the precision and also compared to the master model to identify the trueness, which is how close the surface is the original one. This measurement technique is widely used compare different tridimensional surfaces.[27,28]

Several studies used a benchtop scanner as the gold standard for comparisons.[16, 29-31] In this study, the authors used the benchtop scanner D2000 – Dental System 2018 (3 Shape, Copenhagen, Denmark) to scan the prepared teeth and generate the master model. The master model is considered the reference model to the comparison against the intraoral scans' files. To scan the teeth in the benchtop scanner, a powder layer was necessary. Titanium dioxide free pigment suspension in ethanol (VITA Powder Scan Spray, Vita - Bad Säckingen, Germany) was applied on the teeth before scanning with the benchtop scanner. Due the Trios 3 does not require a powder layer to perform the scans the scans powder free were performed before the use of the powder.

5. Conclusion

Within the limitations of this study, the authors suggest the use of a fine bur to prepare teeth, due the increase of accuracy acquired using a fishing bur for dentin preparation and the maintenance of the accuracy using this protocol for enamel. In relation to the environment, it is suggested to always dry the teeth before scanning to make digital models more accurate.

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Figures.

Figure 1. Expreimental design flowchart.

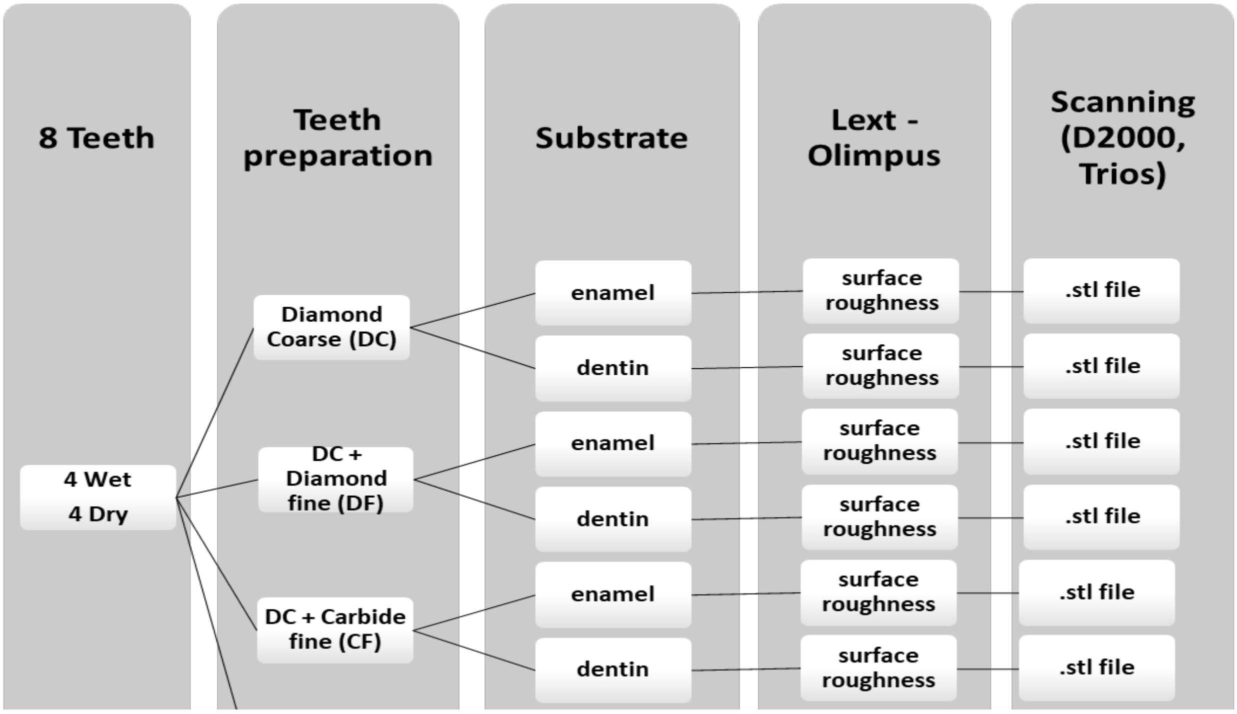


Fig. 2. Protocol used for crown preparation and margin location/substrate for subsequent analysis. A. Each tooth had the mesial margin prepared above the cement-enamel junction (CEJ), Margin mostly in enamel. The distal margin was prepared below the CEJ, margin in dentin. B. Approximately margin measurements (blue area represents the area that was compared using the different scanners by the software Geomagic Control X. Red square represents the area that was measured by the interferometer.) C. Marginal preparation, in the left (mesial) represents the preparation above the CEJ, which means an enamel finishing line, in the right (distal) represents the preparation below the CEJ, meaning a dentin finishing line. D. .stl surface triangulation, representing the mesh acquired from the IOS. This mesh surface is the main data for the accuracy evaluation.

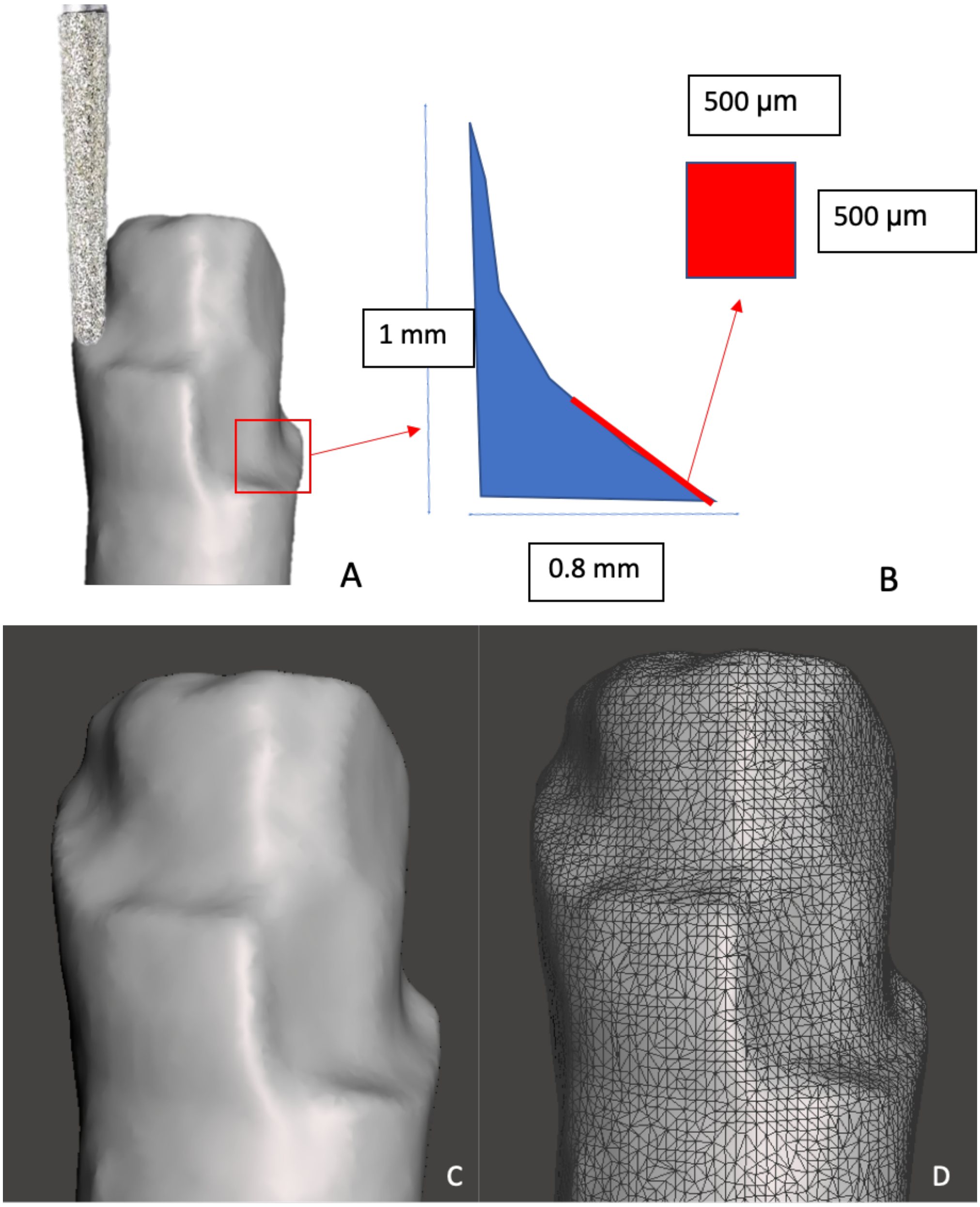


Figure 3. Roughness evaluation of the surface (software Olympus Lext OLS 4000). The yellow square represents the field of view analyzed. The parameters Sa (arithmetical roughness), Sk (Core Roughness Depth), Svk (Reduced Valley Depth), Sxp (Peak extreme height) and the somatory of Sk, Spk and Svk were acquired.

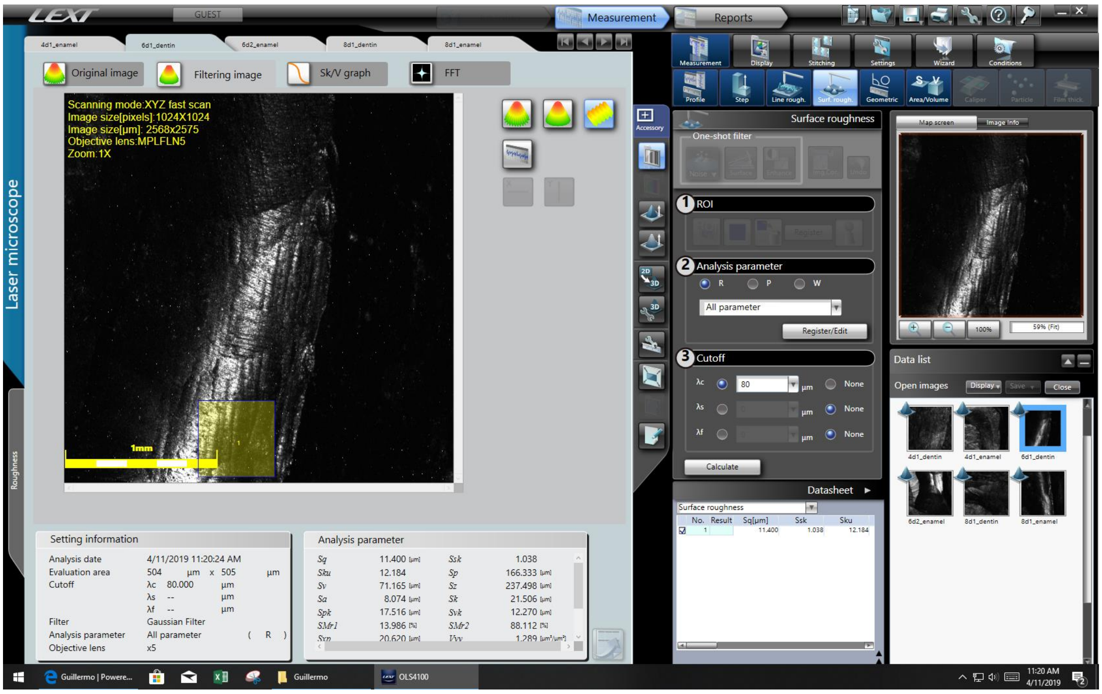


Figure 4 A. Best-fit superimposition of the IOS (green) and bench scanner (blue) surfaces (Geomagic Control X). B. Color map scale for the difference in between the two surfaces.

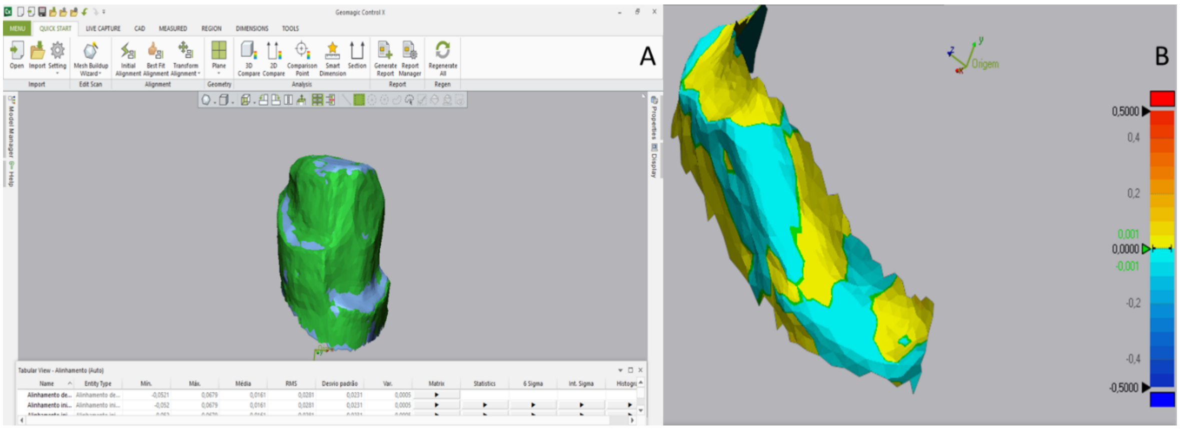
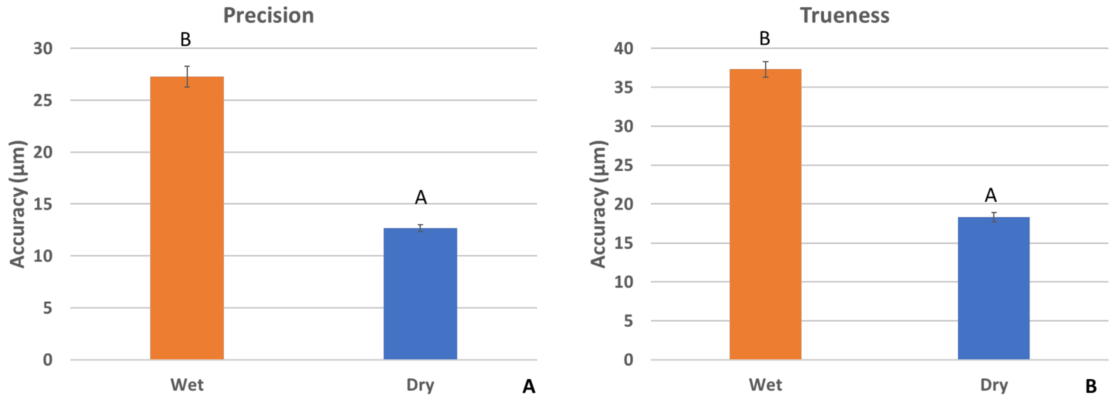
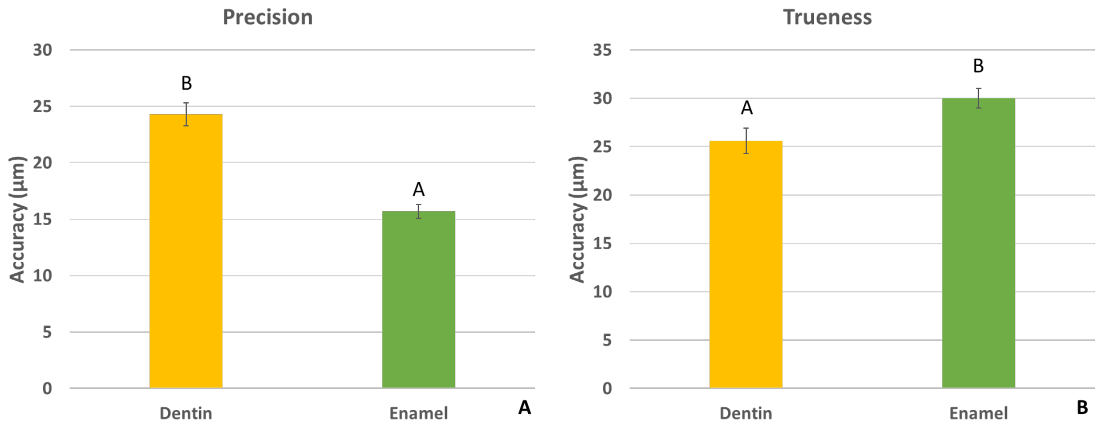


Figure 5 A. IOS Precision on different conditions (Wet/dry) for all groups (Mean +/- SD). B. IOS Trueness analysis of different conditions for all groups (Mean +/- SD).



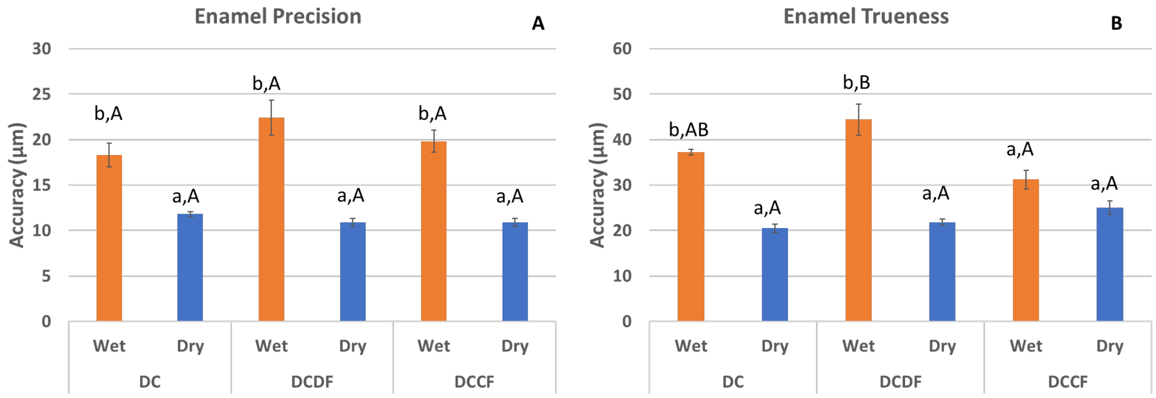
*ANOVA, analysis of variance; Mean (column) and standard deviation. *Significant at P<0.05. Different uppercase letters significantly different within different column colors for assessment of mean trueness and precision comparing different environment for all groups.*

Figure 6 A. IOS Precision of different substrate (enamel and dentin) for all groups (Mean +/- SD). B IOS Trueness of different substrate (enamel and dentin) comparing all groups (Mean +/- SD).



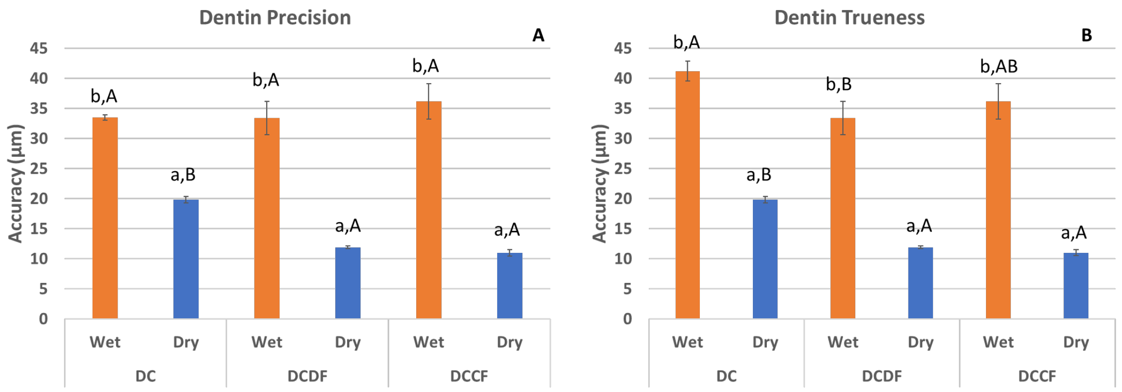
*ANOVA, analysis of variance; Mean (column) and standard deviation. *Significant at P<0.05. Different uppercase letters significantly different within different column colors for assessment of mean trueness and precision comparing different surfaces for all groups.*

Figure 7 A. IOS Precision in enamel margins comparing environment x preparation (represented by comparison between the same colors) and comparing different environment in the same preparation group (represented by the comparison between different colors). B IOS trueness in enamel margins comparing environment x preparation (represented by comparison between the same colors) and comparing different environment in the same preparation group (represented by the comparison between different colors).



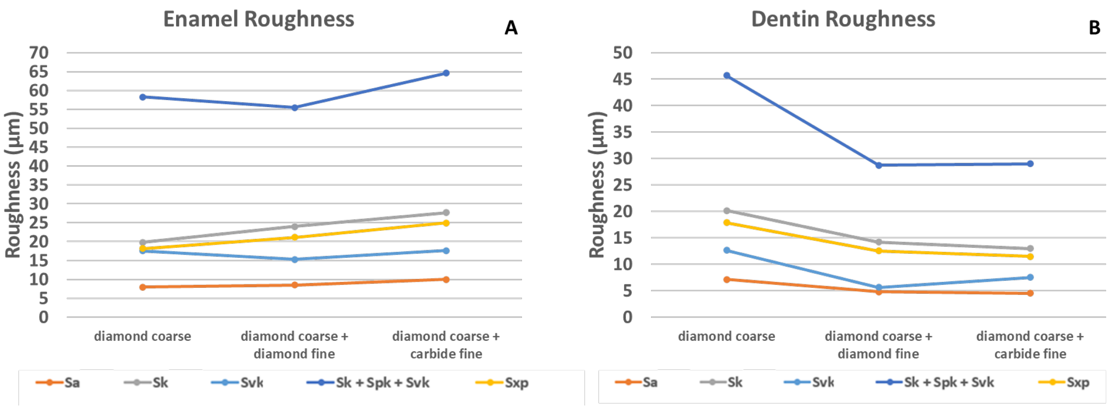
*ANOVA, analysis of variance; Mean (column) and standard deviation. *Significant at P<0.05. Different uppercase letters significantly different within the same column color for assessment of mean enamel trueness and precision of the same environment comparing different preparation group. Different lowercase letters significantly different within different column colors for assessment of mean enamel trueness and precision among the same preparation group comparing different environment.*

Figure 8 A. IOS Precision in dentin margins comparing environment x preparation (represented by comparison between the same colors) and comparing different environment in the same preparation group (represented by the comparison between different colors). B IOS trueness in dentin margins comparing environment x preparation (represented by comparison between the same colors) and comparing different environment in the same preparation group (represented by the comparison between different colors).



*ANOVA, analysis of variance; Mean (column) and standard deviation. *Significant at P<0.05. Different uppercase letters significantly different within the same column color for assessment of mean dentin trueness and precision of the same environment comparing different preparation group. Different lowercase letters significantly different within different column colors for assessment of mean dentin trueness and precision among the same preparation group comparing different environment.*

Figure 9 A. Enamel roughness parameters. Different protocol preparation compared in different roughness parameters. B dentin roughness parameters. Different protocol preparation compared in different roughness parameters.



CONCLUSÕES

4- CONCLUSÕES

Dentro das limitações metodológicas impostas pelo delineamento experimental destes 3 estudos, pode-se concluir-se que:

- O uso de um método de avaliação digital apresentou resultados mais precisos para a avaliação de preparos para coroas. Dentre os parâmetros avaliados, as reduções axiais e oclusais, que se mostraram mais complexas de serem aferidas manualmente, apresentam uma medição mais fidedigna utilizando o método digital se comparado a aferição manual.

- A concordância entre as avalições manuais de professores e alunos e a avaliação digital dos alunos foi moderada, enfatizando a necessidade de uma ferramenta de feedback / avaliação mais confiável e objetiva para contribuir com um processo de aprendizado melhor e mais abrangente para os estudantes de odontologia.

- Os autores sugerem o uso de um instrumento de acabamento para a finalização dos prepares devido ao aumento da acurácia para dentina e a não interferência na acurácia para esmalte. Independente do substrato, também é sugerido secar o dente previamente ao escaneamento para o aumento da acurácia.

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ANEXOS

ANEXOS

Parecer do Comitê de ética

eRESEARCH | REGULATORY MANAGEMENT

View: Application - HUM00144152

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OK

Submission Summary

New Application Submission Description

Study Title: The use of CAD/CAM to evaluate crown preparation in a graduation dentistry school
Supporting Documents or Link to Forms:

12-1.3 Tests, Surverys and/or Interview Questions Jump to 12-1. Exemption #1

Associated Proposals (PAFs):

Outstanding Contingencies:

Type	Description	Date Created	Date Completed	Is Review Required

There are no items to display

Staff Notes

Study Description

eResearch ID:	HUM00144152	**IRB:**	Health Sciences and Behavioral Sciences
Current Study State:	Exempt Approved - Initial	**Application Type:**	**Exempt** Human Subject Research

Study Team Members:

Study Team Member	Study Team Role	Appointment Dept	Student	Friend Account	Accepted Role?	COI Review Required	Edit Rights	PEERRS Human Subjects?
Gustavo Mendonca	PI	Prosthodontics	no	No	N/A	no	yes	yes
Zhaozhao Chen	Co-Investigator		yes	No	Yes	no	yes	yes
Junying Li	Co-Investigator		no	No	Yes	no	yes	yes

Sponsors:

Has PAF not yet been initiated?:

Related PAFs:

ID	Title	PI	Direct Sponsor	Prime Sponsor	State	Has SUBKs?	Related Awards

There are no items to display

Related AWDs:

Award ID	Title	PI	Direct Sponsor	Prime Sponsor	State	Has SUBKs?	Project Period	Awarded PAFs

There are no items to display

Related UFAs:

UFA ID	Title	PI	State	Category	Start Date	End Date

There are no items to display

Internal Sponsors:

Internal Department Sponsor/Support	Other Description	Sponsor Type	Support Type

There are no items to display

UM Oversight:

Required Core Committees:

IRB HSBS

Required Ancillary Committees:

There are no items to display

Risk-Benefit Assessment:
Indirect Benefit Description:

Benefits and Risk Detail:

	Name	Date Modified	Risk Level	Have Direct Benefits	Direct Benefits	Foreseeable Risks
View	HUM00144152	3/14/2018	No more than minimal risk			

Special Considerations: **Vulnerable Subjects:** **Other Considerations:**

Informed Consent Type:
Adult

Adult Consent Type with Signature
There are no items to display

Adult Consent Type without Signature
There are no items to display

Adult Consent Type Waiver of Informed Consent
There are no items to display

Adult Consent Type Other
There are no items to display

Children

Child Consent Type with Signature
There are no items to display

Consent Type Short
There are no items to display

Child Consent Type Waiver
There are no items to display

Chil Consent Type Other
There are no items to display

Parent

Parental Consent Type with Signature
There are no items to display

Parent Consent Type without Signature
There are no items to display

Parent Consent Type Waiver
There are no items to display

Parent Consent Type Other
There are no items to display

Consent Documents:

Name	Version

There are no items to display

Study Abstract:
The digital revolution in Dentistry has gained space with the increase of the production of restorations using the CAD / CAM system – Computer aided design / Computer aided manufacturing. This technology can also be used to scan tooth preparation and evaluate parameters of tooth preparation. Therefore, the use of the technology in classes can develop a most consistent way to evaluate the student to clarify the criteria.
The aim of this study is to develop parameters to use CAD/CAM software built in features to evaluate crown preparation by dental students

during classroon exercises. Typodont teeth are going to be prepared by dental students from University of Michigan, MI, USA, according to standard crown preparation guidelines (Schillinburg 2012). After peparation, in group 1, 3 evaluators are going to evaluate the preparation using the conventional grading system used in Dental School, University of Michigan, MI, USA. Grading criteria are R(excelent), S(good), T(regular), V(fail). And then after scanning, in group 2, the same evaluators are going re-evaluate the same preparations using the Tool Analysis from the scanner software according to the characteristics recommend by the manufacturer. Evaluators will not have access to groups during grades during both grading procedures.
Both grades are going to be compared to confirm if the digital approach will be similar and if it is going to help and clarify the preparation evaluation during classes.

Submission Administrative Information

Minutes of Previous Discussion(s):

Time of Modification	Time of Vote	Meeting	Motion	Yes Votes	No Votes

There are no items to display

Review Type:
Exempt
Known Conflicted Core Committee Members:

First Name	Last Name

There are no items to display

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