UNIVERSIDADE ESTADUAL DE CAMPINAS

Faculdade de Odontologia de Piracicaba

LETICIA DEL RIO SILVA

Reabilitações protéticas CAD/CAM usinadas e impressas: contexto bibliométrico em reabilitações unitárias e precisão dimensional em próteses de arco completo

Milled and printed CAD/CAM prosthetic rehabilitations: bibliometric context in single rehabilitations and dimensional precision in complete arch prostheses

Piracicaba

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Tese apresentada à Faculdade de Odontologia de Piracicaba da Universidade Estadual de Campinas como parte dos requisitos exigidos para a obtenção do título de Doutora em Clínica Odontológica, na Área de Prótese Dental.

Thesis presented to the Piracicaba Dental School of the University of Campinas in partial fulfillment of the requirements for the degree of Doctor in Clinical Dentistry in Dental Prosthesis area.

Orientador: Prof. Dr. Marcelo Ferraz Mesquita

Coorientador: Prof. Dr. Guilherme Almeida Borges

ESTE EXEMPLAR CORRESPONDE À VERSÃO FINAL DA TESE DEFENDIDA PELA ALUNA LETICIA DEL RIO SILVA, E ORIENTADA PELO PROF. DR. MARCELO FERRAZ MESQUITA.

Piracicaba

2025

Ficha catalográfica
Universidade Estadual de Campinas (UNICAMP)
Biblioteca da Faculdade de Odontologia de Piracicaba
Marilene Girello - CRB 8-6159

D387r

Del Rio Silva, Leticia, 1993-
Reabilitações protéticas CAD/CAM usinadas e impressas : contexto bibliométrico em reabilitações unitárias e precisão dimensional em próteses de arco completo / Leticia Del Rio Silva. – Piracicaba, SP : [s.n.], 2025.

Orientador: Marcelo Ferraz Mesquita.
Coorientador: Guilherme Almeida Borges.
Tese (doutorado) – Universidade Estadual de Campinas (UNICAMP), Faculdade de Odontologia de Piracicaba (FOP).

1. Próteses e implantes. 2. Desenho assistido por computador. 3. Adaptação marginal dentária. I. Mesquita, Marcelo Ferraz, 1967-. II. Borges, Guilherme Almeida, 1992-. III. Universidade Estadual de Campinas (UNICAMP). Faculdade de Odontologia de Piracicaba (FOP). IV. Título.

Informações complementares

Título em outro idioma: Milled and printed CAD/CAM prosthetic rehabilitations : bibliometric context in single rehabilitations and dimensional precision in complete arch prostheses
Palavras-chave em inglês:
Prostheses and implants
Computer-aided design
Dental marginal adaptation
Área de concentração: Prótese Dental
Titulação: Doutora em Clínica Odontológica
Banca examinadora:
Marcelo Ferraz Mesquita [Orientador]
Thaís Barbin
Anna Gabriella Camacho Presotto
Rafael Leonardo Xediek Consani
Wander José da Silva
Data de defesa: 19-02-2025
Programa de Pós-Graduação: Clínica Odontológica

Objetivos de Desenvolvimento Sustentável (ODS)
Não se aplica

Identificação e informações acadêmicas do(a) aluno(a)
- ORCID do autor: https://orcid.org/0000-0002-1158-9960
- Currículo Lattes do autor: https://lattes.cnpq.br/5239719366643657

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A Ata da defesa, assinada pelos membros da Comissão Examinadora, consta no SIGA/Sistema de Fluxo de Dissertação/Tese e na Secretaria do Programa da Unidade.

DEDICATÓRIA

Aos meus pais, **Isabel Del Rio Silva e Niraldo Espedito da Silva**, por nunca terem medido esforços na educação de suas filhas. Os dois, mesmo sem ter nível de formação superior sempre entenderam que a educação move montanhas e que este é o bem mais precioso que alguém pode ter, pois ninguém pode tirá-lo de nós. Apesar de não entenderem a dimensão que é a pós-graduação sempre estiveram dispostos a me ajudar e a me apoiar em todos os meus projetos. Em seus braços nunca faltaram palavras de acalento e conforto. Vocês são pais incríveis! Muito obrigada por tudo e por tanto.

Ao meu marido, **Mariano Latorre Bragion**, por estar sempre presente e segurar minha mão nas horas difíceis. Por acreditar mais em mim que eu mesma. Por sempre me incentivar e por estar feliz com a minha felicidade. Meu amor, você me inspira a ser uma pessoa melhor tamanha é sua bondade e cuidado com as pessoas ao seu redor. Obrigada por ser um presente de Deus em minha vida.

À minha irmã, **Nathalia Del Rio Silva,** exemplo de força de vontade e determinação. Por cuidar dos seus com gestos e não só com palavras. Irmãos são benções divinas e Deus não poderia ter me dado maior graça. Obrigada por estar comigo em todos os momentos, por sempre me incentivar, torcer e vibrar comigo a cada conquista.

AGRADECIMENTOS

A **Deus** que por sua infinita misericórdia me trouxe até aqui. Por colocar Seus planos acima das minhas vontades. Por me dar entendimento de que tudo acontece em Seu tempo. Por ter me fortalecido para chegar a esse momento. Por me dar um propósito de vida. Obrigada por me fazer instrumento da Tua vontade e por me abençoar tão grandemente em todos os dias da minha vida. Obrigada por mais essa vitória.

Ao meu Orientador, **Prof. Dr. Marcelo Ferraz Mesquita**, Professor Titular da Área de Prótese Total da Faculdade de Odontologia de Piracicaba da Universidade Estadual de Campinas que esteve sempre ao meu lado durante essa jornada. O senhor é um exemplo de profissional que nos inspira a trilhar o caminho da docência. Sempre preocupado com a didática e o aprendizado de seus alunos. Obrigada pela paciência, compreensão, dedicação e pelas experiências e histórias de vida compartilhadas pois estas nos fazem refletir e crescer como profissionais e mais ainda como seres humanos.

Ao meu Coorientador **Guilherme Almeida Borges,** Pós-Doutorando na área de Prótese Fixa da Faculdade de Odontologia de Piracicaba da Universidade Estadual de Campinas pela direta colaboração na execução deste projeto. Obrigada pela contribuição, disponibilidade, respeito e amizade construídos ao longo desses anos.

À **Universidade Estadual de Campinas – UNICAMP**, na pessoa do Magnífico Reitor, **Prof. Dr. Antonio José de Almeida Meirelles**.

À **Faculdade de Odontologia de Piracicaba – FOP/UNICAMP**, na pessoa do seu Diretor, **Prof. Dr. Flávio Henrique Baggio Aguiar**, e Diretora Associada, **Profa. Dra. Karina Gonzales Silvério Ruiz**.

Ao **Prof. Dr. Valentim Adelino Ricardo Barão**, coordenador geral do programa de Pós-Graduação.

Ao Programa de Pós-Graduação em Clínica Odontologia em nome da **Profa. Dra. Débora Alves Nunes Leite Lima.**

A **Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES)**, Código de Financiamento 001, pelo apoio financeiro por dois anos.

A **Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP)** pelo auxílio à pesquisa, projeto número 2017/16303-3.

Ao Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), pelo auxílio/concessão número 306373/2015-7.

Ao **Centro de Tecnologia da Informação Renato Archer-CTI** (Campinas, SP), por confeccionar o protótipo da maxila edêntula e infraestruturas em EBM; e à **TECNO-HOW – Engenharia Industrial e Comércio Ltda.** (Valinhos, SP), pela confecção das infraestruturas em SLM.

Ao **Laboratório de Prótese Dentária Donato Ltda.** (Piracicaba, SP), na pessoa do técnico em Prótese Dental, **Carlos Donato** e equipe, por usinar as infraestruturas em titânio.

Aos docentes **Profa. Dra. Altair Del Bel Cury**, **Prof. Dr. Frederico Andrade e Silva**, **Prof. Dr. Guilherme Elias Pessanha Henriques, Prof. Dr. Mauro Antônio de Arruda Nóbilo**, **Prof. Dr. Rafael Leonardo Xediek Consani, Profa. Dra. Renata Cunha Matheus Rodrigues Garcia**, **Prof. Dr. Wander José da Silva,** e **Prof. Dr. Wilkens Aurélio Buarque e Silva** pelos conhecimentos transmitidos.

Aos demais **docentes da Faculdade de Odontologia de Piracicaba da Universidade Estadual de Campinas**.

Aos pacientes da Faculdade de Odontologia de Piracicaba (FOP/UNICAMP) fontes de conhecimento e respeito, por propiciarem crescimento pessoal e profissional.

À Sra. **Eliete Aparecida Ferreira Lima Marim**, secretária do Departamento de Prótese e Periodontia, ao técnico do Laboratório de Prótese Total, **Eduardo Pinez Campos** pelo agradável convívio ao longo desses anos, à **Sra. Gislaine Piton**, secretária, da Faculdade de Odontologia de Piracicaba da Universidade Estadual de Campinas por todo auxílio.

Aos amigos de Pós-Graduação do Laboratório de Prótese Total, **Ana Paula Guidi S. Hidalgo**, **Bruna Egumi Nagay**, **Caroline Dini**, **Daniele Valente Veloso**, **João Pedro Silva**, **Juliana Andrade**, **Licínia Pignaton**, **Luana Figueiredo Matias**, **Luís Fernando Miranda**, **Maria Helena Rossy Borges**, **Raphael Cavalcante Costa e Thaís Barbin** pela parceria ao longo dessa jornada.

Aos meus amigos **Anne Caroline Almeida Moura**, **Jéssica Luísa Toledo da Silva**, **Nathalia Alves da Silva**, **Tássio Grigório de Melo e Fernando Araújo** pela cumplicidade e amizade de todos esses anos.

À minha família em Piracicaba nas pessoas de **Maria Josete Latorre Bragion, Antônio Fernando Latorre Bragion**, **Lisete de Moraes Latorre Bragion**, **Camila Latorre Bragion** e **Carolina Latorre Bragion, Leandro D'eva** e **Gabriel Scarassati** pela receptividade e incentivo.

A todas as pessoas que de alguma forma torceram por mim,

Muito obrigada.

EPÍGRAFE

"A alegria que se tem em pensar e aprender

faz-nos pensar e aprender ainda mais."

Aristóteles.

RESUMO

A reabilitação protética utilizando infraestruturas fabricadas via CAD/CAM (*computer-aided design/computer-aided manufacturing*) é considerada método plausível para reabilitar dentes ausentes. Entretanto, não há na literatura um estudo que apresente panorama dos fatores bibliométricos relacionados às reabilitações unitárias confeccionadas por meio das tecnologias CAD/CAM (subtrativa e aditiva); além de serem escassas as informações sobre o desajuste marginal (DM) de infraestruturas de próteses totais fixas (PTFs) comparando design de implantes *all-on-four* e *all-on-six*. (1) Realizar levantamento bibliométrico sobre a reabilitação com próteses fixas unitárias CAD/CAM e (2) Avaliar e comparar o DM de PTFs fabricadas em Ti-6Al-4V. (1) Foi realizada análise bibliométrica dos parâmetros: ano, material da infraestrutura, tecnologia, conexão e moldagem de próteses unitárias CAD/CAM. Para isso, foram coletados dados em quatro bases. Regressão múltipla de Poisson (α=0,05) foi usada para calcular a razão da taxa de incidência e avaliar associação entre próteses unitárias e parâmetros bibliométricos; (2) Foram fabricadas trinta infraestruturas com ambos os designs de implantes confeccionadas pelas tecnologias CAD/CAM de usinagem e manufatura aditiva (MA): *Selective Laser Melting* (SLM) e *Electron Beam Melting* (EBM) (n=5/grupo). Com microscópio óptico (acurácia 1,0 μm) com aumento de 120×, foi verificado o DM formado entre o mini-pilar e a infraestrutura. Essas medidas foram realizadas três vezes por vestibular e lingual por um examinador qualificado (coeficiente de correlação intraclasse 0,987; P<0,001). Uma média foi realizada para a obtenção do DM final das infraestruturas. O método de Kolmogorov-Smirnov foi utilizado para certificar a normalidade dos dados. Anova dois fatores verificou a influência do design e da tecnologia. (1) Após a remoção das duplicatas, avaliação por título, resumo e leitura na íntegra, 805 trabalhos foram incluídos. Foi observado cronologicamente aumento do número de publicações relativas a próteses unitárias. Dentro da tecnologia CAD/CAM, constatou-se maior quantidade de artigos que analisaram MA em comparação com estudos sobre as tecnologias subtrativa e aditiva (P=0,016). As infraestruturas confeccionadas com materiais estéticos foram mais pesquisadas que as em titânio (P=0,012). Reabilitações unitárias com próteses cimentadas (P<0,001) e com ambas as conexões (cimentadas e parafusadas) (P=0,005) foram mais avaliadas que as próteses parafusadas. Estudos que utilizaram apenas escaneamento (P=0,036) foram mais encontrados que aqueles com moldagem convencional e escaneamento do modelo. (2) Na comparação entre os designs, foram observados menores valores de DM para os grupos *all-on-four* [usinagem (*P*=0,002) e SLM (*P*=0,001)]. Na comparação entre as tecnologias, o grupo *all-on-four* mostrou menor DM nas infraestruturas usinadas quando comparadas às fabricadas por MA [SLM (*P*=0,021); EBM (*P*=0,001)]. Para o design *all-on-six*, menores valores de DM foram observados para os grupos usinagem (*P*=0,008) e EBM (*P*<0,001), sem diferença significativa entre ambos. (1) Houve aumento no número de publicações envolvendo próteses fixas CAD/CAM, assim como a pesquisa sobre materiais estéticos. A MA foi cada vez mais reportada, assim como o uso de scanners intraorais. (2) As infraestruturas usinadas e as EBM (*all-on-six*) mostraram-se promissoras. Contudo, os níveis de adaptação marginal encontrados foram considerados clinicamente aceitáveis para todos os grupos. Assim, a manufatura aditiva apresenta-se como tecnologia promissora, oferecendo ótimas oportunidades para a produção de PTFs.

Palavras-chave: Próteses e Implantes. Desenho assistido por computador. Adaptação Marginal Dentária.

ABSTRACT

Prosthetic rehabilitation using frameworks manufactured via CAD/CAM (computer-aided design/computer-aided manufacturing) is considered a plausible method for rehabilitating missing teeth. However, there is no study in the literature that presents an overview of the bibliometric factors related to single prostheses manufactured using CAD/CAM technologies (subtractive and additive); in addition, there is scarce information on the marginal misfit (MM) of full-arch frameworks (FAF) comparing all-on-four and all-on-six implant designs. (1) To carry out bibliometric research on rehabilitation with fixed CAD/CAM single prostheses and (2) To evaluate and compare the MM of FAF manufactured in Ti-6Al-4V. (1) Bibliometric analysis of the parameters was performed: year, framework material, technology, connection and impression of CAD/CAM single prostheses. For this, data were collected in four databases. Poisson multiple regression ($\alpha=0.05$) was used to calculate the incidence rate ratio and evaluate the association between single prostheses and bibliometric parameters; (2) Thirty frameworks with both implant designs were manufactured using CAD/CAM milling and additive manufacturing (AM) technologies: Selective Laser Melting (SLM) and Electron Beam Melting (EBM) (n=5/group). Using an optical microscope (1.0 μm accuracy) and 120× magnification, the MM formed between the mini-abutment and the framework was verified. These measurements were performed three times on the buccal and lingual sides by a previously calibrated examiner (intraclass correlation coefficient 0.987; $P<0.001$). An average of all measurements was performed to obtain the final MM of the frameworks. The Kolmogorov-Smirnov method was used to verify the normality of the data. Two-way ANOVA verified the influence of design and technology. (1) After removing duplicates, evaluating by title, abstract and reading in full, 805 studies met the inclusion criteria. An increase in the number of publications relating to single prostheses was observed chronologically. Relating to CAD/CAM technology, a greater number of articles that studied only AM were found compared to articles comparing subtractive and additive technologies ($P=0.016$). Frameworks manufactured of aesthetic materials were more researched when compared to those made of titanium ($P=0.012$). Single rehabilitations with cemented prostheses ($P<0.001$) and with both connections (cemented and screwed) ($P=0.005$) were more common than screwed prostheses. Studies that used only scanning ($P=.036$) were more recurrent than those that performed conventional impression and cast scanning. (2) In the comparison between the designs, lower MM values were observed for the all-on-four groups [milling (P=0.002) and SLM (P=0.001)]. In the comparison between the technologies, for the all-on-four group, lower MM was observed in the milled frameworks when compared to those manufactured by AM [SLM (P=0.021); EBM (P=0.001)]. For the all-on-six design, lower MM values were observed for milling (P=0.008) and EBM (P<0.001) groups, with no significant difference between them. (1) There has been an increase in the number of publications involving CAD/CAM single prostheses, as well as research on aesthetic materials. AM is increasingly reported, as is the use of intraoral scanners. (2) Milled frameworks and EBM (all-on-six) showed promise. However, the MM levels found were considered clinically acceptable for all groups. Thus, additive manufacturing appears as a promising technology, offering excellent opportunities for the production of FAFs.

Keywords: Prostheses and Implants. Computer-Aided Design. Dental Marginal Adaptation.

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1 INTRODUÇÃO

A substituição de dentes perdidos com implante osseointegrado foi um marco para a Implantodontia, iniciado com a instalação do primeiro implante dentário em 1965 realizado por Brånemark (Abraham, 2014). A partir de então, vários foram os avanços na área desde melhoria no design (macrogeometria e microgeometria), plataforma, tratamentos de superfície dos implantes, uso de biomateriais, enxertos de tecido conjuntivo, dentre outros (Buser *et al.*, 2017). Também foi observada evolução na confecção de próteses sobre implantes que inicialmente eram produzidas por fundição, posteriormente por usinagem e, mais recentemente, por manufatura aditiva, tecnologia que vem ganhando cada vez mais espaço no mercado odontológico (Al-Saleh *et al.*, 2022). Apesar do constante progresso, um método de fabricação não anula o outro, sendo ainda amplamente utilizados e, em alguns casos, combinados para otimizar os resultados (Ciocca *et al.*, 2019).

A tecnologia CAD/CAM (*computer-aided design and computer-aided manufacturing*) permite automatizar o processo de fabricação de infraestruturas eliminando etapas analógicas inerentes ao processo de fundição (Yuzbasioglu *et al.*, 2014). Essa tecnologia possui três principais fases: escaneamento, modelagem (CAD) e fresagem ou impressão tridimensional (CAM) (Alghazzawi, 2016). A fase de escaneamento pode ser realizada de forma intraoral ou com escâner de bancada (escaneamento do modelo) (Lee *et al.*, 2014). A literatura é categórica ao mostrar que o conforto do paciente é superior com o uso do escâner em comparação à moldagem convencional (Yuzbasioglu *et al.*, 2014; Gjelvold *et* al., 2016; Sakornwimon e Leevailoj, 2017; Siqueira *et al.*, 2021). Vários estudos relatam a superioridade (Morsy *et al.*, 2023) ou a ausência de diferença significativa (Boeddinghaus *et al.*, 2015) na confecção de coroas unitárias (Boeddinghaus *et al.*, 2015) e próteses parciais múltiplas (Morsy *et al.*, 2023). Além disso, são destacadas outras vantagens, como melhor aceitação pelo paciente (Sakornwimon e Leevailoj, 2017), menor tempo de moldagem (Siqueira *et al.*, 2021), eliminação de discrepâncias decorrentes da expansão linear e volumétrica dos materiais de moldagem e do gesso (Gjelvold *et al.*, 2016), possibilidade de visualizar e corrigir a moldagem em tempo real (Boeddinghaus *et al.*, 2015) e a praticidade do armazenamento digital em nuvem, dispensando a necessidade de espaço físico para armazenagen de modelos (Manisha *et al.*, 2023).

No sistema CAD/CAM, a obtenção das infraestruturas ocorre de forma subtrativa ou aditiva (Thakur *et al.*, 2023). A subtrativa, também conhecida como fresagem, consiste em usinar um bloco pré-fabricado do material até obter a forma inicialmente desenhada em *software* (Alghazzawi, 2016). Embora seja uma técnica consolidada, existem desvantagens associadas ao seu uso como custo, desgaste e necessidade de substituição das fresas, desperdício de material das áreas do bloco que não foram usinadas, ausência de reprodução de pequenos detalhes, ou seja, o design é dependente do tamanho da fresa (Abduo *et al.*,2014; Al-Saleh *et al.*, 2022). A aditiva, de maneira oposta, manufatura o objeto por meio de camadas sequenciais do material (Schweiger *et al.*, 2021*)* que são unidas de diversas maneiras de acordo com a técnica de fabricação escolhida, com as vantagens de possuir menor custo após aquisição, maior rapidez, maior reprodução de detalhes e sustentabilidade (Alharbi *et al.*, 2017; Revilla-Léon *et al.*, 2019).

A Sociedade Americana de Ensaios e Materiais (ASMT) classifica a manufatura aditiva em sete categorias: estereolitografia, jateamento de material, extrusão de material, "camas de poeira", *binder jetting*, laminação de folhas e deposição direta de energia (ASTM, 2009). Dentre as tecnologias disponíveis no grupo "camas de poeira" a tecnologia SLM (*Selective laser melting*) tem ganhado destaque na Odontologia por produzir próteses unitárias (Huang *et al.*, 2015), infraestruturas parciais (Presotto *et al.,* 2019) e totais (Barbin *et al.*, 2020) com acurada precisão dimensional. Essa tecnologia funde o pó em altas temperaturas por meio de feixes de laser de alta energia (Velôso *et al.,*2022) e apresenta como vantagens a melhoria nas propriedades mecânicas, tribológicas e de corrosão dos materiais (Gokuldoss *et al.*, 2017). Participa também do mesmo grupo a tecnologia EBM (*Electron beam melting)* que difere da SLM principalmente por utilizar elétrons como fonte de alimentação o que resulta também em maior velocidade de fabricação (Velôso *et al.,*2022). Ambas as tecnologias permitem a impressão de objetos em ligas de Ti-6Al-4V que apresentam como características: biocompatibilidade, alta resistência à corrosão, alta resistência mecânica e baixa densidade o que possibilitam seu uso na cavidade bucal (Kim *et al.*, 2020).

A utilização de próteses sobre implantes para reabilitar dentes ausentes constituem opções de tratamento com alta taxa de sucesso independentemente da extensão da prótese (Shadid e Sadaqa, 2012). Apesar disso, nenhum estudo bibliométrico associou as próteses unitárias CAD/CAM com fatores protéticos associados a estas reabilitações (métodos de fabricação, tipos de materiais da infraestrutura e características conexão e moldagem). Ademais, inúmeras são as vantagens associadas ao uso de prótese sobre implante quando comparada às próteses removíveis, tais como preservação óssea, maior conforto, satisfação, função mastigatória e estética (Bandiaky *et al.*,2022). Essas prerrogativas se estendem desde as próteses unitárias até as de arco completo. No caso das próteses unitárias sobre implante, também é importante o tipo de retenção, que pode ser parafusada ou cimentada (Hamed *et al*., 2020). A literatura relata as vantagens e desvantagens ao escolher cada tipo de conexão (Shadid e Sadaqa, 2012). De forma geral, preconiza-se o uso de próteses parafusadas devido à reversibilidade tanto para manutenção, limpeza e apertamento do parafuso quanto para casos de substituição protética (Shadid e Sadaqa, 2012). Ainda assim, as próteses cimentadas também possuem indicação principalmente nos casos de implante com inclinação incorreta onde a saída do parafuso resultaria em complicação estética (Wittneben *et al*., 2017). Diante do exposto, destaca-se que a produção de peças unitárias, especialmente por usinagem, exige menor grau de sofisticação tecnológica, como um número reduzido de eixos, em comparação à fabricação de próteses totais fixas (PTFs) que podem requerer fresadoras com quatro ou cinco eixos. Com base nisso, hipotetizou-se que a documentação do estado da arte, tanto para usinagem quanto para manufatura aditiva, poderia ser mais abundante para essas peças específicas. Assim, para contextualizar essa evolução histórica, buscou-se avaliar os artigos publicados sobre próteses unitárias que utilizam o sistema CAD/CAM subtrativo e aditivo.

Com o aumento da complexidade das necessidades dos pacientes que evoluem de próteses unitárias para próteses totais, as reabilitações implantossuportadas emergem como uma alternativa potencial à reabilitação convencional. Essa abordagem teve sua origem no protocolo de Branemark, que preconizava o uso de, no mínimo, quatro implantes — ou, preferencialmente, seis — para garantir que a reabilitação não fosse comprometida caso algum implante não osseointegrasse ou falhasse ao longo dos anos (Brånemark, 1983). Contudo, mesmo que a biomecânica de transmissão de forças da prótese seja melhor quando há seis implantes (Bhering *et al*., 2016), limitações anatômicas como densidade e grau de reabsorção óssea com consequente proximidade com estruturas nobres tornam as reabilitações de arco completo desafiadoras (Chiapasco e Zaniboni, 2009; Agliardi *et al*., 2014). A pneumatização do seio maxilar e a superficialização do forame mentoniano são alguns dos principais impasses ao se reabilitar maxilas e mandíbulas atróficas (Gonçalves *et al*.,2022). Nessa perspectiva, com o intuito de reduzir as cirurgias de enxerto necessárias para reabilitação com implantes, foi desenvolvido o conceito *all-on-four*, que consiste no uso de quatro implantes, sendo dois anteriores paralelos e dois posteriores inclinados de 30º a 45º (Maló *et al*., 2003). A biomecânica do sistema implantossuportado é favorecida com a redução do cantiléver, assim como pelo uso de implantes distais longos (10-15mm), o que favorece a dissipação de tensões (Maló *et al*., 2005; Gonçalves *et al*.,2022). Ainda que essa técnica seja amplamente difundida até os dias atuais, um ensaio clínico randomizado demonstrou que o conceito *all-on-four* apresenta maior tendência a complicações técnicas e biológicas quando comparado às reabilitações *all-on-six.* (Tallarico *et al., 2016*). Nessa técnica, como o nome indica, são instalados seis implantes, todos verticais. Os quatro implantes mais anteriores, de tamanho convencional, são posicionados nas regiões dos incisivos e pré-molares, enquanto os dois implantes posteriores, de tamanho curto, são colocados na região dos segundos molares (Agliardi *et al*., 2014; Bhering *et al*., 2016). Essa configuração contorna as limitações anatômicas e aperfeiçoa o desenho da prótese devido à ausência de *cantilever* posterior e é indicada principalmente em casos com limitações biomecânicas como atrofia óssea e hábitos parafuncionais (Silva *et al*., 2010).

Para garantir funcionalidade e longevidade das reabilitações, estas devem apresentar precisão e passividade em relação ao protocolo de reabilitação escolhido (Al-Meraikhi *et al*., 2018a), seja *all-on-four* ou *all-on-six*. Nesse sentido, a avaliação do desajuste marginal das infraestruturas protéticas é a primeira etapa para verificar a acurácia de sua fabricação, realizada inicialmente no modelo, antes mesmo da consulta clínica. O objetivo é que a peça assente de forma passiva sobre o modelo e, posteriormente, na cavidade bucal, ou seja, com o mínimo de tensão possível (Barbin *et al*., 2020). Nesse contexto, a literatura relata que valores de 150 µm (Jemt T, 1991; Al-Meraikhi *et al*., 2018a) até 230 µm (Jokstad e Shokati, 2015) são considerados desajustes marginais clinicamente aceitáveis. Valores altos de desajuste implicam em complicações biomecânicas como reabsorção óssea, afrouxamento e/ou fratura do parafuso e fratura da prótese (Svanborg *et al*., 2015). Portanto, o mínimo de desajuste é sempre uma meta para o clínico, uma vez que próteses bem adaptadas proporcionam resultados longevos (Yilmaz *et al*., 2018). Os autores desconhecem trabalho prévio que comparou o desajuste marginal de infraestruturas com design de implantes *all-on-four* e *all-on-six* fabricadas por usinagem, SLM e EBM.

Dessa forma, o objetivo neste estudo foi: (#Capítulo 1) avaliar o estado da arte sobre próteses unitárias aplicando parâmetros bibliométricos (ano, material da infraestrutura, tecnologia, conexão e moldagem); (#Capítulo 2) mensurar o desajuste marginal de infraestruturas de PTFs com designs de implantes *all-on-four* e *all-on-six*; e verificar o efeito da tecnologia CAD/CAM (usinagem, SLM e EBM) no nível de adaptação das próteses. As hipóteses nulas testadas foram: (1) o número de publicações sobre próteses unitárias CAD/CAM (variável dependente) não variaria entre os parâmetros bibliométricos selecionados como variáveis independentes (ano, material da estrutura, tecnologia, retenção, substrato e impressão) e (2) o design e a tecnologia não teriam efeito no desajuste marginal das infraestruturas de PTFs.

2.1 Artigo 1

Artigo aceito no periódico Heliyon.

Comprovante de aceite no anexo 1.

CAD/CAM Single Prosthesis: A 25 Years Bibliometric Assessment of Prosthetic Outcomes

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ABSTRACT

Background. Computer-aided design and computer-aided manufacturing (CAD/CAM) single prostheses on teeth or implants are a viable option to restore denture spaces, using crowns. However, a comprehensive study that presents an overview of bibliometric factors related to the characteristics of this type of rehabilitation on teeth or implant is still lacking.

Objective. The purpose of this bibliometric study was to assess the review progress of papers in the field of CAD/CAM single prostheses regarding bibliometric parameters of year, framework material, technology, retention, and impression.

Material and methods. Four databases were assessed, and 5 bibliometric parameters were evaluated. An incidence rate ratio (IRR) was applied by using a multiple Poisson regression model (a=.05) to assess the association between single prostheses and each bibliometric parameter.

Results. A 25-year bibliometric research was carried out and 1019 studies were evaluated. Of these, 805 papers met the inclusion criteria. Over time, an upward trend was observed in the publication of articles on CAD/CAM single prostheses. Studies using only additive manufacturing had a higher IRR than papers that used both technologies (P=.016, IRR=1.286). Aesthetic materials showed a higher IRR compared with studies that used titanium as framework material (P=.012, IRR=1.258). Cemented prostheses (P<.001, IRR=2.272) and both retentions systems (P=.005, IRR=1.436) exhibited a higher IRR compared to screwed design. Scanning (P=.036, IRR=1.107) had a higher IRR than hybrid method.

Conclusions. The number of studies that reports CAD/CAM single crowns has increased over time. Likewise, as the volume of publications with aesthetic frameworks. Additive manufacturing has been increasingly present in the most publications assessed, as well as the use of intraoral scanners for impressions. Single prostheses cemented retained were most commonly found.

Keywords: Dental Prosthesis; Dental Prosthesis, Implant-Supported; Computer-Aided Design.

INTRODUCTION

The rehabilitation of missing teeth with single crowns on teeth or implants is a validated treatment option that presents reliable long-term results of comfort, function, and aesthetics.[1-5] The investigation for development of new technologies and materials over the years, has become this treatment modality a standard of care in dentistry.[1,6,7] Similarly, indirect restorations are safe options for rehabilitating of lost crowns.[2] For this purpose, metal-ceramic crowns have long been used,[8] however, due to the subjective perception of the patient of preferring more aesthetic prostheses,[9,11,12] new materials such as monolithic zirconia, lithium disilicate and leucite-reinforced glass-ceramics were aesthetic solutions developed to mimic natural teeth.[1,7,13,14]

Research into techniques that are less reliant on manual craftsmanship and human skills culminated in the development of computer-aided design and computer-aided manufacturing (CAD/CAM) technology.[15-17] The first step in manufacturing prostheses via CAD/CAM in a fully digital workflow involves the use of intraoral scanners,[18,19] which have undergone continuous evolution since the 1980s.[20-23] CAD/CAM enables the systematic production of dental prostheses through subtractive or additive methods.[24,25] The subtractive approach, commonly referred to as milling, involves removing material from a prefabricated block using milling burs to create the prosthesis designed in the computer-aided design (CAD) stage.[26] This process can be executed by computer-assisted machines with 3, 4, or 5 axes, with 5-axis milling machines offering higher precision.[15] However, a limitation of subtractive technology is that the reproduction of fine details depends on the smallest available bur diameter.[27] Conversely, additive technology constructs objects layer by layer until the final geometry is achieved. This method offers several advantages, including the ability to print complex geometries, produce larger objects, and enhance sustainability, as unused powder can be recycled. [15,27] Today, both technologies are suitable for producing single prostheses with reliable dimensional stability. Subtractive technology is known for its standardization, while additive manufacturing continues to evolve rapidly. [16,25,26]

To the best of the authors' knowledge, no bibliometric review has specifically investigated the materials, manufacturing methods, and clinical features involved in the rehabilitation of single prostheses on teeth and implants while simultaneously providing an overview of current achievements and offering perspectives for future research. Therefore, this stud aimed to assess the research progress of single prostheses applying bibliometric parameters (year, framework material, technology, connection, and impression). The null hypothesis tested was that the number of publications on CAD/CAM single-unit prostheses (dependent variable) would not vary across the different bibliometric parameters selected as independent variables (year, framework material, technology, retention, substrate, and impression).

MATERIALS AND METHODS

To achieve a bibliometric overview on CAD/CAM single prostheses, a broad search was carried out in the databases Cochrane, Embase, Pubmed, and Web of Science. The research field involved CAD/CAM prostheses, regardless of whether they were single, partial or complete. The search strategy used was described in table 1. The articles were screened and were included if their contents topics focused in dental or implant supported prostheses and subtractive or additive manufacturing technologies in Dentistry. After removing the duplicates, 2 independent investigators (L.D.R.S. and D.V.V.) screened 2654 articles assessing the title and abstract. Then, a manual revision was accomplished by reading the papers in full. After careful analysis, the included papers were obtained (Figure 1). To properly start the data extraction a calibration was performed priorly by the same reviewers with 200 articles randomly selected in online website (https://www.randomizer.org). The Cohen kappa coefficient (κ) showed a inter reliability of k=0.813. Any inconsistency selecting the articles were solved by open discussion to achieve a consensus prior to the analysis. Only articles written in English were included. The papers classified as case reports, case series, systematic reviews, randomized controlled clinical trials (RCTs), nonrandomized controlled clinical trials (N-RCTs), retrospective, cross- sectional, or in vitro studies were included. If the articles were literature review, letter to editor, dental technique, and in silico they were removed. At least one of the groups in the article should include CAD/CAM technology. The research comprised all types of prosthesis and was separated into two categories: the dependent variable, CAD/CAM single prostheses, which included inlay, onlay, laminate veneers, copings, and single crown; whereas the other types of prosthesis (fixed partial dentures, removable partial dentures, overdenture bars, complete-arch fixed frameworks, baseplates, and combinations of rehabilitation types) were the other rehabilitations found. For those included articles, five bibliometric parameters were collected and selected as independent variables: a) year; b) framework material [studies with combination of materials, Co-Cr; Zirconia, Esthetic materials (lithium disilicate, felspathic ceramic, and leucite-reinforced glass-ceramic), and titanium]; c) technology (milling, additive manufacturing, and both); d) retention (cemented, both, and screwed); e) substrate: implant, tooth, master model, implant and tooth; f) impression (scanned, hybrid: conventional impression followed by cast scanning). Meanwhile, the dependent variable was CAD/CAM single prostheses, which included: inlay, onlay, laminate veneers, copings, and single crown. Statistical analysis was performed by means of a software program (IBM SPSS Statistics, v20.0; IBM Corp). A multiple Poisson regressions analysis was used to assess the association of the dependent variable (single prosthesis) with each independent variable (year, technology, framework material, retention, substrate, and impression). Thereafter, crude and adjusted models, incidence rate ratio (IRR) values, and 95% confidence interval (CI) values were plotted. Backward-Wald procedure was applied to obtain the adjusted model. The independent variable withdrawn (*P*>.2) was 'rehabilitation substrate' (tooth, implant, master model, and tooth and implant) to achieve the adjusted model. Therefore, all results with *P*<.05 in the adjusted model were considered statistically significant.

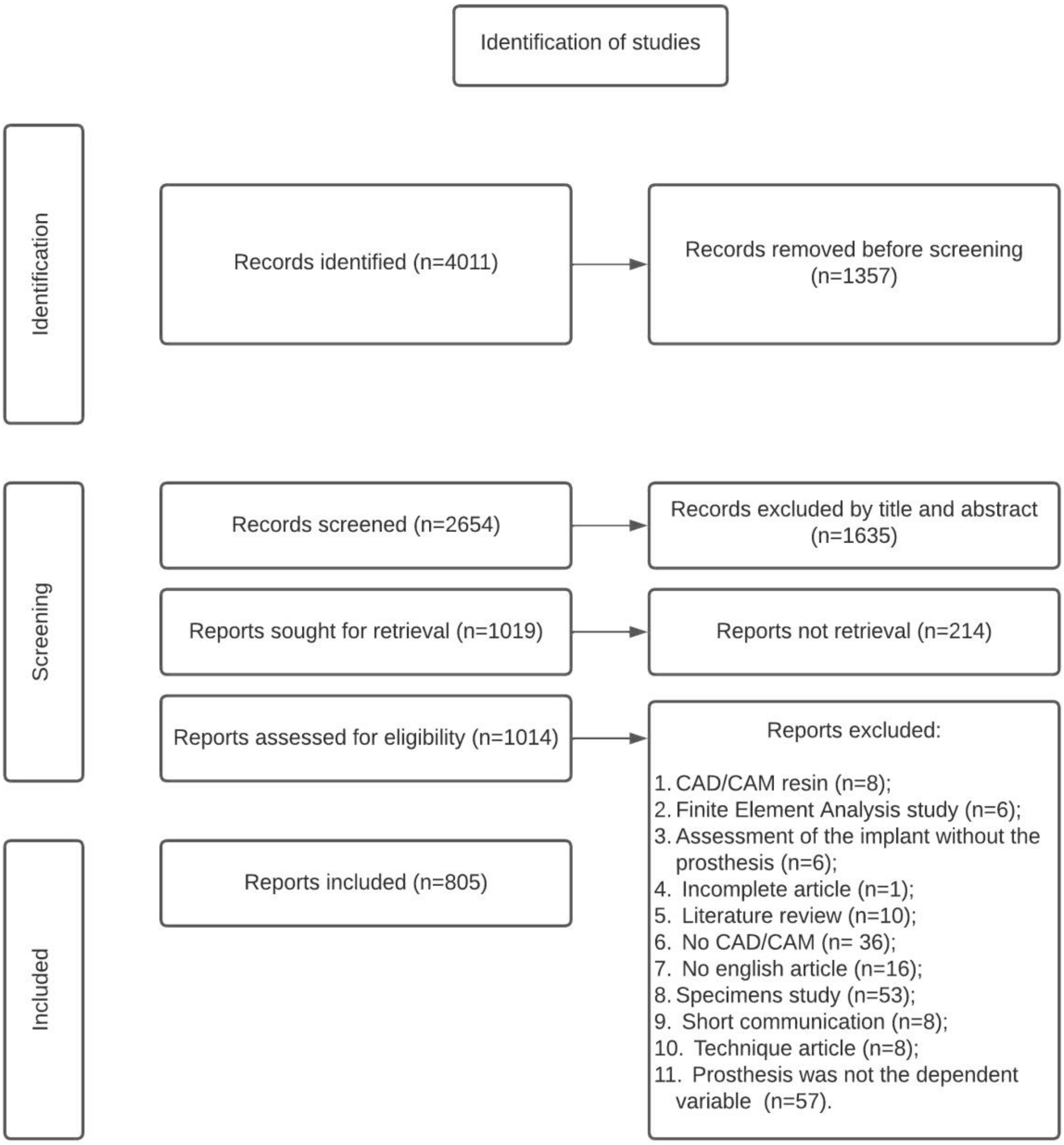

Figure 1. Flow chart showing procedure for selection and inclusion of studies.

TABLE 1 MeSH terms and search strategy.

PubMed
#1 Crowns[MeSH Terms] OR Denture, Partial, Fixed[MeSH Terms] OR Denture, Complete[MeSH Terms] OR Denture, Overlay[MeSH Terms] OR Dental Prosthesis[MeSH Terms] OR Crown*[Title/Abstract] OR Fixed[Title/Abstract] OR Complete[Title/Abstract] OR denture*[Title/Abstract] OR Overdenture*[Title/Abstract] OR dental[Title/Abstract] OR Removable[Title/Abstract] OR Overlay*[Title/Abstract]
#2 Computer-Aided Design[MeSH Terms] OR Printing, Three-Dimensional[MeSH Terms] OR "Computer Aided"[Title/Abstract] OR CAD/CAM[Title/Abstract] OR "Computer Assisted Design"[Title/Abstract] OR Subtractive*[Title/Abstract] OR Additive*[Title/Abstract] OR "Metal block"[Title/Abstract] OR Milling[Title/Abstract] OR EBM[Title/Abstract] OR "electron beam melting"[Title/Abstract] OR SLM[Title/Abstract] OR "selective laser melting"[Title/Abstract] OR 3D print[Title/Abstract] OR 3D printing[Title/Abstract] OR DMLS[Title/Abstract] OR "direct metal laser sintering"[Title/Abstract]
#3 Chromium Alloys[MeSH Terms] OR Cobalt Chromium[Title/Abstract] OR Chromium Cobalt[Title/Abstract] OR Co-Cr*[Title/Abstract] OR Cr-Co*[Title/Abstract] OR Zirconia*[Title/Abstract] OR Titanium[Title/Abstract] OR Titanium[MeSH Terms]
Web of Science
#1 TS=(Crowns) OR TS=(“Denture, Partial, Fixed”) OR TS=(“Denture, Complete”) OR TS=(“Denture, Overlay”) OR TS=(“Dental Prosthesis”) OR TS=(Crown*) OR TS=(Fixed) OR TS=(Complete) OR TS=(denture*) OR TS=(Overdenture*) OR TS=(dental) OR TS=(Removable) OR TS=(Overlay*) OR TS=(Removable)
#2 TS=(“Computer-Aided Design”) OR TS=(“Printing, Three-Dimensional”) OR TS=(“Computer Aided”) OR TS=(“CAD/CAM”) OR TS=(“Computer Assisted Design”) OR TS=(Subtractive*) OR TS=(Additive*) OR TS=(“Metal block”) OR TS=(Milling) OR TS=(“EBM”) OR TS=(“electron beam melting”) OR TS=(SLM) OR TS=(“selective laser melting”) OR TS=(“3D print”) OR TS=(“3D printing”) OR TS=(DMLS) OR TS=(“direct metal laser sintering”)
#3 TS=(“Chromium Alloys”) OR TS=(“Cobalt Chromium”) OR TS=(“Chromium Cobalt”) OR TS=(Co-Cr*) OR TS=(Cr-Co*) OR TS=(Zirconia*) OR TS=(Titanium)
Embase
#1 Crowns:ab,ti OR ‘Denture, Partial, Fixed’:ab,ti OR ‘Denture, Complete’:ab,ti OR ‘Denture, Overlay’:ab,ti OR ‘Dental Prosthesis’:ab,ti OR Crown*:ab,ti OR Fixed:ab,ti OR Complete:ab,ti OR denture*:ab,ti OR Overdenture*:ab,ti OR dental:ab,ti OR Removable:ab,ti OR Overlay*:ab,ti OR Removable:ab,ti
#2 ‘Computer-Aided Design’:ab,ti OR ‘Printing, Three-Dimensional’:ab,ti OR ‘Computer Aided’:ab,ti OR ‘CAD/CAM’:ab,ti OR ‘Computer Assisted Design’:ab,ti OR Subtractive*:ab,ti OR Additive*:ab,ti OR ‘Metal block’:ab,ti OR Milling:ab,ti OR ‘EBM’:ab,ti OR ‘electron beam melting’:ab,ti OR SLM:ab,ti OR ‘selective laser melting’:ab,ti OR ‘3D print’:ab,ti OR ‘3D printing’:ab,ti OR DMLS:ab,ti OR ‘direct metal laser sintering’:ab,ti
#3 ‘Chromium Alloys’:ab,ti OR ‘Cobalt Chromium’:ab,ti OR ‘Chromium Cobalt’:ab,ti OR Co-Cr*:ab,ti OR Cr-Co*:ab,ti OR Zirconia*:ab,ti OR Titanium:ab,ti
Cochrane
#1 MeSH descriptor: [Crowns] explode all trees OR MeSH descriptor: [Denture, Partial, Fixed] explode all trees OR MeSH descriptor: [Denture, Complete] explode all trees OR MeSH descriptor: [Denture, Overlay] explode all trees OR MeSH descriptor: [Dental Prosthesis] explode all trees OR (Crown*):ti,ab,kw OR (Fixed):ti,ab,kw OR Complete[Title/Abstract] OR (denture*):ti,ab,kw OR (Overdenture*):ti,ab,kw OR (dental):ti,ab,kw OR (Removable):ti,ab,kw OR (Overlay*):ti,ab,kw
#2 MeSH descriptor: [Computer-Aided Design] explode all trees OR MeSH descriptor: [Printing, Three-Dimensional] explode all trees OR (Computer Aided):ti,ab,kw OR (CAD/CAM):ti,ab,kw OR (Computer Assisted Design):ti,ab,kw OR (Subtractive*):ti,ab,kw OR (Additive*):ti,ab,kw OR (Metal block):ti,ab,kw OR (Milling):ti,ab,kw OR (EBM):ti,ab,kw OR (electron beam melting):ti,ab,kw OR (SLM):ti,ab,kw OR (selective laser melting):ti,ab,kw OR (3D print):ti,ab,kw OR (3D printing):ti,ab,kw OR (DMLS):ti,ab,kw OR (direct metal laser sintering):ti,ab,kw
#3 MeSH descriptor: [Chromium Alloys] explode all trees OR (Cobalt Chromium):ti,ab,kw OR (Chromium Cobalt):ti,ab,kw OR (Co-Cr*):ti,ab,kw OR (Cr-Co*):ti,ab,kw OR (Zirconia*):ti,ab,kw OR (Titanium):ti,ab,kw OR MeSH descriptor: [Titanium] explode all trees

RESULTS

A 25-year bibliometric research was carried out, which resulted in a total of 4041 articles on CAD/CAM single prosthesis. The papers were retrieved, of which 1019 proceed for title and abstract evaluation after copies removal. Afterwards, 805 articles fulfilled the inclusion criteria (Figure 1). Afterwards, the majority number of studies were related to single crowns (54.2%). The other categories were fixed partial denture, removable partial denture, overdenture bar, complete-arch fixed frameworks, baseplate, and combination of types of rehabilitation. This categorization aimed to provide an overview of the study populations involving CAD/CAM prostheses. While the statistical analysis focused exclusively on single prostheses, additional details were included to highlight the study profiles and the eligibility process. The independent variable with continuous data (year) was based solely on single prostheses. The data (mean± standard deviation) for year was 2016± 4. Of the 437 single prosthesis papers, most 380 (55.2%) were produced by milling, 20 (41.1%) used 3D printing exclusively, and 37 (53.6%) had both technologies in the study. Regarding the framework material 152 (65.8%) compared different materials, 178 (52%) had zirconia as its main focus, followed by esthetic materials 52 (78.8%), Co-Cr 44 (49.5%), and Titanium 11 (14.3%). Most studies 304 (67.4%) used luting agents to retain prostheses while 8 (6.1%) used screws and 9 (33.3%) applied both retention systems. The prostheses manufacturing through scanning was reported in 323 (60.6%) studies, although conventional impression was also used as an initial step (hybrid) in 77 (38.1%) studies.

The multiple Poison regression (Table 2) demonstrated that CAD/CAM single prosthesis, regarding the technology applied, had a higher incidence rate ratio (IRR=1.286) of studies using only additive manufacturing than papers that used both technologies (*P*=.016, 95% CI=1.048, 1.577). Respecting to framework materials, esthetic materials showed a higher incidence rate ratio (IRR=1.258) compared with studies that used only titanium material

(*P*=.012, 95% CI=1.052, 1.504). Concerning retention, a higher incidence rate ratio (IRR=2.272) was observed for cemented prostheses (*P*<.001, 95% CI=2.002, 2.572) and both connections (IRR=1.436) compared to screwed design (*P*=.005, 95% CI=1.007, 1.836). Evaluating impression, scanning had a higher incidence rate ratio (IRR=1.107) than hybrid method (*P*=.036, 95% CI=1.007, 1.218).

Table 2. Bibliometric parameters associated with CAD/CAM single prostheses, during 25 years. Crude and adjusted Poisson regression models.

	Single prostheses n (%)	Crude model				Adjusted model[1]			
				95% CI				95% CI	
Variables	(Mean ±SD)	P	PR	Lower	Upper	P	PR	Lower	Upper
I. Year									
		<.001	1.019	1.01	1.029	<.001	1.020	1.010	1.030
II. Technology									
Milling	380 ± 55.2	.349	1.118	.885	1.411	.356	1.116	.884	1.480
Additive Manufacturing	20 ± 41.1	.014	1.290	1.052	1.582	**.016**	1.286	1.048	1.577
Both[2]	37 ± 53.6	-	Ref.	-	-	-	Ref.	-	-
III. Framework material									
Combination[3]	152 ± 65.8	.163	1.126	0.953	1.331	.169	1.120	.953	1.317
Co-Cr	44 ± 49.4	.320	1.112	0.902	1.371	.334	1.106	.902	1.357
Zirconia	178 ± 52	.815	.982	.840	1.147	.716	.971	.831	1.136
Esthetic materials[4]	52 ± 78.8	.012	1.257	1.052	1.502	**.012**	1.258	1.052	1.504
Titanium	11 ± 14.3	-	Ref.	-	-	-	Ref.	-	-
IV. Connection									
Cemented	304 ± 67.4	<.001	2.312	2.027	2.637	<.001	2.272	2.002	2.572
Both[5]	9 ± 33.3	.002	1.545	1.175	2.033	**.005**	1.426	1.007	1.836
Screwed	8 ± 6.1	-	Ref.	-	-	-	Ref.	-	-
V. Substrate									
Implant	30 ± 24.6	.155	1.264	.915	1.746	-	-	-	-
Tooth	77 ± 56.2	.236	1.218	.879	1.687	-	-	-	-
Master model	320 ± 62.7	.210	1.235	.888	1.719	-	-	-	-
Implant and tooth	5 ± 21.7	-	Ref.	-	-				
VI. Impression									
Scanned	323 ± 60.6	.109	1.093	.980	1.219	**.036**	1.107	1.007	1.218
Impression and scanning	77 ± 38.1	-	Ref.	-	-	-	Ref.	-	-

SD, standard deviation; PR, prevalence ratio; 95% CI, 95% confidence interval; Ref., reference category used; 1, included variables with P<0.2 in the crude model. Bold values in adjusted model inform statistically significant difference. *, single prosthesis (inlay, onlay, laminate veneers, copings, and single crowns) was the reference for the dependent variable in a population of studies that also included other types of prostheses (fixed partial dentures, removable partial dentures, overdenture bars, complete-arch fixed frameworks, baseplates, and combinations of rehabilitation types). 2, both, studies with milling and additive manufacturing groups. 3, combination, studies with more than one type of material in comparative groups. 4, esthetic materials, lithium disilicate, felspathic ceramic, and leucite-reinforced glass-ceramic. 5, both, studies with comparative groups between cemented and screw-retained prostheses.

DISCUSSION

This study observed a notable increase in the number of publications related to the rehabilitation of CAD/CAM single prostheses, predominantly produced through milling. Therefore, the null hypothesis—that the number of publications on CAD/CAM single prostheses (dependent variable) remains unchanged across the various bibliometric parameters selected as independent variables— was rejected. Despite the rapid development of additive manufacturing in engineering, it will take a while for this technology to be standardized for use in everyday dental practice.[16] Probable explanations for this fact are the initial cost of equipment and mainly the lack of standardized parameters for 3D printers.[16] Regardless this technology presenting progressively promising results and within the minimum adaptation required,[25] the oral rehabilitation involves pieces with complex geometries which requires precision for long-lasting results. Our results demonstrated that studies focused on evaluating solely additive manufacturing are more prevalent than studies comparing both technologies. This might be associated with milling being a wellestablished technique, and therefore it is not justified to carry out studies only evaluating its reproducibility. Our data currently reinforces the hypothesis that milling remains in high clinical and research demand, likely due to its close alignment with the clinical scenario.[16,27]

The increasing demand for highly aesthetic rehabilitations substantially stimulates the development of new materials that can accomplish this requirement, either in the field of dental or implant-supported rehabilitations.[14] In the present study**,** a higher number of papers focused on evaluating frameworks manufactured in aesthetic materials than in titanium were observed. Feldspathic ceramic, leucite-reinforced glass-ceramic, and the widespread lithium disilicate were the most found materials in the studies compared with titanium. It means that there is a tendency to research more purely ceramic materials than metal-ceramic ones due to the technical advantages, clinical aspects, and patient reported outcome measures.[9,10] From a technical perspective, factors such as sensitivity to bonding techniques, high translucency, natural dental appearance, and adequate flexural strength are benefits of aesthetic materials when compared to metallic ones.[11] Indeed, monolithic crowns have high fracture resistance, which is related to minimally invasive preparations and might explain why this material is becoming increasingly popular.[12] Moreover, a previous publication[9] retrospectively verified a six-year of clinical performance of single dental crowns rehabilitated with lithium disilicate or metal-ceramic crowns. Regarding the clinical assessment, survival (96% lithium disilicate; 90.8% metal-ceramic) and success rates (96% lithium disilicate; 83.4% metal-ceramic) were higher for all-ceramic crowns when compared to metal-ceramic ones. Finally, this study also reported, by means of Visual Analogue Scale, patients' preference for lithium disilicate crowns in the following areas: color, chewing ability, and overall rating. Finally, a systematic review concluded that resin-bonded fixed partial dentures have a higher success rate than metal-ceramic ones, and the authors emphasize that the evolution of adhesive dentistry in last years could explain this finding. [28]

Concerning the use of aesthetic materials in implant-supported single crowns, Wolfard and cols [3] compared cemented and screw-retained lithium disilicate posterior single crowns from biological and technical aspects. The measurements of bleeding on probing, gingival and plaque index, marginal bone loss, as well as technical complications, were similar for both groups. In our study, cemented prostheses and the comparison between cemented and screwed prostheses had a higher prevalence than the screwed design. Indeed, the preference for cemented prostheses in the field of implant dentistry might be explained by the benefits: compensation for inaccurately implant inclination mainly in the aesthetic area, the ease of reaching passivity by the cement layer, and the similarity with the techniques and protocols used in dental prosthesis.[6] In addition, the literature also reports a lower rate of prosthetic complications with cemented implant-supported single prostheses when compared to screw-retained ones.[4] A randomized controlled clinical trial[8] reported the rates related to the absence of complications, being 54.5% for screw-retained and 91.3% for cement-retained implant-supported single crowns. Although screw-retained prostheses offer the advantage of reversibility, the access opening in the ceramic for the screw can compromise the material's integrity, potentially increasing the risk of fracture.[29] The fact that cemented crowns have fewer technical complications might be associated with the stress relieve performed by the cement layer that distributes occlusal forces, helps to dissipate tension, and equalize possible misfits in the supported implant system; [5,29] however, these issues are sensitive to the technical skills of the operator.[5]

Digital dentistry is an upward tendency that can be assessed by our data, and it has been frequently present in clinical practice.[20] The present study demonstrated a higher prevalence of papers that used only digital workflow compared to those that performed at least one conventional impression followed by scanning the gypsum cast for single prostheses manufacturing. In addition to the advantages associated with the use of intraoral scanners such as improved patient acceptance,[24] visualization of errors seen on the screen in real time,[22] and reducing the distortion of impression materials,[21,24] accomplish part of the process conventionally and another digitally might result in discrepancies adding “error factors”.[20] In vitro study,[18] randomized clinical trials,[17,21] and systematic reviews[19,23] have already demonstrated the absence of difference for adaptation[17,21] and accuracy[18], meanwhile the superiority of intraoral scanner in terms of patient convenience,[17,19,21] marginal and internal fit.[23] In addition to the aforementioned advantages, several studies also report the greater speed,[17,19,21] better occlusal contacts,[21] and lower gag reflex[17] of digital impressions when compared to the use of elastomeric materials.

The results found in this study are similar to cross-sectional studies and, therefore, are valid for the moment in which they were analyzed. This perspective might change depending on the development of technologies and the clinical scenario. The inclusion of systematic reviews duplicates data from clinical trials as they were included in the systematic reviews and meet the inclusion criteria of this study, and for this reason this can also be considered as a limitation of this study. In addition, not having separated the data for single prostheses on teeth and on implants can overestimated the results related to cemented prostheses since prostheses on teeth can only be cemented. The option for a 25-year time frame was performed due to the volume of information collected. Therefore, future bibliometric studies with CAD/CAM single crowns might focus on more recent years, rehabilitation region, whether anterior or posterior, and its association with frameworks and types of aesthetic coverage due to the aesthetic demand.

CONCLUSIONS

Based on the findings of this bibliometric study, the following conclusions were drawn:

1. Over the years there has been an increase in the publication of studies on CAD/ CAM single prostheses;

2. Studies that used only additive manufacturing were more common than those that compared milling and additive technologies;

3. Aesthetic materials had an increase in scientific demand over the years compared to titanium;

4. The cemented retained prostheses and both connections were more reported than the screwed retained;

5. Digital impression was a more widely used approach than the hybrid technique (conventional impression followed by cast scanning).

CRediT authorship contribution statement

Leticia Del Rio Silva: Methodology; Data curation; Visualization; Writing-original draft; Writingreview & editing. **Daniele Valente Velôso**: Methodology; Data curation; Visualization. **Valentim Adelino Ricardo Barão**: Formal analysis; Supervision; Writing-review & editing **Marcelo Ferraz Mesquita**: Writing-review & editing; Validation; Formal analysis; Data curation. **Guilherme Almeida Borges**: Conceptualization; Writing-review & editing; Supervision; Project administration; Formal analysis.

Data availability statement

Data will be made available on request.

Declaration of competing interest

Guilherme Almeida Borges reports financial support was provided by Universidade Estadual de Campinas. The co-author Valentim Adelino Ricardo Barão is an Associate Editor for Heliyon and was not involved in the editorial review or the decision to publish this article. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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2.2 Artigo 2

Title of the article: "**Marginal gap of 3D printed full-arch frameworks supported by all-on-four and all-on-six implant designs**"

Abstract:

Aim: To evaluate the marginal gap of full-arch frameworks (FAF) implant-supported by all-on-four and all-on-six implant designs manufactured by different technologies.

Setting and Design: *In vitro* study.

Methods and Material: Fifteen titanium FAF were manufactured by milling and 3D printing: selective laser melting (SLM) and electron beam melting (EBM) (n = 5/group). The marginal gap between the framework and abutment was measured by a microscope with 1.0 μm accuracy. Measurements were performed three times by a calibrated examiner at the interface between the abutment and the framework on buccal and lingual sides.

Statistical analysis used: Two-way ANOVA was applied to compare the effect implant design and manufacturing technology ($\alpha = .05$).

Results: When implant designs were compared, the all-on-four group [milling ($P = 0.002$) and SLM ($P = 0.001$)] presented lower marginal gap values than those of the all-on-six group. No statistically difference was observed between the EBM frameworks in both designs. Regarding the all-on-four group, milling presented lower marginal gap values than those of the SLM ($P = 0.021$) and EBM ($P = 0.001$) groups. No statistically difference was found between SLM and EBM groups ($P = 0.163$). For the all-on-six framework design, the milling ($P = 0.008$) and EBM groups ($P < 0.001$) exhibited lower marginal gap values than those of

the SLM frameworks. No statistically difference was detected between the milling and EBM groups (*P* = 0.160).

Conclusion: Milled frameworks (both designs) and EBM for the all-on-six design proved to be promising. However, the marginal adaptation levels found were considered clinically acceptable for all technologies studied, including SLM, in both implant designs.

Key-words: Printing, Three-Dimensional; Computer-aided design/computer-aided manufacturing (CAD/CAM), Implant-supported dental prostheses.

Introduction:

Implant therapy has been commonly used to replace missing teeth, with acceptable success rates.[1] The rehabilitation of fully edentulous patients by full-arch implant-supported prostheses may be influenced by anatomic limitations such as maxillary sinus pneumatization and posterior bone resorption.[2] In order to overcome these issues, the all-on-four concept was first introduced to avoid sinus elevation and bone graft surgeries, procedures that are associated with higher cost, time, and postoperative morbidity.[2,3] In the all-on-four concept, tilting the distal implants (from 30º to 45º) avoids these additional procedures and complications in vital areas such as the maxillary sinus.[4] Besides, the placement of short implants in posterior areas can also be an alternative to sinus elevation and bone graft surgeries. The use of these short implants (< 10 mm) is also considered a less invasive and more viable treatment option.[5,6] So, the all-on-six concept can reduce complex surgical procedures, with the advantage that no prosthesis cantilever is required.[7] Reports in the literature have demonstrated that the prosthesis cantilever is associated with stress concentration, which increases biomechanical failures over time.[8,9] Reducing the cantilever in areas that are subjected to high concentrations of chewing forces might decrease the incidence of lateral forces and minimize mechanical stress on the prosthesis.[7,10]

The assessment of marginal misfit of prosthetic frameworks is the first step in verifying manufacturing accuracy. The goal is for the framework to settle passively, that is, without tension development.[11] The literature reports the range from 150µm [12,13] to 230µm [14] are considered clinically acceptable marginal misfit values. High misfit values imply biomechanical complications such as bone resorption, screw loosening and/or fracture, and prosthesis fracture.[15] Thus, passive fit frameworks should be the main goal in the fabrication of an implant-supported prosthesis, to avoid complications and extend the stability and longevity of the implant-supported system.[13,16,17].

Prosthetic rehabilitations with full-arch implant-supported frameworks have demonstrated high success rates and acceptable biomechanical behavior.[18-20] Despite the favorable performance of implant-supported dental prostheses, however, mechanical and biological complications may occur over time due to framework distortions related to the manufacturing process.[16,21] With the goal to reduce steps and inaccuracies from the conventional casting technique, the use of computer-aided design (CAD) and computer-aided manufacturing (CAM) technologies has been widely tested to improve the dimensional accuracy of implant-supported frameworks.[13,19,22]

CAD/CAM technology can be divided according to the fabrication approach.[23] The milling technique is based on the milling of a block shape by means of diamond rotary instruments coordinated by a machine numerically controlled by a computer.[24,27] It has been reported to produce frameworks with levels of adaptation higher than those produced by conventional casting techniques.[25,22] The main disadvantages associated with this method are its low ability to reproduce fine details and material waste.[27,28] As an alternative to the subtractive method, in additive manufacturing (3D printing), the object is to create built-in layers using powder or liquid elements, without material waste.[17,22] Selective laser melting (SLM) and electron beam melting (EBM) are available technologies for prosthesis frameworks printing.[11] In addition, 3D SLM printing has been used to manufacture crowns[23,30] and fixed-partial dental prostheses,[22,31] with satisfactory biomechanical behavior. However, SLM and, in particular, EBM technology are rarely used for the printing of full-arch frameworks (FAF).

Therefore, the aim of this study was to compare the marginal gap of FAF with all-on-four and all-on-six implant designs. Additionally, the effect of CAD/CAM technology (milling, SLM, and EBM) was also observed. The null hypotheses tested were that (1) the design and (2) the technology would have no effect on the marginal gap of the frameworks.

Materials and methods

A simplified design model of a complete edentulous maxilla from the computed tomography bibliography of the Renato Archer Information Technology Center (Campinas, Brazil) was used to create two prototyped master models [Figure 1A, 1B]. The arrangement of the implants and the abutments (Conexão Sistemas de Prótese Ltda., SP, Brazil) in the master model, as well as its characteristics, are described in Table 1.

Figure 1. Master model representing a prototyped replica of an edentulous maxilla, illustrating: A: The All-on-Four concept; B: The All-on-Six concept.

Table 1. Positioning and characteristics of the implants in the master models.

Implant design	Implant positioning	Implant characteristics	Abutment characteristics
All-on-four	Lateral incisors	(2) Standard EH 4.1×11.5 mm	Micro unit 4.1 x 4.0 mm
	Second Pre molar	(2) Long EH 4.1×13 mm (Tilted 30º)	
All-on-six	Lateral incisors	(2) Standard EH 4.1×11.5 mm	Micro unit 4.1 x 4.0 mm
	Second Pre molar	(2) Standard EH 4.1×11.5 mm	
	Second molar	(2) Short EH 5.0×7 mm	Micro unit 4.1 x 5.0 mm

*EH: External Hexagon

For each master model, a FAF was waxed over the abutments. In the all-on-four rehabilitation, it was waxed from the upper right first molar to the upper left first molar [Figure 2A, 2B, 2C], and the upper second molar was added in the all-on-six concept [Figure 2D, 2E, 2F]. A light scanner (Ceramill map 400+; Amann Girrbach, Koblach, Germany) was used to scan the master models and waxes. A *.stl* file was created, and the frameworks were modeled with specific CAD software (Ceramill Mind software; Amann Girrbach). The same CAD was sent to the respective machines according to the manufacturing technologies (n = 5). For the milling group [Figure 2A, 2D], Ti-6Al-4V alloy blocks (89.4% Ti, 6.2% Al, 4% Vn, < 0.4% N, < 0.4% C, < 0.4% Fe, < 0.4% O) (Starbond TI5; Schefter, Mainz, Germany) were manufactured in a milling machine with 5-axes and an integrated irrigation system (CNC D15W; Yenadent, Istanbul, Turkey). The Ti-6Al-4V alloy was used in the SLM [Figure 2B, 2E] machine (MLab Cusing 200R; Ge Additive Company, Cincinnati, Ohio, United States of America) with a powder composition of 88.47% Ti, 6.5% Al, 4.5% Vn, 0.25% Fe, 0.08% C, 0.13% O, 0.05% N, and 0.012% H (CL 41TI ELI, Concept Laser GmbH, Lichtenfels, Germany). Ti grade V was also used in the EBM [Figure 2C, 2F] machine (Q10; Arcam Ge Additive Company), with a powder composition of 89.7% Ti, 6% Al, 4% Vn, 0.1% Fe, 0.03% C, 0.15% O, 0.01% N, and 0.003% H (Arcam Titanium Ti6Al4V, Arcam Ge Additive Company, Molndal, Sweden). All parameters of the milling and additive manufacturing machines are described in Table 2.

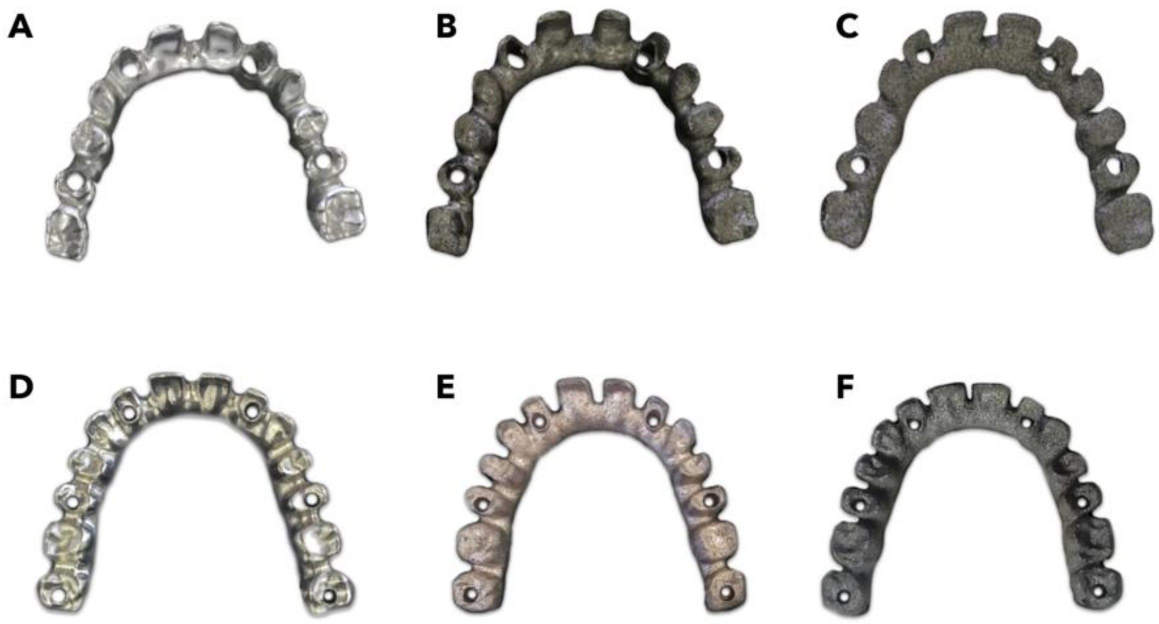


Figure 2. Frameworks produced with different 3D technologies and implant number concepts. All-on-four frameworks produced by: A: Milling; B: SLM. C: EBM. All-on-six frameworks produced by: D: Milling; E: SLM. F: EBM. SLM, selective laser melting. EBM, electron beam melting.

For gap measurement, the frameworks were passively positioned on the master model and kept in position by using a drop of low-shrinkage acrylic resin (GC Pattern Resin; GC America Inc) applied in the mesial of each mini-pillar/framework interface. This fixation allows the passive framework adaptation without any interference. The analysis of the marginal gap was performed by an examiner (L.D.R.S) previously calibrated (Intraclass Correlation Coefficient of 0.996; *P*<.001) using a microscope with 1.0 μm accuracy at 120× magnification (UHL VMM 100 BT; Walter Uhl, Asslar, Germany) and an analyzing unit (QC

220 HH Quadra-Check 200; Metronics Inc., Cincinnati, Ohio, United States of America). Three measurements at the framework/abutment interface on buccal and lingual views, in oppositely positions, were performed, and an average for each framework was obtained. A hexagonal support was prototyped to standardize the set (master model/framework) during the marginal gap readings [Figure 3].

Table 2. Parameters of milling and additive manufacturing machines. SLM, selective laser melting. EBM, electron beam melting.

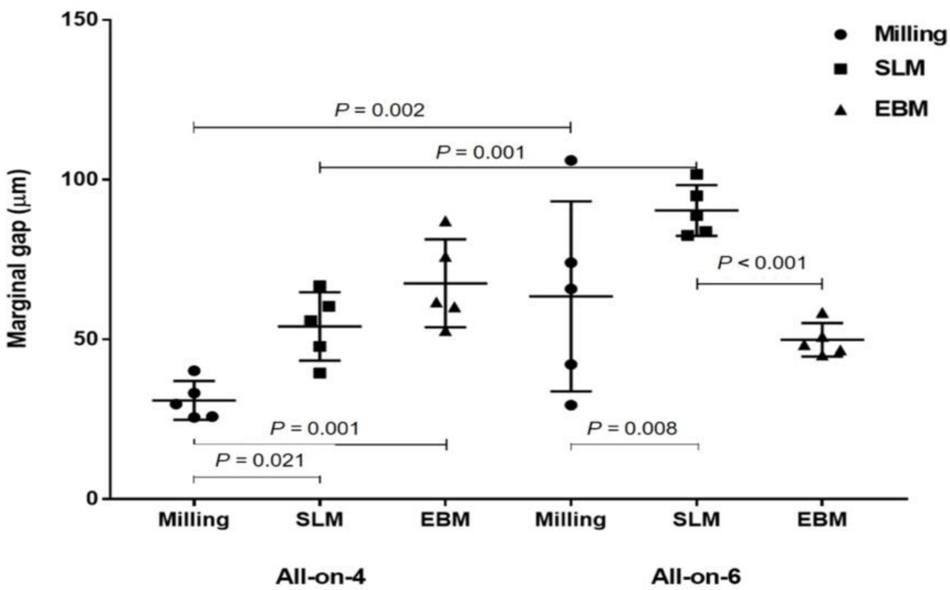
	MILLING		SLM	EBM
Smallest controllable increment	0.1 µm	Particle size	15 to 45 µm	45 to 100 µm
Travel limit A axis	+ - 28 degrees	Power layer thickness	25 µm	50 µm
X Y Z Axis motor powers	400w	Fiber laser	200 W	3000 W
Accuracy	10 < µm	Focus diameter	75 µm	3.073 mA
Repeatability	2 < µm	Working atmosphere	Argon	High vaccum
Spindle speed range	60000 rpm	Scan speed	1250 mm/s	4530 mm/s
Max. Power consumption	2.7 kW	Power supply	1.5 kW	7 kW

Figure 3. Prototyped octagonal support stabilizing both the master model and the framework during measurement acquisition. The dotted line indicates possible positions for standard readings. The blue overlay highlights the incidence of light direction during image obtention. All-on-Four SLM framework under the microscope. SLM: Selective Laser Melting.

Data were analyzed using Kolmogorov-Smirnov method to verify normality. The two-way ANOVA test was applied to investigate the influence of the implant designs and technologies on the marginal gap values (α =.05). The SPSS software (IBM SPSS Statistics v20.0; IBM Corp., New York, United States of America) was used to perform the analyses. The sample size was calculated by software (G*Power; Universität Heinrich-Heine, Düsseldorf, Germany) with a significance level of 5% and a power test of 95%. At least 4 samples were required for the analyses to be performed.

Results

The implant design (between-subjects $P = 0.004$), technology (between-subjects $P = 0.004$), and the design×technology interaction (within-subjects $P = 0.001$) affected the marginal gap values [Graph 1]. The milled ($P = 0.002$) and SLM ($P = 0.001$) all-on-four framework designs showed lower marginal gap values than those of the all-on-six. No statistical difference was found between the EBM framework designs. Regarding the all-on-four groups, milling showed lower marginal gap values than those of the SLM ($P = 0.021$) and EBM ($P = 0.001$) groups. No statistical differences were found between the SLM and EBM groups ($P = 0.163$). For the all-on-six framework designs, the milling ($P = 0.008$) and EBM ($P < 0.001$) groups presented lower marginal gap values than those of the SLM group. No statistical differences were found between the milling and EBM groups ($P = 0.160$).



Graph 1. Box plots of marginal gap values (μm) for milling, SLM, and EBM on all-on-4 and all-on-six implant designs. Bars indicate statistical difference between groups ($P<.05$, Bonferroni test). SLM, selective laser melting. EBM, electron beam melting.

Discussion

The effects of design (all-on-four/all-on-six) and manufacturing techniques (milling/additive manufacturing) on the marginal gap of FAF were evaluated. The first null hypothesis was rejected, because design did influence the marginal gap values. Less extensive frameworks are fewer susceptible to three-dimensional changes, which may explain the favorable outcomes for the all-on-four group.[15] Previous biomechanical reports[16,32] used laboratory master models without considering human anatomy, whereas this study manufactured frameworks with an arch more pronounced in both designs, simulating human anatomy. Moreover, all-on-six rehabilitations are more susceptible to distortions due to their greater length, which may make marginal adaptation difficult.[13]

Two previous finite element analysis (FEA) studies[7,9] compared the biomechanical behavior of frameworks in all-on-four and all-on-six implant designs and reported that the all-on-six concept exhibited the most favorable stress outcomes, probably due to the greatest number of implants to stress distribution. Bhering et al,[7] applied a unilateral 150N oblique force into the posterior teeth of frameworks manufactured with different materials, such as zirconia, cobalt-chromium (Co-Cr), titanium, and Topcu Ersöz and Mumcu,[9] compared the same materials as well, and additionally the high-performance polymer polyetheretherketone (PEEK). In our study, a titanium alloy was chosen because of its advantages of being lighter than zirconia or Co-Cr, and the possibility of being manufacturing through three technologies (milling, SLM and EBM). On one hand, FEA allows stress to be observed three-dimensionally, which can correspond to the distortions that occur in the implant-supported system. On the other hand it does not use real components, such as implants and frameworks,[19,33] which was the aim of our study, the evaluation of the vertical axis of misfit comparing milled and printed frameworks.

Previous reports[13,34] compared marginal gap of all-on-four milled frameworks in zirconia and titanium. An industrial computed tomography scanner showed similar clinically acceptable marginal gap values for these materials in both studies. Katsoulis et al,[16] using the one-screw test, measured the marginal gap of frameworks supported by six implants manufactured by cast (Co-Cr) and milling (zirconia and titanium) . The milled zirconia and titanium frameworks showed comparable marginal gap values, while those of Co-Cr casted frameworks presented clinically unacceptable values as expected. An explanation is that the methodology used in both papers was different from that used in our study. The prosthetic screws were tightened by the one-screw test protocol, [16,20-22] which may overestimate marginal gap values, since the unscrewed extremity creates a lever arm and presents higher misfit values than when the framework is passively settled, as in this study.

CAD/CAM technology is associated with high accuracy and consistency because there is less human interference.[24,27,28] In this study, the all-on-four milling frameworks showed lower marginal gap values compared to SLM and EBM frameworks. Therefore, the second null hypothesis was rejected, because the technology affected the marginal gap values. This difference can be explained by sequential layering and by the melting temperature achieved during the SLM and EBM fabrication process, which affects the dimensional precision of the final framework.[11,27,28] The subtractive method, however, currently produces more homogenous objects, making this method more predictable for the fabrication of prosthesis frameworks.[19,23]

Conflicting our results, a previous publication[22] found lower marginal gap values for 3-unit fixed-partial dentures manufactured by SLM compared with frameworks manufactured by milling and conventional casting techniques. Furthermore, the same study reported lower standard deviations in the frameworks fabricated by the additive technology. The disparity found may be attributable to the framework's length difference. Objects with smaller dimensions may be subjected to fewer distortions during the manufacturing process than FAF.[27] In addition, the method by which the frameworks are manufactured can be challenging, due to their inherent full-arch complexity. The distortions intrinsic to the process may act in different axes, being favorable or unfavorable for final framework dimensional precision. However, even though such behavior is impossible to predict and control, it is important to emphasize that the marginal gap values found in this study for all designs and technologies are clinically acceptable for dental practice. [32,34]

3D printing is a recent approach to the design, development, and production of dental prostheses.[11,29] As a novel manufacturing technology, inaccuracies may occur. Nevertheless, 3D printing presents advantages as a sustainable bio-technology because the powder used can be recycled,[31] large objects can be produced in a short manufacturing time, and delicate details that burs cannot achieve can be replicated.[24] The protocols established for SLM, and particularly for EBM manufacturing, have not been consolidated. Certain parameters, such as layer thickness, powder particle size, and laser speed and intensity, can be modified by the manufacturer to improve accuracy and mechanical properties.[27]

It is important to highlight that measuring the marginal gap of the FAF after the manufacturing process in the cast and before the application of the ceramic coverage it is mandatory, since if at this time the FAF is not sufficiently adapted, it will not be possible to proceed on to the next phases. This study showed promising results with FAF that presented acceptable levels of marginal misfit, nevertheless future research is necessary to elucidate the effects of ceramic coverage on marginal gap values of FAF frameworks. In a clinical scenario, the decision about which concept to use should be based on anatomical, biomechanical, and financial considerations. The choice for rehabilitation with more implants is a goal for minimizing complications without compromising clinical outcomes. In addition, finite element analysis could be applied for investigation of the stress distribution to the implants and prosthetic components. Furthermore, randomized clinical trials are needed to support the acceptable marginal gap values found without the occurrence of biomechanical prosthetic complications over time.

Conclusions

Within the limitations of this in vitro study, in spite of full-arch frameworks having complex geometries, the marginal gap in both implant designs (all-on-four and all-on-six) and the three technologies (milling, SLM, and EBM) were found to be clinically acceptable. Furthermore, after determining which would be the best implant design for each clinical case, when opting for the all-on-four design milled frameworks should be the preferred option. While in rehabilitation on six implants both milled and EBM frameworks could be chosen. Thus, 3D printing might be considered a promising technology for manufacturing full-arch frameworks.

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Figure legends

Figure 1. Master model representing a prototyped replica of an edentulous maxilla, illustrating: A: The All-on-Four concept; B: The All-on-Six concept.

Figure 2. Frameworks produced with different 3D technologies and implant number concepts. All-on-four frameworks produced by: A: Milling; B: SLM. C: EBM. All-on-six frameworks produced by: D: Milling; E: SLM. F: EBM. SLM, selective laser melting. EBM, electron beam melting.

Figure 3. Prototyped octagonal support stabilizing both the master model and the framework during measurement acquisition. The dotted line indicates possible positions for standard readings. The blue overlay highlights the incidence of light direction during image obtention. All-on-Four SLM framework under the microscope. SLM: Selective Laser Melting.

List of Abbreviations:

Abbreviation	**Definition**
3D	three-dimensional
CAD/ CAM	computer-aided design computer-aided manufacturing technologies
CO-CR	cobalt-chromium
EBM	electron beam melting
FAF	full-arch frameworks
FEA	finite element analysis
SLM	selective laser melting

Acknowledgements:

Name	Role
Pedro Yoshito Noritomi	For assistance and for supplying edentulous maxilla replica manufacturing and the electron beam melting frameworks
Paulo Inforçatti Neto	For assistance and for supplying the selective laser melting frameworks
Carlos Donato	For manufacturing the milled Ti-6Al-4V frameworks.

Source(s) of support: This work was supported by the São Paulo Research Foundation (FAPESP, grant numbers #2017/15297-0, #2018/10378-4, and #2017/16303-3); by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) - Finance Code 001; and by the Brazilian National Council for Scientific and Technological Development (CNPq, grant numbers #306373/2015-7 and #170040/2018-6).

Conflicting Interest (If present, give more details): nil

Contribution Details:

Enter the role of contributors in the first column and names of the contributors in the columns 2, 3, and so on.

Role (Concepts, Design, Definition of intellectual content, investigation, manuscript writing, etc.)	Contributor 1 Leticia	Contributor 2 Thaís	Contributor 3 Daniele	Contributor 4 Guilherme	Contributor 5 Marcelo
Literature search	✓				
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Data analysis	✓	✓	✓		✓
Statistical analysis	✓	✓			

Manuscript preparation	✓	✓		✓	
Manuscript editing	✓			✓	
Manuscript review	✓	✓	✓	✓	✓
Concept, design					✓
Definition of intellectual content					✓

Ethical policy and Institutional Review board statement: not applicable

Patient declaration of consent statement: not applicable

Data Availability statement: The data set used in the current study is available (tick the appropriate option and fill the information)

- ❑ repository name

  ____

- ❑ name of the public domain resources

  ____

- ❑ dataset can be made available after embargo period due to commercial restrictions

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- ✓ data availability within the article or its supplementary materials
- ✓ available on request from (contact name/email id)

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3 DISCUSSÃO

As reabilitações dentárias, sejam unitárias ou totais, têm como objetivo restaurar a forma, função e estética do paciente. Embora o implante dentário seja a base dessa reabilitação, o sucesso do tratamento, do ponto de vista do paciente, está na prótese dentária. A tecnologia CAD/CAM foi incorporada na Odontologia no início dos anos 1980. Desde então, a indústria busca transformar processos analógicos em tecnológicos com o propósito de alcançar reprodutibilidade e precisão (Strub *et al*., 2006). Apesar de ser uma tecnologia utilizada há mais de 40 anos, não há na literatura estudo bibliométrico que documentou essa evolução histórica e associou os fatores protéticos envolvidos com as reabilitações unitárias CAD/CAM pelas tecnologias subtrativa ou aditiva. A revisão bibliométrica realizada nessa tese, demonstrou aumento no número de publicações referentes à reabilitação com próteses unitárias CAD/CAM. Foi observado maior volume de estudos que pesquisaram exclusivamente a tecnologia aditiva que os estudos que comparam as duas tecnologias CAD/CAM. Isso pode ser atribuído ao fato de a usinagem ser uma técnica consolidada, de modo que, atualmente, trabalhos que se baseiam exclusivamente na avaliação de sua reprodutibilidade já não se justificam (Rutkūnas *et al*., 2022; Valenti *et al*., 2022).

A crescente demanda por reabilitações estéticas impulsiona as pesquisas para o aprimoramento de materiais que possam atender a esse requisito (Hosseini *et al*., 2013). Foi constatado maior volume de trabalhos que pesquisaram infraestruturas estéticas (cerâmica feldspática, vitrocerâmica reforçada por leucita e dissilicato de lítio) que infraestruturas em titânio. O que recai sobre a implicância estética e a propensão de se explorar a aplicação de materiais puramente cerâmicos quando comparados aos metalocerâmicos. Além da exigência estética do paciente (Batson *et al*., 2014; Aziz e El-Mowafy, 2023), algumas razões técnicas incluem o uso da Odontologia adesiva, a resistência flexural compatível com o dente e o mimetismo com o substrato dentário (Chen *et al*., 2021). Ademais, a literatura reporta adesão deficiente do titânio à cerâmica devido à camada de óxido formada na interface durante a queima da cerâmica o que pode causar falhas adesivas e fraturas do recobrimento estético (Antanasova *et al*., 2018). Outro resultado foi um maior volume de publicações que reportam o uso de próteses cimentadas quando comparadas às parafusadas. O uso de coroas cimentadas sobre implante tem sua principal aplicação em situações na qual há comprometimento da estética devido ao posicionamento incorreto do implante. Além disso, outros motivos para a preferência pela cimentação são a facilidade de obtenção da passividade devido à compensação do cimento e a proximidade da técnica com a prótese fixa dentária (Wittneben *et al*., 2017).

Os dados do presente trabalho demonstram maior prevalência de estudos que utilizaram apenas odontologia digital em comparação com aqueles que realizaram técnica híbrida (moldagem analógica seguida de digitalização do modelo de gesso). A utilização de escâneres intraorais possui diversas vantagens sob a perspectiva do paciente, que incluem melhor receptividade (Yuzbasioglu *et al*., 2014), maior velocidade (Gjelvold *et al*., 2016; Sakornwimon e Leevailoj, 2017; Siqueira *et al*., 2021) e menor reflexo de vômito (Gjelvold *et al*., 2016). No tocante ao cirurgião-dentista ainda podemos listar os benefícios: visualização de erros vistos no momento do escaneamento (Boeddinghaus *et al*., 2015), redução da distorção dos materiais de impressão (Yuzbasioglu *et al*., 2014; Gjelvold *et al*., 2016), melhores contatos oclusais (Gjelvold *et al*., 2016) e melhor adaptação marginal e interna (Manisha *et al*., 2023).

A evolução da tecnologia CAD/CAM é claramente perceptível no contexto de pacientes parcialmente desdentados. Essa tecnologia aprimorou a precisão do processo de fabricação de infraestruturas de PTFs, reduzindo a necessidade de seccionar e soldar, procedimentos frequentemente realizados para infraestruturas fundidas (Svanborg et al., 2015) No entanto, ao reabilitar pacientes totalmente desdentados com próteses sobre implantes, é fundamental considerar o nível de adaptação da infraestrutura, o qual pode estar diretamente relacionado à sua extensão (Al-Meraikhi et al., 2018b), assim como à configuração dos implantes utilizados, conforme as evidências encontradas por meio do Capítulo 2 do presente trabalho. Dessa forma, o grupo *all-on-four* apresenta menor extensão, número de implantes e curvatura o que pode justificar a menor alteração tridimensional e a maior facilidade de adaptação marginal nesse tipo de infraestrutura (Svanborg *et al*., 2015). Por outro lado, estudo prévio utilizando a metodologia de elementos finitos 3D comparou o comportamento biomecânico de infraestruturas em designs de implantes *all-on-four* e *all-on-six* e demonstrou resultados favoráveis de tensão para a configuração com seis implantes provavelmente devido ao maior número de implantes para distribuição de tensão (Bhering *et al*., 2016). A análise de elementos finitos permite observar tensões tridimensionalmente, que podem corresponder às distorções que ocorrem no sistema implantossuportado, mas não utiliza componentes reais, como implantes e infraestruturas (Presotto *et al*.,2017). Vale ainda ressaltar que no estudo de Bhering e col. (2016) foi realizada a aplicação de força oblíqua unilateral de 150 N, com angulação de 30º nos dentes posteriores, o que também explicaria a diferença nos resultados encontrados entre os estudos. Apesar das metodologias e objetivos diferentes, é aconselhável ponderar a avaliação do sistema implantossuportado como um todo quando da escolha da quantidade de implantes ou método de fabricação da infraestrutura.

A literatura relata trabalhos prévios (Katsoulis *et al.*,2014; Al-Meraikhi *et* al., 2018a; Yilmaz *et* al., 2018) que avaliaram o desajuste marginal de infraestruturas de PTFs com diferentes metodologias. Al-Meraikhi *et* al., 2018a e Yilmaz *et* al., 2018 compararam o desajuste marginal de infraestruturas sob design de implantes *all-on-four* fresadas em zircônia e titânio. Para realizar essa mensuração foi utilizado escâner de tomografia computadorizada industrial que demostrou valores de desajuste marginal clinicamente aceitáveis (abaixo de 150µm) e semelhantes para esses materiais em ambos os estudos. Em contrapartida, Katsoulis *et al.*,2014 compararam infraestruturas suportadas por seis implantes fundidas em Co-Cr e usinadas em zircônia e titânio. As infraestruturas em zircônia e titânio apresentaram valores marginais de desajuste similares, enquanto as de Co-Cr apresentaram valores clinicamente inaceitáveis, como esperado. Em todos os trabalhos acima citados foi utilizada a metodologia do parafuso único para medir o desajuste marginal (Katsoulis *et al.*,2014; Al-Meraikhi *et* al., 2018a; Yilmaz *et* al., 2018). Sob outra perspectiva, a metodologia proposta no nosso estudo diverge das relatadas anteriormente. O fato de as infraestruturas serem assentadas passivamente resulta em nível real de desadaptação quando comparada a utilização do teste do parafuso único (Katsoulis *et al.*,2014; Presotto *et al.*, 2019). Isso se deve ao fato do parafuso protético apertado na extremidade superestimar os valores de desajuste, em razão de a extremidade desaparafusada criar um braço de alavanca e apresentar maiores valores de desajuste do que quando a estrutura é assentada passivamente.

A forma de fabricação da infraestrutura (usinagem, SLM e EBM) influenciou no nível de adaptação das próteses. Nesse estudo, as infraestruturas usinadas *all-on-four* apresentaram valores de desajuste marginais inferiores aos das estruturas SLM e EBM. Mesmo com a constante evolução da manufatura aditiva, o método subtrativo ainda produz objetos mais homogêneos, e por isso é amplamente difundido na prática clínica (Kim *et al.*, 2016). Os maiores valores de desajustes encontrados nas tecnologias SLM e EBM podem ser explicados pelo processo de fabricação, que inclui a deposição sequencial das camadas do material em altas temperaturas de fusão (Abduo *et al.*, 2014; Alharbi *et al.*, 2017).

A manufatura aditiva é considerada uma abordagem relativamente recente para a produção de próteses dentárias, especialmente as de arco completo. Assim como qualquer tecnologia nova, há necessidade de curva de aprendizado, até que possam existir protocolos a serem seguidos (Alharbi *et al*., 2017). Apesar disso, a manufatura aditiva apresenta vantagens como produção de grandes objetos em curto tempo de fabricação, reprodução de detalhes que as brocas não conseguem replicar, além de ser uma tecnologia sustentável porque o pó utilizado pode ser reciclado (Qiu *et al*., 2013). Em um cenário clínico, a decisão sobre qual configuração de implante utilizar deve ser baseada em considerações anatômicas, biomecânicas e financeiras. A escolha pela reabilitação com mais implantes é uma meta para minimizar complicações, sem comprometer os resultados clínicos.

4 CONCLUSÃO

Ao analisar o panorama apresentado pelo estudo bibliométrico, conclui-se que houve maior número de publicações sobre próteses unitárias CAD/CAM. Dentre as tecnologias avaliadas, os artigos que analisaram a manufatura aditiva predominaram em comparação àqueles que utilizaram a usinagem como grupo de comparação. Foi observado também volume maior de pesquisas focadas em infraestruturas estéticas, em detrimento ao titânio. Artigos que utilizaram próteses cimentadas ou combinações de conexões (cimentada e parafusada) foram mais frequentes do que os que utilizaram apenas próteses parafusadas. O escaneamento intraoral foi mais amplamente adotado que a técnica híbrida (moldagem convencional seguida de escaneamento do modelo). Para reabilitações em arco completo independentemente do design de implantes escolhido, e de acordo com os achados do presente trabalho, as infraestruturas usinadas mostraram-se promissoras. Resultados similarmente promissores foram encontrados para infraestruturas confeccionadas por EBM para o design *all-on-six*. Entretanto, os níveis de adaptação marginal encontrados foram considerados clinicamente aceitáveis para todas as tecnologias estudadas, inclusive SLM, em ambos os designs de implantes. Assim, a manufatura aditiva se apresenta como uma tecnologia promissora, oferecendo boas oportunidades para a produção de infraestruturas de arco completo, mas ainda carece de estudos para o desenvolvimento de protocolos específicos de confecção para tal finalidade.

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Publication: Heliyon

Publisher: Elsevier

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