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Faculdade de Odontologia

Programa de Pós-Graduação em Odontologia

Tese

IMPRESSÃO 3D PARA EDUCAÇÃO EM ODONTOLOGIA – UMA REVISÃO DE ESCOPO

Márcia Regina de Mello

Pelotas, 2020

Márcia Regina de Mello

IMPRESSÃO 3D PARA EDUCAÇÃO EM ODONTOLOGIA – UMA REVISÃO DE ESCOPO

Tese apresenta ao Programa de Pós-Graduação em Odontologia da Universidade Federal de Pelotas, como requisito parcial à obtenção do título de Doutor em Biomateriais e Biologia Oral – ênfase Materiais Odontológicos.

Orientadora: Prof. Dra. Adriana da Silva

Coorientador: Prof. Dr. Wellington Luiz de Oliveira da Rosa

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Márcia Regina de Mello

**IMPRESSÃO 3D PARA EDUCAÇÃO EM ODONTOLOGIA –
UMA REVISÃO DE ESCOPO**

Tese aprovada como requisito parcial para obtenção do grau de Doutor em Biomateriais e Biologia Oral – ênfase Materiais Odontológicos, Programa de Pós-Graduação em Odontologia, Faculdade d eOdontologia, Universidade Federal de Pelotas.

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Banca examinadora:

Prof. Dra. Adriana Fernandes da Silva
Doutora em Biologia BucoDental/Histologia e Embriologia pela Universidade Estadual de Campinas-UNICAMP

Prof. Dr. Mateus Bertolini F. dos Santos
Doutor em Clínica Odontológica - Prótese Dental pela Universidade e Estadua Campinas-UNICAMP

Prof. Dr. Rafael Pino Vitti
Doutor em Odontologia -Materiais Dentários pela Universidade <mencionar Universidade Estadual de Campinas-UNICAMP

Prof. Dr. Carlos Enrique Cuevas Suárez
Doutor em Odontologia - Materiais Dentários pela Universidade Federal de Pelotas

Prof. Dr. Otacílio Luiz Chagas Jr. (suplente)
Doutor em Odontologia - Cirurgia e Traumatologia Buco-Maxilo-Facial pela Pontifícia Universidade Católica do Rio Grande do Sul-PUCRS

Prof. Dr. Marco Antonio da Silva (suplente)
Doutor em em Odontologia - Área de Biologia BucoDental/Histologia e Embriologia pela Universidade Estadual de Campinas-UNICAMP

Dedico este trabalho ao meu esposo Franco
pelo incentivo incessantemente, ao meu filho Andrei
pela parceria nas viagens à Pelotas nesse período de aprendizado,
aos meus pais pelo apoio incondicional.

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"Sobre as ondas do mar, sobre as águas na areia, minha força é do mar, minha mãe é sereia!"

"Deus em sua infinita bondade e sabedoria, Amém!"

“Só fizemos melhor aquilo que repetidamente insistimos em melhorar. A busca da excelência não deve ser um objetivo, e sim, um hábito.”

(ARISTÓTELES)

Notas Preliminares

A presente tese foi redigida segundo o Manual de Normas para Dissertações, Teses e Trabalhos Científicos da Universidade Federal de Pelotas de 2020, adotando o Nível de Descrição em Artigos, descrita no referido manual. <http://sisbi.ufpel.edu.br/?p=documentos&i=7> Acesso em: 23/07/2020.

Resumo

MELLO, Márcia Regina de. **IMPRESSÃO 3D PARA EDUCAÇÃO EM ODONTOLOGIA – UMA REVISÃO DE ESCOPO. 2020**. 70f. Tese – Programa de Pós Graduação em Odontologia –Faculdade de Odontologia. Universidade Federal de Pelotas, Pelotas, 2020.

O objetivo desta revisão de escopo foi avaliar a influência da tecnologia de impressão 3D no processo de ensino-aprendizagem na área odontológica. Para isso, foram realizadas pesquisas em quatro (04) bancos de dados eletrônicos: MedLine (PubMed), Web of Science, Scopus e Embase. Dois revisores avaliaram, independentemente, o título e os resumos de estudos potencialmente relevantes, bem como posteriormente a leitura integral dos mesmos atingindo um índice de concordância kappa de 0.84 na primeira fase e 0,81 na segunda fase. Foram incluídos apenas estudos relacionados ao uso da impressão 3D no ensino de odontologia na língua inglesa. Um total de 22 estudos preencheram todos os critérios e foram publicados entre 2013 a 2020. As especialidades que estudaram a impressão 3D direcionadas ao ensino foram a endodontia, dentística e cirurgia. As preferências no ensino com a impressão 3D, quanto a forma de aquisição de imagens foi a tomografia computadorizada de feixe cônico (CBCT). Em relação à tecnologia mais utilizada reportada foi a *StereoLithoGraphy* (SLA) e o material considerado para impressão é a resina manufaturada aditiva, sendo o objeto anatômico mais impresso para o ensino odontológico os dentes. Os benefícios pautados da impressão 3D estão relacionados a integração, aplicabilidade, variabilidade e realismo quando comparado, auxiliado ou substituindo a abordagem de ensino tradicional. As impressões 3D oferecem autonomia do ponto de vista didático ao estabelecer e variar o objetivo educacional usando a tecnologia de impressão 3D, aplicando como base situações de pacientes reais. É possível que a impressão 3D como método de ensino torne-se uma ferramenta viável e enriquecedora ao processo de ensino-aprendizagem odontológico.

Palavras-chave: impressão tridimensional, educação odontológica, material de ensino, manufaturas aditivas, modelo odontológico

Abstract

MELLO, Márcia Regina de. **3D PRINTING FOR DENTISTRY EDUCATION - A SCOPING REVIEW.** 2020. 70p. Thesis – Graduate Program in Dentistry- Faculty od Fentistry. Federal University of Pelotas, Pelotas, 2020.

The objective of this scope review was to evaluate the influence of 3D printing technology on the teaching-learning process in the dental area. For this, research was carried out in four (04) electronic databases: MedLine (PubMed), Web of Science, Scopus and Embase. Two reviewers independently evaluated the title and abstracts of potentially relevant studies, as well as their full reading, reaching a kappa agreement index of 0.84 in the first phase and 0.81 in the second phase. Only studies related to the use of 3D printing in the teaching of dentistry in the English language were included. A total of 22 studies met all criteria and were published between 2013 and 2020. The specialties that studied 3D printing directed to teaching were endodontics, dentistry and surgery. The preferences in teaching with 3D printing, regarding the form of image acquisition was the cone-beam computed tomography (CBCT). Regarding the most used technology reported was StereoLithoGraphy (SLA) and the material considered for printing is additive manufactured resin, being the most printed anatomical object for dental teaching were teeth. Two reviewers independently evaluated the title and abstracts of potentially relevant studies, as well as their full reading, reaching a kappa agreement index of 0.84 in the first phase and 0.81 in the second phase. Only studies related to the use of 3D printing in the teaching of dentistry in the English language were included. A total of 22 studies met all criteria and were published between 2013 and 2020. The specialties that studied 3D printing directed to teaching were endodontics, operative dentistry and surgery. The preferences in teaching with 3D printing, regarding the form of image acquisition was the cone-beam computed tomography (CBCT). Regarding the most used technology reported was StereoLithoGraphy (SLA) and the material considered for printing is additive manufactured resin, being the most printed anatomical object for dental teaching were teeth. The guided benefits of 3D printing are related to integration, applicability, variability, economy and realism when compared, aided or replaced by the traditional teaching approach. 3D printing offers educational autonomy by establishing and varying the educational objective using 3D printing technology, applying real patient situations as a basis. It is possible that 3D printing as a teaching method becomes a viable and enriching tool for the dental teaching-learning process.

Key-words: three dimensional printing, dental education, teaching material, additive manopaths, dental model.

Sumário

1 Introdução

A tecnologia digital vem globalmente ganhando espaço na Odontologia (FERNANDEZ; NIMMO; BEHAR-HORENSTEIN, 2016). Os avanços tecnológicos oportunizam oferecer metodologias de ensino e aprendizado a uma população estudantil evoluída tecnologicamente e sedenta por recursos inovadores (FERRO; NICHOLSON; KOKA, 2019). Em ressonância a esses avanços, a Odontologia, em particular no âmbito da imagem e modelagem 3D, com a tomografia computadorizada de feixe cônico (CBCT), o scanner intraoral e planejamento virtual 3D, associados ao CAD CAM (Computer Aided Design - Computer-Aided Manufacturing), encontram-se em substancial evolução (DAWOOD *et al.*, 2015; SHAH; CHONG, 2018).

O processo de manufatura aditiva (MA), impressão tridimensional (impressão 3D) ou prototipagem rápida (RP), de acordo com a ISO/ASTM 52900 (2015), é definido como o processo de agregar materiais, normalmente camada por camada, de forma a construir um objeto a partir de dados de um modelo virtual computacional em 3D, sendo classificada em 7 categorias distintas: *Vat Photopolymerisation-StereoLithoGraphy (SLA), Material Jetting, Binder Jetting (3DP), Material Extrusion - Fused Deposition Modelling (FDM), Powder Bed Fusion (SLS/SLM), Directed Energy Deposition (DED) e Sheet Lamination (LOM)*. A variedade de categorização permite, na Odontologia, uma grande diversidade de matérias-primas para fabricar estruturas conforme a necessidade e os princípios de aditivos, incluindo combinações aglutinante/pó, polímeros (resina e termoplásticos), cerâmicas e metais (BARAZANCHI *et al.*, 2017).

A receptividade e corroboração da Odontologia à impressão 3D se dá devido a sua aplicabilidade abrangente nas distintas especialidades, seja no processo ensino-aprendizagem, pesquisa, diagnóstico, planejamento, treinamento ou tratamento (RENGIER *et al.*, 2010; SHAHBAZIAN *et al.*, 2012; SOARES *et al.*, 2013; HÖHNE; DICKHAUT; SCHMITTER, 2020; REYMUS *et al.*, 2020; SEIFERT *et al.*, 2020; HANAFI *et al.*, 2020; HÖHNE; SCHWARZBAUER; SCHMITTER, 2019; MARTY *et al.*, 2019; NICOT *et al.*, 2019; LANTADA; MORGADO, 2012; BARAZANCHI *et al.*, 2017; LANTADA; MORGADO, 2012). Atualmente, o uso da impressão 3D na Odontologia permite criar com precisão formas geométricas únicas e complexas em alta resolução (DAWOOD *et al.*, 2015). As aplicabilidades desta tecnologia, do uso clínico ao educacional, são documentados na literatura, proporcionando bons estudos na Periodontia com guias cirúrgicos; na Prótese com fabricação de próteses fixas e removíveis; na Ortodontia com modelos diagnóstico, colagem indireta e movimentação dentária; na Cirurgia para planejamento, simulação e reconstrução pós traumática; na Implantodontia com planejamento e tratamento com guias cirúrgicos; na Dentística simulando cárie e na Endodontia para confecção de guia, além de dentes de treinamento educacional (ANDERSON; WEALLEANS; RAY, 2018; NIKZAD; AZARI, 2008; KUMAR; GHAFOOR, 2016; D'HAESE *et al.*, 2012; KUMAR; GHAFOOR, 2016; KRÖGER; DEKIFF; DIRKSEN, 2017; WERZ *et al.*, 2018).

Considerando outros aspectos, o ensino de estratégias inovadoras em pré-clínica odontológica é necessário para motivar e beneficiar os alunos principalmente para a compreensão e memorização das estruturas anatômicas envolvidas na atividade de aprendizagem. Dessa forma, a tecnologia tem potencial significativo para complementar as abordagens convencionais de treinamento, onde a associação com a impressão 3D torna-se viável e acessível ao processo de ensino-aprendizagem. Além disso, são obtidas as peças anatômicas naturais como, e. dentes extraídos, o que resulta em maior dificuldade de obtenção, principalmente por questões éticas e de saúde. Assim, modelos de dentes artificiais têm sido utilizados como alternativa (ANDERSON; WEALLEANS; RAY, 2018).

Didaticamente, para o treinamento pré-clínico da graduação ou pós-graduação, alguns autores preferem desenvolver seus próprios modelos de simulação de treinamento clínico em impressão 3D (MARTY *et al.*, 2019). O ensino odontológico historicamente tem por base o uso de dente extraído, quando disponível. Pela maior dificuldade de aquisição de dentes humanos, atualmente por questões éticas e salubres, os dentes artificiais e manequins industrializados têm sido utilizados (ANDERSON; WEALLEANS; RAY, 2018). Protótipos 3D dentais têm sido usados para simular exercícios pré-clinicos, comparando com os artificiais e naturais (ANDERSON; WEALLEANS; RAY, 2018; MARENDING *et al.*, 2016; ROBBERECHT *et al.*, 2017; KFIR *et al.*, 2013). A validação de protótipo 3D para treinamento e planejamento da exodontia de dente supranumerário foi relatado como exercíco da técnica cirúrgica através da individualização do caso para comparação a modelos tradicionais (SEIFERT *et al.*, 2020; CHAE *et al.*, 2020). Dessa forma, modelos impressos em 3D para treinamento com base na situação real do paciente é uma alternativa já considerada indispensável na educação odontológica (HANISCH *et al.*, 2020a).

Com o avanço da tecnologia a readequação das técnicas de ensino e aprendizado, os currículos odontológicos passarão a necessitar da implementação da impressão 3D no ensino da graduação e pós-gradução, auxiliando no desenvolvimento e competência das habilidades motoras finas adquiridas pelos discentes (ANDERSON; WEALLEANS; RAY, 2018; SHAH; CHONG, 2018). Embora haja estudos na área de impressão 3D voltadas ao processo ensino-aprendizagem, a literatura em sua grande maioria é dedicada a relatos de caso e trabalhos pré-clínicos (ANDERSON; WEALLEANS; RAY, 2018). Dessa maneira, essa revisão de escopo teve por objetivo avaliar a influência da tecnologia de impressão 3D na melhora da qualidade da educação odontológica. A hipótese testada foi de que a impressão 3D em Odontologia melhoraria a qualidade do ensino viabilizando a tecnologia como auxiliar e acessível ao processo de aprendizagem.

1.1 Objetivo geral

Avaliar a influência da tecnologia de impressão 3D na melhora da qualidade da educação odontológica por meio de uma revisão de escopo.

1.1.1 Objetivos específicos

Analisar os diferentes tipos de impressão 3D que têm sido utilizados para o ensino odontológico.

Identificar as formas de aquisição das imagens, para posterior impressão 3D.

Descrever os objetos de impressão 3D utilizados para o ensino odontológico.

Classificar o material de impressão 3D empregado, bem como os tipos de impressoras.

Analisar as vantagens e as limitações da tecnologia de impressão 3D para o ensino na Odontologia.

2 Projeto de pesquisa

Desenvolvimento de sistemas bioativos para obturação de canais radiculares

O projeto de pesquisa foi aprovado em 11 de outubro de 2017, durante **Qualificação Fechada** pela Banca Examinadora composta pelos Professores Doutores Orientador Cesar Zanchi, Melissa Damian, Otávio Dávila. Fizeram parte como Co-orientador Rafael Pino Vitti e convidados - suplente 1 Rafael Lund, suplente 2 Wellington da Rosa.

2.1 Introdução

O diagnóstico, tratamento e prognóstico das patologias pulpares envolvem íntimas conexões anatômicas e vasculares entre tecidos periodontais e pulpares. Entre os fatores etiológicos e contribuintes para o desenvolvimento e progressão da lesão endodôntico-periodontal estão os microrganismos, traumas, reabsorções radiculares e perfurações, exigindo terapia endodôntica efetiva (GONÇALVES; MALIZA; ROCHA 2017)

Os bacilos anaeróbios gram-negativo são microrganismos primários responsáveis pelas infecções endodônticas e apresentam natureza polimicrobiana. Já as denominadas infecções secundárias envolvem microrganismos gram-positivos facultativos que permanecem viáveis devido a incompleta desinfecção ou obturação deficiente do sistema de canais. Estas falhas na terapia endodôntica podem resultar na cronificação do processo inflamatório, tornando estes microrganismos mais resistentes as terapias convencionais. (STUART *et al.*, 2006; CARR *et al.*, 2009).

A infiltração coronal pós terapia endodôntia tem sido considerada uma causa secundária da periodontite apical, tendo em vista a ação dos organismos persistentes à terapia (RICUCCI, SIQUEIRA, 2011).

É fundamental garantir saúde periradicular e intra-radicular, para isso isolar o espaço intra-radicular de agentes irritantes que possam permanecer e eliminar possíveis infiltrações pelos tecidos periapicais ou pela cavidade oral para os canais preenchidos (LI et al, 2013).

Chugal *et al.* (2011) em estudo sobre a comunidade bacteriana da porção apical dos dentes, mostraram diversificação maior nas infeções primárias do que nas infeções secundárias e puderam concluir que alguns microrganismos provavelmente não são erradicados durante a terapia endodôntica, tornando essencial a sanificação dos canais acessórios radiculares (KAWASHIMA; WADACHI; SUDA, 2009), garantindo suas propriedades biológicas, antimicrobiana, inibição da reabsorção dentária, indução na formação de tecido duro e inativação de endotoxinas (MOHAMMADI; DUMMER, 2011; MIZUNO; BANZAI, 2008).

Mesmo após o preparo biomecânico e obturação podem persistir micro-organismos no interior dos canais radiculares, os quais causam insucesso endodôntico (SIQUEIRA; ROÇAD; RICUSSI, 2010; VERA *et al.*, 2012). Entre outras causas de fracasso endodôntico estão a infiltração coronal, fraturas radiculares, erros de diâmetro, comprimento e direção, não identificação de canais extra, limas pequenas, sobre extensões com sub-obturação, perfurações, instrumentos fraturados, falhas cirúrgicas, alterações no periodonto, o preenchimento incompleto dos canais, irrigação insuficiente dos canais, ausência de medicação intracanal, instrumentação inadequada ou até as irregularidades do sistema de canais. Independentemente da etiologia do insucesso, o que existe em comum na falha do tratamento endodôntico é a infiltração ou recontaminação bacteriana (BERNARDES *et al.*, 2010; MACHADO *et al.*, 2013

A falta de material obturador ou uma falha no processo de obturação, permite a proliferação bacteriana, assim como uma fratura ou infiltração coronal (YAVARi *et al.*, 2015). Diferentes e complexas morfologias dos canais radiculares, podem reter restos de tecido necrótico e bactérias (ALI et al, 2016). Os novos materiais obturadores necessitam ser biologicamente compatíveis, eficazes na eliminação de infecções e recontaminações, já que os atuais materias demonstram incapacidade na adaptação superficial e no acesso a zonas restritas como canais acessórios. (LI et al, 2013).

A forma como são realizados o selamento apical e coronal influenciam no prognóstico a longo prazo dos dentes tratados endodonticamente (KALA *et al.*, 2014).

Estudo em pré-molares mandibulares humanos, divididos em grupos conforme o cimento selador de base resinosa AH Plus, Meta Seal e Gutta Flow 2, o cimento Gutta Flow 2 mostrou capacidade de vedação superior aos demais (KUMARI *et al.*, 2017).

A técnica convencional de obturação dos sistemas de canais radiculares é realizada empregando dois componentes principais: um material sólido (gutta-percha) funciona como um núcleo de preenchimento do espaço intracanal, e, um cimento com objetivo de selar entre a parede dentinária e o material obturador (ASMANN *et al.*, 2012) A gutta-percha tem biocompatibilidade considerada aceitável, pois apresenta boa reação tecidual e sua função principal é evitar nova infiltração de microrganismos após a desinfecção do sistema de canais (ZHOU *et al.*, 2013) Entretanto não propicia a obturação dos sistemas de canais radiculares, pois não tem aderência à superfície da dentina, necessitando do cimento com fluidez adequada para preencher irregularidades e discrepâncias entre a gutta-percha e as paredes radiculares, a fim de obturar em três dimensões de forma hermética e estável (BELLADONNA *et al.*, 2014).

Vários tipos de cimentos endodônticos estão disponíveis no mercado atualmente (CHANDRASEKHAR *et al.*, 2011). Entretanto, cimentos à base de zinco e eugenol tem o inconveniente da libertação de concentrações potencialmente citotóxicas de eugenol, causando divergências quanto à sua biocompatiblidade (PANZARINI *et al.*, 2012). Os cimentos de hidróxido de cálcio tendem a dissolver-se ao longo do tempo, deixando espaços e comprometendo a obturação endodôntica, cimentos a base de Ionomero de vidro dificultam a remoção em nova intervenção endodôntica. A toxicidade e mutagenicidade dos cimentos à base de resina não impedem sua ampla utilização atual. Novos cimentos à base de MTA apresenta alcalinidade capaz de enfraquecer a dentina radicular, além de não aderir à dentina. As biocerâmicas são materiais biocompatíveis e parecem ser promissores cimentos endodônticos, porém as técnicas de retratamento convencionais não são capazes de remover totalmente os cimentos biocerâmicos (CHANDRASEKHAR *et al.*, 2011).

Almeida *et al.*, (2017) justificando que ainda há poucos estudos in vitro e falta ensaios clínicos a longo prazo sobre propriedades de selantes endodônticos à base de silicato de cálcio, realizaram revisão sistemática comparando as propriedades fisicoquímicas e biológicas dos selantes à base de silicato de cálcio com os convencionais. As propriedades de interesse no estudo foram a força de ligação, radiopacidade, pH, solubilidade, ajuste e tempo de trabalho, mudança dimensional, fluxo, liberação de íons de cálcio, atividade antimicrobiana, biocompatibilidade e citotoxicidade. Os selante com base de silicato de cálcio cumprem os requisitos da ISO 6876:2012 na maioria doas propriedades fisico-quimicas, exceto para solubilidade e quando comparados ao convencionais, são aceitáveis seus resultados biológicos.

Dentes uniradiculares distribuídas aleatoriamente em 3 grupos usando cada grupo um selante Endo-CPM, MTA Fillapex e AH Plus, que posteriormente foram radiografadas a fim de verificar a presença de espaços vazios. Após 7 dias armazenados em 37ºC e 100% de umidade, os espécimes foram avaliadas. O selante Endo-CPM mostrou força de adesão significativamente maior que os demais, as fatias de espécimes MTA Fillapex e AH Plus falharam na interface selante/dentina, ao contrário do Endo-CPM onde as falhas foram misturadas ocorrendo entre interface selante/dentina e também com o material obturador. Radiograficamente o cimento Endo-CPM mostra lacunas e vazios detectáveis no interior do canal obturado. MTA Fillapex tem resistência aceitável ao deslocamento, semelhante ao AH Plus (ASSMANN *et al.*, 2012).

Recentemente surgiu a proposta do uso de cimentos e cones obturadores a base de polímeros metacrilatos – CPoint. Projetado para expandir de forma não uniforme radialmente, sem alterar axialmente, à medida que absorve a umidade no espaço intracanal a fim de melhorar a capacidade de vedamento ao preencher todo o espaço no canal radicular na obturação (HIGHGATE, LLOYD, 2007). CPoint contém um revestimento de polímero hidrofílico em torno de um núcleo central (HEGDE, 2015). A presa inicial do sistema CPoint não é afetada, inclusive melhorou com o tempo, quando comparado à Gutta Percha/AH Plus (HASSAN,DIAB, AHMED, 2016). Estudo de Didato et al (2013) afirma que a expansão do material CPoint é consistente após 20 minutos de sorção em água.

Conforme Eid *et al.* (2013), o CPoint é um ponto endodôntico polimérico que aproveita a expansão radial não isotrópica induzida pela água para se adaptar às irregularidades do canal. Os autores estudaram seus efeitos sobre o potencial de viabilidade e mineralização de células tipo odontoblastos em ratos. Concluiram que a biocompatibilidade in vitro da CPoint é comparável à gutta-percha em termos de efeitos sobre a viabilidade celular, bem como o potencial de mineralização, além de possuir riscos toxicológicos insignificantes e provável resposta rapida e favorável in vivo. Também possui risco mínimo no reparo da desmineralização de tecido duro em lesões periapicais por osteogênese.

Em estudo de expansão lateral baseada no tempo (20 e 40 min, 1, 2, 3, 4, 5, 6, 7, 8 e 24 h), utilizou-se dois tamanhos 25 e 40 (taper 0,06 cônicos) de dois lotes de pontos de obturação expansíveis em água (CPoint) e um ponto de gutta-percha de tamanho similar 40 (taper 0,06 cônico EndoSequence como controle) a várias distâncias do ponto apice 5, 10 e 15 mm, armazenados a 37ºC. A dimensão lado-a-lado de cada ponto foi determinada usando o software de imagem. As mudanças na dimensão da CPoint foram significativamente maiores para ambos os tamanhos em cada distância da ponta após 20 min de imersão em água Gutta-percha não mudou significativamente do valor seco durante a imersão em água. O CPoint quando exposto à água, a expansão lateral de um novo ponto de obturação endodôntica hidrofílica aumenta significativamente em dimensão dentro de 20 min, enquanto que um ponto convencional de guta-percha não. As características de expansão lateral inter-lote de CPoint são consistentes (DIDATO *et al.*, 2013)

A fim de estudar a resistência à degradação do sistema expansível em água –Cpoint, Hassan, Diab e Ahmed (2016), selecionaram dentes incisivos centrais superiores humanos para estudo da detoriorização dos obturadores. Os canais radiculares foram preenchidos com C-Point ProTaper F4 / Endosequence BC selador e Protaper Universal guta-percha Pontos F4 / AH-Plus selador utilizando a técnica do cone simples foi utilizado para ambos os materiais testados, onde o C-Pont apresentou valores médios mais elevados. O sistema obturador C-Point/Endosequence no período inicial não foi efetado e não se deteriorou com o envelhecimento, apresentando um desempenho melhor do que o sistema da guta-percha/AH-Plus.

Entre as propriedades desejadas ao material obturador ideal, Weiner & Schilder (1971) descrevem fácil manipulação, estabilidade dimensional, impermeabilidade, não solúvel na umidade, ação antimicrobiana, selamento dos canais, não irritante ao tecidos periapicais, ser estéril e de fácil remoção, além da radiopaco para diferenciá-lo das demais estruturas. A radiopacidade tem recebido maior atenção em função das técnicas de diagnóstico por imagem, uma vez que permitem a diferenciação entre diferentes tecidos dentais, ósseo e material restaurador. Além disso, a praticidade e precisão destas técnicas tem aumentado a demanda destes exames de imagem. Assim, tanto a *American Dental Association* – ADA (2000) e a International Organization for Standardization -ISO (2001) conforme suas especificações, determinam que os cimentos endodônticos devem possuir uma radiopacidade, respectivamente, maior ou igual a 2mm e 3mm de alumínio. Embora a recomendação ADA e ISO determinem um valor específico para a radiopacidade e radiopacificadores, ainda deixa a desejar na interpretação tomográfica, pois a padronização destes valores são elevados para o diagnóstico, assim como os radiopacificadores são muito densos, ambos causam artefatos de imagem que prejudicam a interpretação diagnóstica e infelizmente não há outro critério de avaliação.

Marín-bauza *et al.* (2012), testou as propriedades físico-químicas de selantes, exceto a alteração de mudança dimensional, todas as outras propriedades testados estão em conformidade com ANSI / ADA.

Na avaliação da citotoxicidade in vitro de selantes endodônticos (GuttaFlow Bioseal, GuttaFlow2 e MTA Fillapex) em células-tronco do ligamento periodontal humano, Collado-González et al (2017), usaram AH Plus como referência, comparando-os quanto à viabilidade celular e à fixação celular. O cimento GuttaFlow Bioseal exibiu uma melhor citocompatibilidade do que GuttaFlow2, apresentaram menor citotoxicidade do que MTA Fillapex e AH plus. Testes revelaram um alto grau de proliferação, disseminação celular e apego, especialmente quando se usam discos GuttaFlow Bioseal

Viapiana et al (2014) usaram cimento experimental à base de Portland para avaliar propriedades físico-químicas com agentes radiopacificadores (óxido de nióbio e óxido de zircónio micro e nanopartículas) em comparação com os seguintes cimentos convencionais: AH Plus, MTA Fillapex e Sealapex. Foram testados tempo de presa, a resistência à compressão, fluxo, espessura, radiopacidade, solubilidade, estabilidade dimensional e libertação de formaldeído. MTA Fillapex teve o tempo de endurecimento mais curto e mais baixos valores de resistência à compressão em comparação com os outros materiais. Cimento experimental à base de Portland teve valores semelhantes aos materiais convencionais, mas com espessuras maiores e radiopacidade inferior ao recomendado pela ISSO 6876 e 57 ANSI da ADA, além de expansão dimensional e menor solubilidade comparados a MTA Fillapex e Sealapex. Nenhum dos cimentos endodônticos avaliadas libertou formaldeído após a mistura. Os cimentos endodônticos experimentais baseados em cimento Portland tiveram tempo de presa e capacidade de fluxo adequados para o uso clínico, resistência à compressão satisfatórias e baixa solubilidade.

O avanço tecnológico, possibilitou o auxilio da Tomografia Tomputadorizada Cone Bean (TCCB) na investigação de fratura radicular vertical (FRV) em diferentes situações clínicas. Na ausência de qualquer material intracanal, a fratura pode ser detectada com exatidão na TCCB. Porém na presença de material intracanal, isso é dificultado devido aos artefatos de imagem causados por esses materiais, a guta-percha gera um artefato endurecimento que impossibilita a visualização da extensão da VRF (DUTRA *et al.*, 2017). Outros distintos estudos em endodontia, afirmam que os artefatos de imagem, devem-se a presença da radiopacidade causada pelos componentes dos materiais endodônticos como cimentos e cone de guta-percha (TANOMARU-FILHO et al 2007; ÖZER, 2010; SCHULZE *et al.*, 2011; PATEL *et al.*, 2013; BECHARA, 2013; BRITO Jr. *Et al.*, 2014).

Na avaliação de fraturas radiculares em amostras de dentes tratados endodonticamente, Bechara et al (2013) comparou TCFC de grande volume, um de pequeno e um sistema de radiografia periapical digital que utiliza placa de fósforo. Afirmaram que TCFC de grande volume não aumentou a acurácia no diagnóstico de fraturas radiculares nos dentes tratados endodonticamente, em comparação com um sistema de radiografia periapicais digitais.

Com intuito de investigar a fratura vertical de raiz (FVR) Dutra *et al.*, (2017), simularam diferentes situações clínicas para avaliação através de imagens de tomografia computadorizada com feixe cônico (TCFC), analisando a influência de diferentes materiais intracanal e coroa. Fraturas foram induzidas mecanicamente em quatro situações clínicas reproduzidas em vitro: sem preenchimento –simulando dentes não tratados, guta-percha – cone 50 bem ajustado, pino de liga de ouro encaixado na câmara da raiz e coroa cerâmica metálica. Tomógrafo tridimensional TCFC Prexion foi utilizado para gerar as imagens. A ausência de material no canal radicular permite a detecção com precisão da FVR usando a TCFC. A presença de guta-percha gerou um artefato de endurecimento de feixe baixo que não impediu verificar a extensão da fratura. A presença de uma passagem de ouro intra-canal tornou a linha de fratura aparente menor do que realmente era nas imagens sagitais. Nas imagens axiais, uma fratura só foi detectada quando o terceiro apical estava envolvido. A presença de uma coroa de metal não gerou artefatos adicionais na superfície da raiz em comparação com a postagem de ouro intracanal por si só.

Sabe-se que em grande parte dos casos em que há suspeita da presença de fraturas, também há presença de material obturador, pinos ou núcleos metálicos.

Apesar da precisão na formação da imagem, algumas ocorrências podem dificultar sua interpretação, tal como os artefatos da técnica (COSTA et al 2011).

As associações de endodondia e radiologia americanas, American Association of Endodontists - Americam Academy of Oral and Maxilofacial Radiology (2015), declaram e aprovam sua posição em relação ao uso da TCCB, a fim de fornecer base científica e orientação no tratamento endodôntico: a TCFC deve ser usada somente quando a história clínica do paciente e o exame clínico demonstrar que os benefícios para o paciente superam os riscos potenciais, portanto, não deve ser usada rotineiramente para o diagnóstico endodôntico ou para fim de rastreio, na ausência de sinais clínicos e sintomas, e sim, quando a necessidade de imaginologia não podem ser atendidas por dose mais baixa nas radiografias bidimensionais (AAE and AAOMR, 2015).

2.2 Objetivo

2.2.1 Objetivo geral

O objetivo deste estudo será desenvolver sistemas de obturação de canais radiculares com propriedades bioativas e radiopacidade que não produza artefatos em exames de tomografia computadorizada.

2.2.2 Objetivos específicos

- Desenvolver cones obturadores flexiveis a base de dimetacrilatos de alto peso molecular contento componentes bioativos;
- Desenvolver cimento resinoso dual contento componentes bioativos;
- Avaliar a capacidade de selamento, alteração volumetrica, liberação de íons cálcio, ph e citotoxicidade de cones e cimentos experimentais;
- Avaliar a radiopacidade e geração de artefatos em tomografia computadorizada de cones obturadores com diferentes tipos e concentrações de radiopacificadores

2.3 Materiais e métodos

2.3.1 Formulação de blenda monomérica para e elaboração de cones

Será formulada uma blenda a partir de monômeros dimetacrilatos de alto peso molecular que, uma vez polimerizados, poderá ser obtido um polímero de alta flexibilidade, alta resistência tensil e com uma capacidade de ter uma expansão de até 1% do seu volume.

O sistema de iniciação preferido para a fabricação dos cones será fotoativação, utilizando um sistema binário convencional com um fotoiniciador tipo II mais uma amina terciária como coiniciador.

A blenda conterá partículas de radiopacificadores tais como fluoreto de yttérbio ou óxido bismuto em uma concentração tal que permita atingir como mínimo a radiopacidade de 3mm na escala de alumínio.

Finalmente, será acrescentada na composição da blenda uma concentração determinada de diversas fontes liberadoras de cálcio, tais como cloreto de cálcio, silicato de cálcio ou hidróxido de cálcio.

2.3.2 Fabricação dos cones

Serão utilizados moldes de silicone de adição para a fabricação de cones para obturação de condutos radiculares de um calibre no. 80.

A blenda previamente formulada será depositada dentro do molde e fotoativada durante 60s. Uma vez polimerizado, o cone será removido do molde e limpo com uma solução de álcool.

Os cones serão armazenados em ambiente seco e obscuro até sua utilização.

2.3.3 Formulação do cimento para selamento de canais radiculares

Será formulado um material resinoso de ativação dual em duas pastas contendo como base monômeros dimetacrilatos de alto peso molecular que, uma vez polimerizados, darão lugar à formação de um polímero com características flexíveis, alta resistência tensil e higroscópico.

Em relação ao sistema de ativação, uma das pastas irá a conter um sistema de fotoiniciação binário formado por um fotoiniciador tipo II mais uma amina terciária como coiniciador. Em quanto outra das pastas terá na sua composição um peróxido para promover a polimerização através de uma reação redox quando misturadas ambas pastas.

Semelhante à blenda utilizada para os cones, o cimento terá na sua composição um material radiopacificador para atingir uma radiopacidade de 3mm na escala de alumínio, assim como uma sustância liberadora de cálcio.

Finalmente, para ajuste de viscosidade, uma carga de tamanho nanométrica será acrescentada até atingir as características clínicas desejáveis.

2.3.4 Caracterização dos cones para preenchimento de canais radiculares.

A radiopacidade dos cones fabricados será avaliada conforme o descrito na norma ISO 6876 2001.

Para a expansão lateral dos cones será utilizado um microscópio binocular conforme a metodologia descrita em Didato, 2013. (Time-based lateral hygroscopic expansion of a water-expandable endodontic obturation point. Journal of Dentistry).

2.3.5 Caracterização do cimento para selamento dos canais radiculares.

Os cimentos formulados serão caracterizados quanto a escoamento, tempo de trabalho, tempo de pressa, espessura de película, alteração dimensional, solubilidade e radiopacidade segundo as metodologias contidas dentro da norma ISO 6876 2001.

A liberação de cálcio será avaliada utilizando um leitor de íons de bancada. A liberação de cálcio dos materiais será conferida às 3, 12, 24 e 72 horas após polimerização.

2.3.6 Liberação de cálcio (de discos do cimento e de discos feitos com o material do cone 6x1mm)

Em um recipiente com 40 mm de diâmetro e com 50 mililitros de água destilada e deionizada com pH previamente medido. Colocar as amostras no interior do recipiente, de tal maneira que o mesmo fique imerso na água. O recipiente é fechado cuidadosamente. O corpo de prova não deve entrar em contato com as paredes do recipiente. O conjunto é levado à uma estufa a 37 graus centígrados e, em 24horas, 48 horas, 7 dias, 14 dias e 30 dias deve ser removido 4ml a água para análise de liberação de cálcio

Para leitura e monitoração da liberação de cálcio será utilizado o espectrofotômetro de absorção atômica, equipado com uma lâmpada de catódo oco específica para cálcio

2.3.7 Avaliação do pH

Em um recipiente com 40 mm de diâmetro e com 50 mililitros de água destilada e deionizada com pH previamente medido. Colocar as amostras dos cimentos no interior do recipiente, de tal maneira que o mesmo fique imerso na água. O recipiente é fechado cuidadosamente. O corpo de prova não deve entrar em contato com as paredes do recipiente. O conjunto é levado à uma estufa a 37 graus centígrados e, após 3 horas faz-se a primeira medida do pH. As medidas subsequente serão tomadas com intervalo de 24 horas, durante uma semana. Deve-se fazer duas medições para cada cimento utilizado para obter uma média.

A leitura do pH será realizada com auxílio de um pHmetro. Observar a precisão do aparelho com medições constantes de tampões em pH 4,7,9.

2.3.8 Sorção e Solubilidade

Suspendem-se as amostras no recipiente, de modo que não haja contato com nenhuma superfície. Colocar 50 ± 1 ml de água destilada e deionizada e fechar o recipiente. Guarda-se o recipiente e seu conteúdo na estufa a 37 graus centígrados por uma semana e, então, removem-se as amostras, enxaguam-nas com um pouco de água destilada deionizada e removem-se o excesso de água com um filtro de papel. Colocar as amostras em um desidratador de pentóxido de fósforo ou outro desidratante apropriado por 24 horas. A seguir pesar as amostras, aproximando para os 0,001g mais próximos. A perda em massa de cada par de amostras deve ser expressa em porcentagem e este resultado deve ser anotado como sendo a solubilidade do cimento. Pode-se aproximar os resultados para o 0,1% mais próximo. Anotar peso inicial - peso final = diferença e porcentagem

2.3.9 Selamento radicular

Utilizar microtubos de polipropileno (tubos para centrífuga do tipo eppendorf) com capacidade de 1,5 mL. As pontas dos tubos seccionadas transversalmente com uma discoteca de carborundum, de tal forma que, ao inserir os espécimes, aproximadamente 3 milímetros da sua porção apical ficaram projetadas no tubo de plástico. Uma junção entre o remanescente radicular e o eppendorf selada com Araldite de presa rápida. Depois da montagem dos remanescentes radiculares, os sistemas identificados com o número correspondente a cada amostra e grupo. Em., Conjuntos (remanescente radicais e tubos de plástico), acondicionados em frascos de vidro de 15 ml transparentes, estéreis contendo um corte de papel alumínio (5 × 5 cm). Os frascos de vidro que contêm os conjuntos são tamponados com algodão e embalados individualmente para esterilização em gás de óxido de etileno a 56 ° C. Todas as etapas subsequentes à esterilização, realizadas em câmara de fluxo direto para evitar a contaminação das amostras. Para o teste de infiltração bacteriana, utilizar caldo de BHI (Brain Heart Infusion) (Acumedia, EUA) preparado segundo instruções do fabricante (proporção de 37 g de pó para 1000 mL de água destilada), autoclavado a 120 ° C durante 20 Minutos e mantido em geladeira por 24 horas. Depois deste período, 7 mL da solução BHI são dispensadas em cada um dos 34 frascos de vidro esterilizados. Os conjuntos (espécimes-tubos plásticos) montados no interior dos frascos de vidro de modo a porção apical dos espécimes fique imersa no caldo de BHI. Parte superior do dispositivo recoberta com papel alumínio estéril e parafilme. Os dispositivos são identificados numericamente e mantidos em estufa a 37 ° C, durante quatro dias, para confirmação da esterilidade do conjunto Cepas de *Enterococcus faecalis* utilizadas para avaliar a infiltração das obturações. Inicialmente faz-se a coloração e análise da morfologia da cepa para confirmação de sua pureza. O microrganismo é reativado em 4,0 mL de caldo BHI esterilizado e mantido em estufa a 37 ° C, durante 24 horas. *E. faecalis* é transferida para tubo contendo 100 ml de caldo BHI esterilizado e incubado em estufa a 37 ° C, durante 15 horas. Após este Período, o Número de *E. faecalis* presente e contado em leitura por espectrofotômetro. Análise é realizada pela contagem de unidades formadoras de Colónia por mililitro de microrganismos, padronizando o inóculo em 10UFC / mL

2.3.10 Inclusão e Exclusão

Com base no estudo de Lisboa, Silva Neto, Carneiro *et al.* (2017) e Dutra *et al.* (2017):

Dentes humanos unirradiculados in vitro (incisivos, caninos e pré molares uniradiculares), armazenados em solução de cloreto de sódio a 5% e trocada diariamente por 4 dias.

Serão selecionados por inspeção visual, dentes com ápice completo, raízes retas e únicas. Não serão incluídos dentes com mais de uma raiz ou canal, que apresentarem tratamento endodôntico prévio, trincas ou fraturas, cáries extensas, ápices abertos, reabsorções radiculares, dilaceração apical, bifurcações e/ou anomalias radiculares.

Para comprovar a presença de canal único, serão realizadas Tomografias Computadorizadas de Cone Bean –TCCB.

As coroas dentárias de todos os dentes removidas com disco diamantado, de modo que cada espécime fique padronizado com 16 mm de comprimento radicular a partir do ápice.

2.3.11 Instrumentação e Obturação dos Canais

Para a remoção do tecido pulpar e determinação do comprimento real do canal, serão utilizados instrumentos 15 K-Flexofile (Dentsply- Maillefer, Ballaigues, Suíça). O instrumento será introduzido no canal até que a ponta fique visível no forame apical. A partir desta medida, 1 mm será reduzido para se estabelecer o comprimento de trabalho. A patência apical será confirmada com a inserção de um instrumento 25 K-Flexofile através do forame apical antes e depois do preparo do canal radicular.

Cada canal radicular será instrumentado por meio da técnica coroa-ápice, utilizando instrumentos rotatórios de níquel-titânio ProTaper Universal (Dentsply Maillefer, Ballaigues, Suíça), finalizando com a lima F3, sendo que todos os instrumentos serão utilizados até o comprimento de trabalho. A cada troca de instrumento, os canais radiculares devem ser irrigados com 3 mL de hipoclorito de sódio 2,5% (NaOCL).

Depois da instrumentação, todos os canais radiculares serão lavados com 5 mL de NaOCL 2,5%. Em seguida, serão preenchidos com 3 mL de solução de EDTA 17% por 3 minutos para remoção da *smear layer*. A irrigação final será realizada com 5 mL de NaOCL 2,5% e os canais serão secos com cones de papel absorvente.

Em seguida, inicia-se o processo de obturação. Será utilizado o Sistema Bioativo de cone e cimento e como controle, guta percha e cimento AHPlus. O cone será introduzido ao mesmo tempo que o cimento no canal radicular. O Sistema Bioativo não necessita de compactação, pois o material auto expande pela absorção de H2O.

2.3.12 Análise da interferência dos materiais endodônticos na avaliação Tomográfica (TCCB):

Os mesmos dentes selecionados serão utilizados. O preparo e obturação dos canais será o mesmo. A diferença será na escolha de alguns destes dentes para sofrer indução de fratura sob força mecanizada na raiz. Os dentes são mergulhados em cera derretida para simular o ligamento periodontal. Uma mandíbula não humana, previamente à montagem dos dentes, será hidratada por imersão em água e envolta por cera com espessura de 15mm, para simular tecido mole da face. Após posicionam-se os dentes na mandíbula e o conjunto é levado para obtenção das imagens no aparelho TCCB (Instrumentarium OP 300®, Instrumentarium dental, Tuusula, Finlândia). O protocolo módulo Endo será utilizado para aquisição e avaliação avaliação (exposição, Voxel e Fov selecionados automaticamente pelo equipamento):

Grupo 1 - Controle: dentes fraturados com tratamento convencional com guta percha e cimento AH Plus

Grupo 2 – Dentes fraturados obturados com sistema bioativo

Grupos experimentais - cones com diferentes radiopacificadores em diferentes concentrações (0%, 5%, 10%, 20%, 30%)

- Radiopacificadores: Fluoreto de Ytérbio, Óxido de Bismuto, Tungstato de Cálcio

A imagens serão adquiridas em DICOM e avaliação da imagens ocorrerá no programa OnDemand 3D® que acompanha o equipamento. Para melhor visualização das reconstruções multiplanares, as imagens serão processadas utilizando um mesmo filtro de nitidez, brilho e contraste. Dois radiologistas e dois endodontistas com mais de cinco anos de experiência em TCFC selecionaram simultaneamente uma reconstrução coronal, uma sagital e três axiais para cada dente. A seleção das reconstruções coronal e sagital será determinada pela melhor representação de imagem encontrada. Para a seleção das reconstruções axiais, serão adotados os seguintes critérios de localização: a reconstrução axial cervical 1mm abaixo do limite amelocementário, enquanto que o axial apical, 3mm acima do ápice radicular e o axial médio corresponde a metade do comprimento da raíz. Essas reconstruções serão montadas no template do programa OnDemand 3d® e salvas em arquivos pdf (Portable Document Format).

Em outro momento, três radiologistas e endodontistas experientes realizarão individualmente as avaliações das imagens diretamente no programa OnDemand e em pdf em momentos distintos, avaliando os seguintes parâmetros: qualidade de imagem e sua classificação quanto ao auxílio diagnóstico dos tecidos radiculares, presença/ausência de artefatos, intensidade de artefatos por terços, presença sugestiva de outro tipo de alteração dentária radicular, e qual alteração dentária presente. A avaliação deve ser realizada em ambiente com pouca intensidade de luz, utilizando monitores específicos utilizado nos centros de radiologia e o programa Adobe Reader®. Aos examinadores, será permitido utilizar os recursos oferecidos pelo programa OnDemand3D. No intervalo de uma semana, as imagens serão reavaliadas pelos mesmos avaliadores sob as mesmas condições.

2.3.13 Análise dos Dados

Os dados serão analisados através frequências absolutas e percentuais através do software IBM SPSS Statistics 21, EUA. Para avaliar a diferença entre os grupos serão utilizados o teste Qui-quadrado de Pearson, o teste Exato de Fisher quando as condições para utilização do teste Qui-quadrado não foram verificadas ou o teste da Razão de Verossimilhança quando não foi possível a obtenção do teste Exato de Fisher. O nível de significância adotado será de 0.05 Para avaliação inter e intra-examinador será realizado o teste Kappa adotando 95% de confiabilidade e 5% de erro. Serão obtidos os coeficientes kappa médios para cada item. Para a obtenção dos testes estatísticos realizar-se-à a moda.

2.4 Orçamento

	Valor R$
Limas endodônticas rotatórias	500,00
Tomografia Computadorizadas Cone Bean	3.000,00
Estatística	1.000,00
Impressões e encadernações	500,00
Materiais escritório	200,00
Deslocamentos	1.000,00
Revisão português/inglês	500,00

2.5 Cronograma

	Revisão de Literatura	Qualificação	Aquisição/Preparo Material	Teste piloto	Fase Experimental	Organização de Resultados	Análise Estatística	Redação final	Defesa	Submissão publicação
Julho 2016	X									
Agosto 2016	X									
Setembro 2016	X									
Outubro 2016	X									
Novembro 2016	X									
Dezembro 2016	X									
Janeiro 2017	X									
Fevereiro 2017	X									
Março 2017	X									
Abril 2017	X									
Maio 2017	X									
Junho 2017	X									
Julho 2017	X									
Agosto 2017	X									
Setembro 2017	X									
Outubro 2017	X	X	X							
Novembro 2017	X		X	X						
Dezembro 2017	X				X					
Janeiro 2018	X					X				
Fevereiro 2018	X						X			
Março 2018	X							X		
Abril 2018	X							X		
Maio 2018	X							X		
Junho 2018									X	
Julho 2018										X

3 Relatório do trabalho de campo

Como pode-se perceber, no projeto qualificado o assunto difere completamente do trabalho da referida defesa. Isso se deve por problemas de saúde do antigo orientador e conforme decisão de Colegiado do Programa de Pós-Graduação, passei a ser orientada em julho de 2019 pela Profª. Drª. Adriana Fernandes da Silva.

Tentamos dar continuidade ao projeto, porém não obtivemos autorização e após conhecimento e readequação, em novembro de 2019 iníciamos um novo projeto de pesquisa clínica, a qual seria aplicada juntamente com alunos da graduação, sobre técnicas de restauração em classe II e avaliação em Tomografia Computadorizada de Feixe Cônico, sendo realizado a partir de fevereiro do corrente ano, após aprovação do comitê de ética e pesquisa. No entanto, não houve possibilidade da realização da etapa laboratorial desse estudo, em virtude da pandemia de COVID-19, da família dos coronavírus, que se estabeleceu no período, impossibilitanto o andamento da parte em questão.

Desta forma, em comum acordo, deu-se início durante o período de quarentena, a pesquisa em questão sobre Impressão 3D para Educação em Odontologia – uma Revisão de Escopo. Para a realização deste, houve um processo de calibração dos revisores do estudo quanto às buscas nas bases de dados competentes, bem como o protocolo da mesma, possibilitando que todas as etapas fossem realizadas de forma criteriosa.

4 Artigo

3D PRINTING FOR DENTAL EDUCATION - A SCOPING REVIEW[1]

[1]Artigo estruturado segundo as normas do periódico *Journal of Anatomy*

Abstract

The objective of this scope review was to evaluate the influence of 3D printing technology on the teaching-learning process in the dental area. For this, research was carried out in four (04) electronic databases: MedLine (PubMed), Web of Science, Scopus and Embase. Two reviewers independently evaluated the title and abstracts of potentially relevant studies, as well as their full reading, reaching a kappa agreement index of 0.84 in the first phase and 0.81 in the second phase. Only studies related to the use of 3D printing in the teaching of dentistry in the English language were included. A total of 22 studies met all criteria and were published between 2013 and 2020. The specialties that studied 3D printing directed to teaching were endodontics, dentistry and surgery. The preferences in teaching with 3D printing, regarding the form of image acquisition was the cone-beam computed tomography (CBCT). Regarding the most used technology reported was StereoLithoGraphy (SLA) and the material considered for printing is additive manufactured resin, being the most printed anatomical object for dental teaching were teeth. Two reviewers independently evaluated the title and abstracts of potentially relevant studies, as well as their full reading, reaching a kappa agreement index of 0.84 in the first phase and 0.81 in the second phase. Only studies related to the use of 3D printing in the teaching of dentistry in the English language were included. A total of 22 studies met all criteria and were published between 2013 and 2020. The specialties that studied 3D printing directed to teaching were endodontics, operative dentistry and surgery. The preferences in teaching with 3D printing, regarding the form of image acquisition was the cone-beam computed tomography (CBCT). Regarding the most used technology reported was StereoLithoGraphy (SLA) and the material considered for printing is additive manufactured resin, being the most printed anatomical object for dental teaching were teeth. The guided benefits of 3D printing are related to integration, applicability, variability, economy and realism when compared, aided or replaced by the traditional teaching approach. 3D printing offers educational autonomy by establishing and varying the educational objective using 3D printing technology, applying real patient situations as a basis. It is possible that 3D printing as a teaching method becomes a viable and enriching tool for the dental teaching-learning process.

Keywords: three-dimensional printing, dental education, teaching material, additive manopaths, dental model

1. Introduction

The development of 3D printing is a trend topic in health area due to the possibility of customized products with low cost and small scale (OBEROI *et al.*, 2018). Currently, in dentistry, the use of 3D printing allows accurately creating unique and complex geometric shapes in high resolution (DAWOOD *et al.*, 2015). The impact of 3D printing on dentistry is investigated in studies in periodontics with the use of surgical guides for correction of gingival smile, orthodontics for tooth movement and indirect bonding of appliances, implantology for planning and as a surgical guide (ANDERSON; WEALLEANS; RAY, 2018; NIKZAD; AZARI, 2008; Kumar, Kumar, GHAFOOR, 2016; D'HAESE *et al.*, 2012; Kumar, Kumar , GHAFOOR, 2016; KRÖGER; DEKIFF; DIRKSEN, 2017; WERZ *et al.*, 2018). In addition, the contribution of additive manufacturing in the teaching process as in pediatric dentistry has been studied. Besides, it has been used as a basis imaging of a patient for training (Marty *et al.*, (2019), as to offer operational skills in oral and maxillofacial surgery, or in customized models with lower cost and realistic alternative to traditional methods (Chae *et al.*, (2020). The validation of 3D prototype for supranumerary dental extraction was reported as training of the surgical technique, as well as individualization for comparison with traditional models (SEIFERT *et al.*, 2020; CHAE *et al.*, 2020).

Considering other aspects, teaching innovative strategies in dental pre-clinical are needed to motivate and benefit the students especially for understanding and memorization the anatomic structures involved in learning activity. This way, the technology has significant potential to supplement the conventional training approaches, where the association with 3D printing becomes viable and accessible to the teaching-learning process. Besides, the obtained the natural anatomical pieces as e.g. extracted teeth, which results in greater difficulty in getting mainly for ethical and health reasons. Thus, models of artificial teeth have been used as an alternative (ANDERSON; WEALLEANS; RAY, 2018). But the number of studies with 3D dental prototypes is increasing as a lower cost alternative, used to simulate pre-clinical exercises, comparing them with artificial and natural ones (ANDERSON; WEALLEANS; RAY, 2018; MARENDING *et al.*, 2016; ROBBERECHT *et al.*, 2017;

KFIR *et al.*, 2013).

For educational purposes in health sciences, virtual models are the differentiated didactic alternative for co-hosting techniques and approaches providing information that can be difficult to acquire when illustrated in traditional teaching (LARA *et al.*, 2020). During pre-clinical education innovative strategies are needed to motivate and assist students in understanding the structures involved in the specific technique, so technology has significant potential to complement traditional training approaches, where the association with 3D printing becomes viable and accessible in enriching the teaching-learning process (SOARES *et al.*, 2013). 3D education can help educators standardize the acquisition of skills among students (LUMPUR; KINGDOM, 2014). In a study on the innovative pedagogies of the future, it was reported the importance of reducing the distance between the aspirations of education and current educational practice, seeking interactive and engaging forms of learning with the use of active pedagogies, in an integrative way, also as a tool for evaluating and reflecting the pedagogical approach (HERODOTOU *et al.*, 2019).

This scoping review aimed at mapping of 3D printing technology on dental education. Thus, it was also analyzed the different types of 3D printing that have been used for dental education; the ways in which images were acquired; the 3D printing materials and objects used; as well as the types of printers and identify the advantages and limitations of 3D printing technology in dentistry.

2. Methods

This scoping review is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA Statement) guidelines (Moher David *et al.*, 2009). The protocol for this scope review was registered with the Open Science Framework – OSF.

2.1. Eletronic Searchs

The search in the electronic literature was carried out by two independent reviewers (MRM and NM), using four databases: MedLine (PubMed), Embase, Scopus, and Web of Science up to August 2020, no restriction of time and using only English language. The search strategy containing the terms are detailed in Table 1. The references of the included articles were also examined. After identifying the databases, the articles were imported into the Mendeley software reference manager

(Elsevier Inc., Mendeley Ltd. New York, NY), to remove duplicates. Afterwards, these articles were exported to the the systematic review web application Rayyan QCRI (OUZZANI *et al.*, 2016).

2.2. Selection Criteria of Study

The selection by title and abstract took place according to the following eligibility criteria independently by the reviewers: (1) studies using 3D printing to the teaching and learning process in dentistry were included, and (2) studies written in english language. Studies with materials and structures not applicable to the dentistry teaching, literature review articles, case reports (or series of case reports), manufacturer documents, abstracts, editorials, technical notes, comments, studies published in languages other than English and studies using only virtual 3D software were not included. Those who appeared to meet the inclusion criteria, or where insufficient data were provided in the title and abstract to make a clear decision, were selected for independent analysis of the full text. The agrement in the selection process by two reveiwers was evaluated using Kappa statistics. Disagreement over the eligibility of the studies was discussed among reviewers with two other experienced reviewers (AFS, WLOR) until consensus.

2.3. Data extraction and analysis

The data of the selected articles were tabulated using the software Microsoft Excel® (Microsoft, Redmond, CA). In case of lack of information or impossibility of acquiring the full-text article, the author was contacted by e-mail. When there was no return within 30 days, the work was not included in this review. The information collected were authors, year of publication, journal, country, form of materialacquisition for printing, 3D printed object, type technology for 3D printing, material used for printing and 3D printer used, main dental specialty application (Table 2). Other data such as number of participants, as well as their education levels, compared group, objective, conclusion, advantages and limitations of the studies were also analyzed (Table 3).

Due to the high degree of heterogeneity of the materials used for 3D printing in terms of different printers for a wide variety of applications.

Results

2.4. Search strategy

A total of 6,146 articles potentially relevant were collected from the four databases (Figure 2). Also, in the manual search 3 studies were identified. After the removal of the duplicates, a total of 2,511 articles were subject to title and abstract screening. After application of the eligibility criteria, 34 articles were included for full-text reading. A suitable agreement between the reviewers was obtained using *Kappa statistics (K=0.84* and *0.81)*. One of the 34 articles: one was excluded because the full-text could not be accessed, (GANESH, 2018) . Another article was excluded because it was in a language other than English (YANG; PENG; HUANG, 2019). Other studies were excluded because were clinical trials, case reports or series of case reports (F.D. *et al.*, 2018; G.D. *et al.*, 2016; Y. *et al.*, 2016). Four studies did not use 3D printing and were excluded (C. *et al.*, 2017; D. *et al.*, 2019; M.-C. *et al.*, 2019; S.O. *et al.*, 2019). Also, three studies were not related to the teaching of dentistry (CRESSWELL-BOYES *et al.*, 2018; KALBERER *et al.*, 2019; MOHMMED *et al.*, 2018) and two were literature reviews (FERRO; NICHOLSON; KOKA, 2019; SHAH; CHONG, 2018). Thus, after detailed analysis, 22 articles were included in the scoping review.

2.5. Descriptive analysis

The included articles were published between 2013 and 2020 (n=22), where the largest amount of study on 3D printing in dental education was published in the years 2019 (n=10) and 2020 (n=6) (Figure 3a). Most studies were conducted in Germany (n=10), followed by France (n=3) and Switzerland (n=2). Among the journals in which the articles are published, the largest number appears in the European Journal of Dental Education (n=8), followed by the International Endodontics Journal (n=4) and Journal of Dental Education (n=4). By differentiating dental specialties, studies appear in the aforementioned areas of Endodontics (n=7), Operative Dentistry (n=6) and Surgery (n=6). Among other specialties: dental morphology, Dental Morphology (n=1), Pediatric Dentistry (n=1) and one study evaluated the general knowledge of dental students in relation to 3D printing (Figure 3b).

Regarding the acquisition of images for subsequent 3D printing, the method of acquisition of computed tomography of the conic beam (CBCT) has the preference of the authors (n=8), followed by the use of scanner (n=5) or association of both methods (n=4), micro CT, computed tomography (CT) and *Digital Imaging and Communications in Medicine* (DICOM) images acquired by magnetic resonance imaging (MRI) and ultrasonography (US) were also used (Figure 3c). The type of technology for 3D printing used was variable, with SLA preference (n=9). FDM/FFF (n=3), Polyjet (n=3), DLP (n=2), SLS (n=1) were also used, and other articles did not report this infomation (n=7). One of the studies compared 4 different types of technology (Figure 3d). The 3D printing objects frequently mentioned in the studies were teeth (n=8), followed by the maxilla and mandible together (n=5), and teeth with adjacent structures (n=3). It was also mentioned maxilla and mandible alone, premaxilla region, fixed prosthesis, and root root. One study did not report the object printed (VENKATAGANAKARTHIK; GANAPATHY; VISALAKSHI, 2019) (Figure 4a).

Among the printing materials, 4 studies did not report the type of material used, 12 studies preferred resin, and the association of PLA and ABS was used in 2 studies. Nylon (n=1), liquid photopolymer (n=1), Rigid CMYKW and elastomer digital materials (n=1) and PLA (n=1) were also mentioned (Figure 4c). A total of 860 participants reported were involved in the studies, consisting mainly of undergraduate students (n=720), but also graduated (n=136) and teachers (n=4) (Figure 4b).

The 3D printer used had great variation with 12 different brands used, which can be analyzed individually in Table 2. Regarding the comparison of 3D printing, the studies compared with the traditional method using artificial and/or human (n=10), only to the industrialized artificial model (n=2), only to the human model (n=4), to the animal model (n=1) and six studies did not report this information. The selected studies compare 3D printing with standard teaching models in dentistry: human tooth or corpse, animal cadaver and artificial replica of industrial manufacturing. Details on studies related to objective, conclusion, advantages and limitations are found in Table 3.

3. Discussion

Technological advances provide teaching and learning methodologies to a technologically evolved student population thirsting for innovative resources (FERRO; NICHOLSON; KOKA, 2019).

Thus, 3D printing can play an important role in dental education with training in printed teeth for prosthetic preparations in a wide variety of applications in different specialties.

One of the areas that 3D printing can be used for dental education is operative dentistry for printing artificial teeth. This type of training tooth was also considered hygienic and easy to handle (KRÖGER; DEKIFF; DIRKSEN, 2017). A limitation reported by included studies were in relation to hardness between enamel and dentin (HÖHNE; SCHMITTER, 2019), and the uniform appearance between adjacent structures such as the gum (KRÖGER; DEKIFF; DIRKSEN, 2017).

In endodontics, the use of 3D printing, as well as in operative dentistry, takes place in the printing of teeth and some adjacent structures, with SLA and Polijet technology allowing the creation of diversified objects (HANAFI *et al.*, 2020). What differentiated in the specialties is the way of acquiring these teeth before printing. Mold acquisition can be obtained by conical beam computed tomography (CBCT), intraoral scanner or the association of both (BOONSIRIPHANT *et al.*, 2019; SOARES *et al.*, 2013). Due to the need for detailed molding of the channels, endodontics used CBCT, which offers image resolution with richness in detail (ROBBERECHT *et al.*, 2017; SHAH; CHONG, 2018). For dental root access surgeries, there is a need for improvements in relation to the gingival mask, which could not properly refer to the incision and real flap (HANISCH *et al.*, 2020). In the research carried out in comparison to artificial, printed and natural teeth, 3D printing was considered equivalent to artificial replica, but none of them had similar hardness to the human structures (REYMUS *et al.*, 2019). Other limitations reported were due to the low visibility of the pulp chamber, increasing the risk of errors during access and insertion of accessory cones by thermal compaction technique (HANAFI *et al.*, 2020). The use of manufactured resin was unanimous in the choice of this specialty due to its specificities (HANAFI *et al.*, 2020; HANISCH *et al.*, 2020; HÖHNE; SCHWARZBAUER; SCHMITTER, 2019; REYMUS *et al.*, 2018, 2019). There are new studies in endodontics testing the usefulness of ceramic simulators for root canal printing (ROBBERECHT *et al.*, 2017). Among the advantages for 3D printing in endodontis, it is reported the economic flow of work in the production of teeth for training, the approximate reality to the human tooth, hygiene, standardization of replicas (HÖHNE; SCHWARZBAUER; SCHMITTER, 2019), morphology, radiopacity and the possibility of measuring the channel with foraminal localization technology (BRANCO *et al.*, 2019).

For oral surgery, FDM technology was mainly used for dental education proposes (NICOT *et al.*, 2019; SEIFERT *et al.*, 2020). Another differentiated feature in the specialty were the printing materials chosen, such as acrylonitrile-butadiene-styrene (ABS), polylactic acid (PLA), resin or Nylon (CHAE *et al.*, 2020; NICOT *et al.*, 2019a; TUCE *et al.*, 2019; WERZ *et al.*, 2018). Besides, it was reported impressions of more complete structures as jaw, maxilla, maxillary sinus, soft tissue. This allowed the training for students prior to its clinical application (WERZ *et al.*, 2018). The advantages in oral surgery are in relation to realistic anatomy, lower cost when compared to the standard model, visualization of noble structures and ease transportation (NICOT *et al.*, 2019a; YAO *et al.*, 2019).

The insertion of new technologies in the classroom does not break with the typical pedagogical traditionalism of the teacher speaking or commenting to passive students, in addition to "students get tired easily after the effect of novelty" (CYSNEIROS, 1999), the role of the teacher and the act of teaching show another observable trend in the case of distance learning (e-laerning), competing for the reduction of the costs of educational activity and heating the market of technological insums. This technological incorporation in other spheres of social life, among them in teaching, came almost as a "requirement" for the formation of individuals adapted to this type of society (SOUSA; COIMBRA, 2020)

The implications in health sciences education by COVID-19 will be enormous in the training of students in specific fields by reducing learning, making it relevant to discuss elements favorable to professional education based on purposes, knowledge and innovation(QUISPE-JULI *et al.*, 2020), in view of the low cost of production and the advantage of rapid verification and development of prototypes to this end (ANDRADE *et al.*, 2020).

To the teacher, 3D impressions offered autonomy from the didactic point of view when establishing and varying the educational objective using 3D printing technology according to their educational objective, applying in situations of real patients or natural pieces. These alternative and integrative techniques become in dentistry increasingly accessible, viable, economical and enriching to the dental teaching-learning process.

Among the objectives mentioned are motivation, facilitation, projection, creation, feasibility, introduction, evaluation, comparison, knowledge and establishment of 3D printing technology as a potentially significant teaching form in dentistry. Thus, the benefits of integration, applicability, variability, economy and realism of these are exalted when compared, assisted or replaced by the standard and traditional teaching approach. In addition to improving skills, sharpening subjective perceptions, avoids ethical and practical issues involving teaching.

4. Conclusions

Based on the evidences founded, the use of 3D printing in dental education seems be a coadjvant method to improve the teaching-learning process in different dental area.

Declarations of interest

The authors have stated explicitly that there are no conflicts of interest in connection with this article

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APPENDIX

Tables

Table 1. Terms used in search strategy of (terms mesh and embase)

PubMed (*MedLine*)
#1 AND #2 AND #3
#1(“dental education”)OR (“Education, Dental”) OR (“Dentistry education”) OR (“Dental, Education”) OR (“dental health education”) OR (“Dental Health”) OR (“Health, Education”) OR (“Health Education, Dental”) OR (“Education, Health”) OR (teaching) OR (“Method, Teaching”) OR (“Methods, Teaching”) OR (“Teaching Method”) OR (“Material, Teaching”) OR (“Materials, Teaching”) OR (“Teaching Material”) OR (“Teaching Materials”) OR (learning) OR (“dental student”)OR (“Student, Dental”) OR (“dental students”)
#2(“3 D Printing”) OR (“3-D Printings”) OR (“3-D Printing”) OR (“3 Dimensional Printing”) OR (“3-Dimensional Printing”) OR (“Three-Dimensional Printings”) OR (“3D-printing”) OR (“Three Dimensional Printings”) OR (“three dimensional printing”) OR (“Printing, Three-Dimensional”) OR (“3D Printing”) OR (“3D Printings”) OR (“Printing, 3D”) OR (“Printings, 3D”) OR (“Printing, Three Dimensional”) OR (“3D-Printed Model”) OR (“Printing, 3-Dimensional”) OR (“Printings, 3-Dimensional”) OR (“Printing, 3-D”) OR (“3-D Virtual Model”) OR (“3-D virtual models”) OR (“3D virtual model”) OR (“3D virtual models”) OR (“Dental Models”) OR (“dental model”) OR (“Models, Dental”) OR (“Model, Dental”) OR (“imaging phantom”) OR (“Imaging Phantoms”) OR (“Phantom, Imaging”) OR (“Radiologic Phantoms”) OR (“Phantoms, Radiologic”) OR (“Phantom, Radiologic”) OR (“Radiologic Phantom”) OR (“Radiographic Phantoms”) OR (“Phantoms, Radiographic”) OR (“Phantom, Radiographic”) OR (“Radiographic Phantom”) OR (Stereolithographies) OR (stereolithography)
#3(Dentistry) OR (Tooth) OR (Teeth) OR (Odontology) OR (Dental)
Embase
#1 AND #2
#1'dental education' OR 'dental health education' OR teaching OR learning OR 'dental student' OR 'dental students' OR 'dentistry education' OR 'dental practice'
#2'3-d virtual model' OR '3-d virtual models' OR '3d virtual model' OR '3d virtual models' OR 'three dimensional printing' OR 'anatomic model' OR 'dental model' OR 'imaging phantom' OR 'models and phantoms' OR phantom OR '3d printer' OR 'dental 3d printer' OR 'stereolithography'

OR '3d printed replicas' OR 'imaging phantoms'

SCOPUS

#1 AND #2 AND #3

#1 ("dental education") OR ("Education, Dental") OR ("Dentistry education") OR ("Dental, Education") OR ("dental health education") OR ("Dental Health") OR ("Health, Education") OR ("Health Education, Dental") OR ("Education, Health") OR (teaching) OR ("Method Teaching") OR ("Methods, Teaching") OR ("Teaching Method") OR ("Material, Teaching") OR ("Materials, Teaching") OR ("Teaching Material") OR ("Teaching Materials") OR (learning) OR ("dental student") OR ("Student, Dental") OR ("dental students")

#2 ("3 D Printing") OR ("3-D Printings") OR ("3-D Printing") OR ("3 Dimensional Printing") OR ("3-Dimensional Printing") OR ("3D-printing") OR ("Three-Dimensional Printings") OR ("Three Dimensional Printings") OR ("three dimensional printing") OR ("Printing, Three-Dimensional") OR ("3D Printing") OR ("3D Printings") OR ("Printing, 3D") OR ("Printings, 3D") OR ("Printing, Three Dimensional") OR ("3D-Printed Model") OR ("Printing, 3-Dimensional") OR ("Printings, 3-Dimensional") OR ("Printing, 3-D") OR ("3-D Virtual Model") OR ("3-D virtual models") OR ("3D virtual model") OR ("3D virtual models") OR ("Dental Models") OR ("dental model") OR ("Models, Dental") OR ("Model, Dental") OR ("imaging phantom") OR ("Imaging Phantoms") OR ("Phantom, Imaging") OR ("Radiologic Phantoms") OR ("Phantoms, Radiologic") OR ("Phantom, Radiologic") OR ("Radiologic Phantom") OR ("Radiographic Phantoms") OR ("Phantoms, Radiographic") OR ("Phantom, Radiographic") OR ("Radiographic Phantom") OR (stereolithographies) OR (stereolithography)

#3 (dentistry) OR (tooth) OR (teeth) OR (odontology) OR (dental)

Web of Science – WOS

#1 AND #2

#1 **TS=((**“dental education”)OR (“Education, Dental”) OR (“Dentistry education”) OR (“Dental, Education”) OR (“dental health education”) OR (“Dental Health”) OR (“Health, Education”) OR (“Health Education, Dental”) OR (“Education, Health”) OR (teaching) OR (“Method, Teaching”) OR (“Methods, Teaching”) OR (“Teaching Method”) OR (“Material, Teaching”) OR (“Materials, Teaching”) OR (“Teaching Material”) OR (“Teaching Materials”) OR (learning) OR (“dental student”) OR (“Student, Dental”) OR (“dental students”)**)**

#2 **TS=((**“3 D Printing”) OR (“3-D Printings”) OR (“3-D Printing”) OR (“3 Dimensional Printing”) OR (“3-Dimensional Printing”) OR (“Three-Dimensional Printings”) OR (“3D-printing”) OR (“Three Dimensional Printings”) OR (“three dimensional printing”) OR (“Printing, Three-Dimensional”) OR (“3D Printing”) OR (“3D Printings”) OR (“Printing, 3D”) OR (“Printings, 3D”) OR (“3D-Printed Model”) OR (“Printing, Three Dimensional”) OR (“Printing, 3-Dimensional”) OR (“Printings, 3-Dimensional”) OR (“Printing, 3-D”) OR (“3-D Virtual Model”) OR (“3-D virtual models”) OR (“3D virtual model”) OR (“3D virtual models”) OR (“Dental Models”) OR (“dental model”) OR (“Models, Dental”) OR (“Model, Dental”) OR (“imaging phantom”) OR (“Imaging Phantoms”) OR (“Phantom, Imaging”) OR (“Radiologic Phantoms”) OR (“Phantoms, Radiologic”) OR (“Phantom, Radiologic”) OR (“Radiologic Phantom”) OR (“Radiographic Phantoms”) OR (“Phantoms, Radiographic”) OR (“Phantom, Radiographic”) OR (“Radiographic Phantom”) OR (Stereolithographies) OR (stereolithography))

Table 2. Characteristics of included studies

Author Year	Journal	Country	Acquisition		3D Printed Object	Tecnology Type	Printing Material	Printer
Operativ Dentistry								
HÖHNE; SCHWARZBAUER; SCHMITTER (2020)	European Journal of Dental Education	Germany	CBCT Orthophos XG 3D (Dentsply Sirona, York, Pennsylvania, USA)	InEos X5 scanner (Dentsply Sirona, York, Pennsylvania, USA) **standard dental study model** (KaVo, Biberach an der Riß, Germany) and a **prepared 5mm model tooth**	First permanent molar reconstruction of the tooth and the pulp geometry	SLA	Rigid photopolymer resin (RS-F2-RGWH-01, Formlabs Inc.)	Form2 3D printer (Formlabs Inc.)
HÖHNE; SCHWARZBAUER; SCHMITTER (2019)	Journal of Dental Education	Germany	CBCT Orthophos XG 3D (Dentsply Sirona, York, Pennsylvania, USA)	InEos X5 scanner (Dentsply Sirona, York, Pennsylvania, USA) **standard dental study model** (KaVo, Biberach an der Riß, Germany)	First permanent molar reconstruction of the tooth and the pulp geometry	SLA	Rigid photopolymer resin (RS-F2-RGWH-01) (RS-F2-PKG-CR) (RS-F2-GPWH-04) (RS-F2-GPGR-04) Formlabs Inc.)	Form2 3D printer (Formlabs Inc.)
HÖHNE; SCHMITTER (2019)	Journal of Dental Education	Germany	CBCT Orthophos XG 3D (Dentsply Sirona, York, Pennsylvania, USA)	InEos X5 scanner (Dentsply Sirona, York, Pennsylvania, USA) **standard dental study model** (KaVo, Biberach an der Riß, Germany)	First permanent molar reconstruction of the tooth and the pulp geometry	SLA	Rigid photopolymer resin (RS-F2-GPWH-04, Formlabs Inc.)	Form2 3D printer (Formlabs Inc.)
BOONSIRIPHANT *et al.*, (2019)	Journal of Prosthodontics	Iowa City, IA		3M True Definition Scanner 3M ESPE, St. Paul, MN)	fixed dental prosthesis dentoform tooth	SLA	photopolymer resin FLGPGR 02 (Formlabs Inc.)	Form2 3D printer (Formlabs Inc.)
KRÖGER; DEKIFF; DIRKSEN (2017)	European Journal of Dental Education	Germany	3D scanner (Lava C.O.S., 3M Deutschland GmbH, Seefeld, Germany) OR (Atos II, GOM, Braunschweig, Germany)		teeth and the adjacent gingiva	PolyJet	liquid photopolymer (MED690, Stratasys, Rehovot, Israel)	Objet Eden 260V Stratasys, Rehovot, Israel

SOARES *et al.*, (2013)	Journal of Dental Education	Brazil	Sontact scanner (MDX-40, Roland, Renato Archer Research Center, Campinas, SP, Brazil)	natural tooth (premolar)	SLS	nylon and with raw gypsum powder color material.	ZPrinter 310 equipment (DTM Corp., Austin, TX)
Author Year	**Journal**	**Country**	**Acquisition**	**3D Printed Object**	**Tecnology Type**	**Printing Material**	**Printer**
			Endodontics				
HANAFI *et al.*, (2020)	International Endodontic Journal	Germany	CBCT	Natural teeth 20 incisor 26 premolar 22 molar	SLA	Resin (Somerville, Massachusetts, USA)	Formlabs Form 2 ™ (Somerville, Massachusetts, USA)
HANISCH *et al.*, (2020)	Int J Environ Res Saúde Pública	Germany	CBCT		Polyjet	white photopolymer resin (MED690, Stratasys, Rehovot, Israel)	Objet Eden 260V (Stratasys, Rehovot, Israel)
REYMUS *et al.*, (2020)	International Endodontic Journal	Germany	A molar was digitally designed according to the workflow recently presented (Reymus *et al.* 2019)	Molar	DLP/Polyjet /NR/NR 3D-printed resin for educational use 3D-printed resin for dental models 3D-printed resin for crowns and bridges 3D-printed resin for prototypes	Resin **Print ee** [VOC] (VOCO, Cuxhaven, Germany) **NextDent Model** [NDM] (NextDent, Soesterberg, Netherlands) **Vero White Plus** [VWP] (Sculpteo, Villejuif, France)	**Solflex 350** (VOCO, Cuxhaven, Germany) **D20II** (Rapidshape, Heimsheim, German) **Objet 30 Prime** (Stratasys, Rechovot, Israel)
(REYMUS *et al.*, 2019a)	International Endodontic Journal	Germany	CBCT Kodak 950, 10 9 595 cm, 90 kV, 3.2 mA, 8 s, 311 mGy cm 2)	First maxillary premolar	SLA	Resin resin of the manufacturer (Grey Resin, Formlabs) mixed with barium sulphate powder for achieving adequate radio opacity	Print 2, Formlab (Form 2 in Open Modus; Gingiva Mask, Nextdent, Soesterberg, Netherlands)
HÖHNE; SCHWARZBAUER; SCHMITTER (2019)	European Journal of Dental Education	Germany	Micro-CT (tooth) (Frauenhofer IIS, Erlangen, Germany Scanner (mannequin) InEos X5	Lower left first molar	SLA	Resin (RS - F2 - GPWH - 04, Formlabs Inc)	3D Form2 (Formlabs Inc)
REYMUS *et al.*, (2018)	International Endodontic Journal	Germany	CBCT	Pré Maxilla	SLA	Resin of the manufacturer	(Form 2, Formlabs)

Author Year	Journal	Country	Acquisition	3D Printed Object	Tecnology Type	Printing Material	Printer
			(Kodak 9300, 5x5x5 cm, 78 kV, 6,3 mA, 20s, Kodak, Rochester, Nova York, EUA)			(Grey V3 FLGPGR03, Formlabs) In order to achieve radiopacity 10g of barium	(Formlabs Inc.)
ROBBERECHT *et al.*, (2017)	European Journal of Dental Education	France	Micro-CT (SkyScan 1172; Bruker, Kontich, Bélgica)	Root canal	SLA	Ceramic simulators (CS)	CryoCeram (CryoBeryl Software, Valenciennes, França
Author Year	**Journal**	**Country**	**Acquisition**	**3D Printed Object**	**Tecnology Type**	**Printing Material**	**Printer**
			Surgery				
SEIFERT *et al.*, (2020)	Eur J Dent Educ	Switzerland	TC Tomografia Computadorizada	mandibles	FDM / FFF	polylactic acid (PLA) (Esun Industrial Co., Ltd.)	MakerBot Replicator (MakerBot Industries)
CHAE *et al.*, (2020)	Journal of Dental Education	Seoul Korea	Scanner (T500, Medit, Seul, Coréia)	maxilary and mandibular extraction of supernumerary teeth (SNT	NR	Resin material (DIOnavi-SG, Dio Co., Busan,Coreia)	3D printer DIO PROBO Light-cured (DIOnavi-Model, Dio Co., Busan, Coréia)
YAO *et al.*, (2019)	Eur J Dent Educ	China	CBCT	Impaccted third molar adjacent tooth, bone, nerve and soft tissue, mock-up seated on the model retainer	NR	Rigid CMYKW and elastomer digital materials NR	NR AMMA Additive Manufacturing for Medical Applications Ltd, Hong Kong
NICOT *et al.*, (2019)	Dental Traumatology	France	DICOM TC RM UsS	zygomatic fracture + bifocal mandibular fracture	FDM	ABS/PLA craniofacial trauma using acrylonitrile-butadiene-styrene (ABS) or polylactic acid (PLA) as raw material	UPplus2 ® (Beijing TierTime Technology Co.Ltd.)
TUCE *et al.*, (2019)	J. 3D Print. Med	USA	CBCT Pax-i3d CBCT (Vatech, Gyeonggido, Coréia). Scanner	Maxillary maxillary sinus lift procedure	NR	Dental Resin NextDent SG (NextDent BV, Utrecht, Holanda)	3D Wanhao D7 (Wanhao 3D Printer, Jinhua, China)

Author Year	Journal	Country	Acquisition	3D Printed Object	Tecnology Type	Printing Material	Printer
WERZ *et al.*, (2018)	Eur J Dent Educ	Switzerland	CBCT NR	maxilary and mandibular maxillary models for sinus lift training mandibular models extraction of third molars	NR	polylactic acid filament and acrylonitrile butadiene styrene (PLA, MakerBot Industries) and (ABS, MakerBot industries).	MakerBot Replicator 5th Generation 3D Printer (MakerBot Industries, New York, USA)
Others							
MARTY *et al.*, (2019)	European Journal Of Dental Education	Toulouse France	CBCT NR	Teeth 85	DLP	Resin (Voco® V-print Cuxhaven, Germany)	Voco® Solflex 350 3D® (Voco® V-print Cuxhaven, Germany)
VENKATAGANAKAR THIK; GANAPATHY; VISALAKSHI (2019)	Drug Invention Today	India	NR	NR	NR	NR	NR
CANTÍN; MUÑOZ; OLATE, (2015)	Int. J. Morphol.	Chile	Scanner Scanner 3D NextEngine ™ HD (NextEngine, Inc., CA, EUA)e ScanStudio HD Pro®, usando o MultiDrivehardware	dental arch sup / inf complete	FDM - FFF	NR	MBot Grid II 3D Not Report

Cone Beam Computed Tomography (CBCT); StereoLithoGraphy (SLA); Selective Laser Sintering (SLS); Direct Light Processing (DLP); Fused Deposition Modeling (FDM/FFF); Not Report (NR); Computed Tomography (TC); Magnetic Resonance (RM); Ultrasound (US)

Table 3. Relevant study information

Author	Participants	Compared Group		Restaurativ Dentistry
HÖHNE; SCHWARZBAUER; SCHMITTER (2020)	38 students fourth-year dental	standard model and natural	**Objective**	The purpose of this study was the design, feasibility and evaluation of a 3D printed tooth model with internal preparation for dental education in crown preparation and to analyze the quality of the prepared printed teeth in comparison to prepared standard model teeth.
			Conclusion	The feasibility of this teaching concept was confirmed students rated the printed tooth model as significantly better than the standard tooth model
			Advantages	The main advantage of this affordable printer is its great diversity, with up to 18 different materials. The materials are easy to use and, unlike other printers, have interesting features.
			Limitations	NR
HÖHNE; SCHWARZBAUER; SCHMITTER (2019)	38 students fourth-year dental 30 experienced dentists	standard model and natural	**Objective**	The purpose of this study was the design and establish a 3D printed tooth with different layers for enamel and dentin for education in crown preparation.
			Conclusion	The 3D printed artificial tooth with different layers for simulation of enamel and dentin had benefits for education compared to a standard model with an artificial tooth in the training of full coverage crown preparation
			Advantages	• 3D printed teeth with different material properties for enamel and dentin were useful in learning a correct crown preparation by the students and experts. • Their interest to control their tooth preparation using a tooth model containing a prepared tooth for the illustration of an ideal preparation and direct control abilities
			Limitations	• The distinctive discrimination in hardness between the enamel and dentin layer was criticized as well in the free text questions as in the questionnaire by the students and experts. The difference should be stronger in their opinion. This problem can be solved by a new material combination for the enamel and dentin layer in the next generation of the printed tooth • Conducted at a single dental school, its results may not be generalizable to students in other programs
HÖHNE; SCHMITTER (2019)	47 students fourth-year dental for preclinical education	standardized model using an artificial tooth and a real tooth	**Objective**	The purpose of this study was the design and create 3D printed teeth with anatomical details for use in preclinical dental education
			Conclusion	Overall, the printed tooth had many features to help train students. The questionnaire confirmed the students' perceptions of the value of such a tooth for use in dental education
			Advantages	The 3D printed tooth had benefits for education in contrast to a standard model tooth in the training of a complete prosthodontic situation with caries excavation, pulp capping, core build-up, and crown preparation
			Limitations	• Desire for a harder material for the printed tooth. • Distinctive discrimination between enamel and dentin would be helpful
BOONSIRIPHANT *et al.*, (2019)	NR	NR	**Objective**	Help with visual recognition, and to motivate and facilitate dental student learning in pre clinical simulation clinic exercises.
			Conclusion	NR
			Advantages	assist in learning and teaching, but also reduce time for faculty course preparation, as they can be printed within hours and reduce costs compared to conventional stone study models that need to be impressed and poured , and can use them to compare their tooth preparations

			Limitations	NR
KRÖGER; DEKIFF; DIRKSEN (2017)	22 Students fourth-year dental	NR	**Objective**	Contribution is to introduce our workflow to create 3D printed simulation models based on real patient situations for hands-on practice. The models intend to provide an additional learning effect by allowing the simulation of more realistic tooth positions and a wider variability of dental cases and procedures
			Conclusion	The models shall give students at the pre-clinical stage of their education the opportunity to prepare themselves better for their daily routine on patients in clinical courses and for their future profession. Because the approach allows integrating a large variety of exercises from different dental disciplines, we believe that its application area is huge.
			Advantages	• The 3D printed simulation models can be used just like common typodonts in training and examinations. As the models are based on real patient situations, they could also be used in combination with additional material (photographs, X-rays, anamnesis questionnaire, medical findings/history). • This would further increase the realism of the simulated treatment at the phantom. • Printed teeth are more hygienic and have a better handling
			Limitations	• The uniform look and feel of the simulated teeth and gingiva. • Display no interdental spaces. • The simulated caries was hard to discover visually. • Missing of the gingiva mask that they are used to from the familiar models • Is that they are reproducible
SOARES *et al.*, (2013)	41 students first-year class of 2010 at the Dental School 4 teatchers second year	evaluating the new didactic material compared to conventional one.	**Objective**	Introduce rapid prototyping technologies and the generation of virtual models in dental education
			Conclusion	This technology has significant potential to complement traditional training approaches. The association of RP models with 3D virtual models is a viable and accessible technique that helps and enriches the teaching-learning process
			Advantages	• Improvement of teaching quality when combining 3D virtual technology with the generation of real models for theoretical and laboratory dental rehabilitation • Students can grasp concepts of different types of cavity preparations more easily with discriminative learning devices in their hands
			Limitations	NR
Author	**Participants**	**Compared Group**	**Endodontics**	
HANAFI *et al.*, (2020)	68 students third year	previously used benchtop models mainly based on self-assessment	**Objective**	To evaluate a modular 3D print training dental model with embedded human teeth and electronic working length determination for undergraduate endodontic education.
			Conclusion	The modular 3D print models created in this study allowed a variation in individual teaching scenarios according to the skills and competence levels demanded by the instructors. The exchangeable, reusable and affordable sextants allow the use of any tooth in the dentition. Students judged the new model positively and felt much better prepared for clinical endodontic practice, especially with regard to the working length determination
			Advantages	• The level of difficulty that can be created with the model can be individually adapted to the needs and skills – this may be interesting for postgraduate education. • The vast majority of students positively evaluated the modular training model in 3D printing,

				despite being more demanding. • They also recommended its use in pre-clinical education and training. The model allowed for a more realistic simulation of the clinical situation and led to reduced stress levels in endodontic treatment in subsequent clinical courses.
			Limitations	• The most common problems listed by students were: low visibility, dark pulp chamber and increased risk of procedural errors - especially when calcifications were present During the filling of the root canal, most students had problems inserting accessory cones using the technique cold side compaction
HANISCH *et al.*, (2020)	35 participants for the typodont model 33 students for the 3D-printed model Students of dentistry in their 9th semestre	Industrially manufactured training model (Frasaco®, Tettnang, Germany)	**Objective**	Use 3D printing technology to manufacture individualized surgical training models for root tip resection (apicoectomy) on the basis of real patient data and to compare their suitability for dental education against a commercial typodont model
			Conclusion	Individual 3D-printed surgical training models based on real patient data offer a realistic alternative to industrially manufactured typodont models.
			Advantages	The3D printed models can be redesigned on a regular basis and easily adapted to specific learning goals. Training models for exercising other oral surgical procedures, e.g.,wisdom tooth removal or dental implant surgery, can also be made using the presented techniques
			Limitations	There is still room for improvement with respect to the gingiva mask for learning surgical incision and flap formation.
REYMUS *et al.*, (2020)	10 Dentists of several years of clinical experience They are all involved in the university to teach endodontics to undergraduate students	comparison with commercially available replicas and human teeth	**Objective**	To assess the suitability of several 3D-printed resins for the manufacturing of tooth replicas for endodontic training in comparison with commercially available replicas by analysing the properties of the materials and comparing them with real teeth during endodontic training
			Conclusion	No material was able to simulate human dentine from all perspectives tested. Only VOC had comparable radiopacity to that of dentine. The hardness of all tested tooth replicas was lower than that of human dentine. Nevertheless, 3D-printed tooth replicas seem to be equivalent to commercially available tooth replicas in terms of specifications of the materials and their evaluation during training.
			Advantages	NR
			Limitations	NR
REYMUS *et al.*, (2019)	105 Students in the third	human teeth and the printed teeth	**Objective**	To assess the feasibility of producing artificial teeth for endodontic training using 3D printing technology, to analyse the accuracy of the printing process, and to evaluate the teeth by students when used during training

	and fourth year	were scanned and compared with the original	**Conclusion**	The presented workflow will enable dental educational institutions to manufacture their own tooth replicas for endodontic training. For this purpose, teeth with certain desired anatomic characteristics can be selected to reduce redundancy in endodontic education. The accuracy of the printer is suitable for the production of realistic replicas. Students appreciate the short-term availability of the replicas and their standardization which results in better comparability and thus leads to greater fairness in the training simulation
			Advantages	• Its great advantage is not only justified by the possibility of exercising direct influence on the design and manufacturing process but also in the immediate availability of the product. For dental schools, 3D printing offers unexpected possibilities for the development of new, individual training models that are either not yet available on the market or are too expensive to purchase in high quantities. • Moreover, there is a wide selection of different printers and manufacturers to choose from.
			Limitations	• Such as lateral root canals, small isthmuses or very narrow root canals, cannot yet be reproduced with a 3D printer such as the one used in this study. For such special training measures, commercial replicas are still the first choice. • Conventional resin for 3D printing is not able to reproduce the physical properties of a biological material such as dentine.
HÖHNE; SCHWARZBAUER; SCHMITTER (2019)	48 students 4th year	Comparison to a real tooth	**Objective**	To design, establish and test the feasibility of a 3D printed tooth used for a dentin post preparation. The benefits for education were evaluated by a questionnaire
			Conclusion	The feasibility of this teaching model for dentin post preparation was confirmed. The workflow was cost-effective for the production of the teeth with the usage of 3D printing technology. The printed tooth enabled the students to get experience in dentin post preparation on a printed tooth model before patient treatment. The results of the questionnaire showed the great interest of the students in the printed tooth model, and the model was rated as good to very good. This finding was also supported by the significant improvement between the preparations attempts.
			Advantages	• Lower cost and standardized production in large numbers • Very good and realistic training situation • Availability and hygienic aspects Students were able to check drilling and control the axis orientation.
			Limitations	• The hardness of the material was criticized • Requesting more models with different anatomy of the channels Best fit on the mode
REYMUS *et al.*, (2018)	32 undergraduate students final year	NR	**Objective**	To assess the feasibility of creating a realistic model for hands-on training in dental traumatology using 3D printing technology, and then to investigate the added value of working with the website dentaltraumaguide.org.
			Conclusion	3D printing technology offers new possibilities for training specific dental treatments that are currently difficult to imitate.

Author	Participants	Compared Group		
			Advantages	• Practical training using a realistic model is capable of expanding the expertise for treating traumatic dental injuries much more than with a theoretical lecture. • This model could be used to reach a broader audience, for example, general dentists; they could increase their knowledge of traumatic injuries to the teeth with handson training and gain additional experience in this specific field
			Limitations	NR
ROBBERECHT *et al.*, (2017)	NR	tooth natural and artificial commercial resin blocks	**Objective**	The aim of this study was to develop a reproducible biomimetic root canal model for pre-clinical and postgraduate endodontic training.
			Conclusion	This novel anatomic root canal simulator is well suited for training undergraduate and postgraduate students in endodontic procedures
			Advantages	• It is thus well suited for practising endodontic procedures, can be mounted on phantom heads and can be used to determine the working length with an apex locator. • It is also suitable for training students and conducting research on new endodontic technologies is possible to reproduce the radio-opacity of a tooth and variations in root canal morphology. • The endodontic treatments confirmed that the CS provided good tactile sensation during instrumentation and displayed suitable radiological behaviour
			Limitations	Whilst the absence of the crown shape is a drawback for daily use in pre-clinical education, future research will concentrate on resolving this limitation
Author	**Participants**	**Compared Group**	**Surgery**	
SEIFERT *et al.*, (2020)	38 Students fourth-year dental	compare pig	**Objective**	This study provides an exemplary description of the fabrication of 3D-printed individualised patient models and assesses their educational value compared to cadaveric models in oral and maxillofacial surgery
			Conclusion	3D-printed patient individualised models presented a realistic alternative to cadaveric models in the undergraduate training of operational skills in oral and maxillofacial surgery. Whilst the 3D-printed individualised patient models received positive feedback from students, some aspects of the model leave room for improvement.
			Advantages	particularly praised the realistic human anatomy and the possibility of assembling individualized 3D printed patient models on a phantom head to obtain a more realistic simulation of intraoral operations at a lower cost than a pig's head
			Limitations	A less fragile silicone gingiva and a better differentiation between the color of teeth and bones were the most desired suggested improvements for individualized 3D patient models, cadaveric model was rated significantly more realistic in terms of soft tissue simulation and obtained better scores in tasks in which soft tissue manipulation
CHAE *et al.*, (2020)	30 participants (11 experienced and inexperienced	NR	**Objective**	Validate a printed three-dimensional (3D) model for Introduction: This study aimed to validate a printed three-dimensional (3D) model for provide training for extraction of supernumerary teeth (SNTs)
			Conclusion	A 3D printed model for surgical extraction of the SNT can improve surgical skill and, especially, shortening the learning curve for beginners. With this model, pediatric dentists with little experience in SNT surgery or dental students can improve their surgical skill, avoiding ethical and

	19)			practical issues.
			Advantages	Educational training with a 3D simulation model for SNT extraction can be highlighted in pre-clinical contexts to educate students who have no experience in SNT extraction.
			Limitations	Above all, as this was an in vitro, clinically unavoidable problems, such as lip retraction and mouth opening and behavior management, were not considered in the present study. Since we used an identical model with the same position in the two surgical sequences, the educational effect would not be accurately assessed, and the knowledge acquired about the location of the SNT during training can affect the results
YAO *et al.*, (2019)	21 dentists just graduated, without	NR	**Objective**	Recent graduates in dentistry, using a new assessment instrument based on radiographic data from the CFFC A secondary objective was to investigate whether a short simulation practice on 3D printed models can improve the spatial representation capacity related to the surgical anatomy of third molars
			Conclusion	An instrument for measuring DASRA based on 3D radiographic images can assist educators in assessing the spatial skills of beginning surgeons. Practice on 3D printed anatomically accurate models can benefit dentists in pre-clinical surgical training and has the potential to improve their ability to spatially represent dental anatomy
			Advantages	• For teaching, it is really realistic. Students can receive data from the CBCT and 3D model to visualize the vital structure • For practice, it helps to predict obstacles, such as blocking; crown removal path 48 after section. We can test different tooth cutting approaches, as the separation of various structures is realistic
			Limitations	• A major limitation for the development of DASRA was the absence of an established instrument. The color of the teeth is less realistic, and the model has no difference in contours between root and crown. It is difficult to section the crown, because the tooth texture is a little softer than the real one. The sensation of "falling" when cutting the pulp crown is not clear. The drill sensation cutting through tooth or bone is not like the real case, as I feel the drill trembling • The bones are very soft and there is no bone flexibility; The sensation / manipulation is not realistic for bone removal it is very easy to leave during elevation The soft tissue is easy to tear The model has no simulation of opening the mouth and difficulty in accessing / angulating the instrument, etc.
NICOT *et al.*, (2019)	NR	Cadáver human	**Objective**	A low-cost 3D printed model has been introduced into the oral and maxillofacial surgery teaching program of undergraduate students to improve education and mechanical comprehension of craniofacial trauma
			Conclusion	The use of 3D printed models is an efficient method for medical and dental education, bridging the gap between theory and practice. possible to produce models of practices at low cost. To date, FDM is the most widely used and affordable 3D printing technology available
			Advantages	• Finally, it is not necessary to be in an anatomy laboratory unlike a cadaver course and teaching can be performed in a classroom or in a clinical department • Once printed, all models can then be easily transported since a complete set weighs less than 100 g.
			Limitations	NR

TUCE *et al.*, (2019)	NR	artificial comercial model	**Objective**	To develop 3D printing and dentistry methods for building physical models that enable one to simulate a sinus lift surgery
			Conclusion	The 3D-printed models and surgical guides are useful training materials. They could be help ful also in a dental practice for surgical planning and for illustrating the procedure to the patient
			Advantages	NR
			Limitations	N R
WERZ *et al.*, (2018)	10 experienced cranial maxillofacial surgeon	Traditional educational model	**Objective**	The aim of this study was to evaluate whether inexpensive 3D models can be suitable to train surgical skills to dental students or oral and maxillofacial surgery residents. Furthermore, we wanted to know which of the most common filament materials, acrylonitrile butadiene styrene (ABS) or polylactic acid (PLA), can better simulate human bone according to surgeons' subjective perceptions
			Conclusion	3D printing with inexpensive FDM 3D printers is a promising method to create training models for oral and maxillofacial surgery residents as well as dental students for selected surgical procedures
			Advantages	• Simple and cost- efficient manufacturing process • Individual models of real patient cases can be produced in a small scale, on which many kinds of surgical procedures can be simulated • Methodology is suitable for basic and advanced surgical education • PLA is the better choice for most of the simulation models because it is biodegradable, non-toxic and most similar to bone at low temperature while drilling • ABS is easier to process, because it is more resistant to melting and easier to cut, the better choice for training models that require extensive drilling when a non- cooled rotary instrument is desired.
			Limitations	• Suggested improvements for the soft tissue simulation such as increasing the thickness and tear resistance of the silicone layer • PLA does require continuous cooling to prevent melting.
Author	**Public**	**Compared Group**		**Others**
MARTY *et al.*, (2019)	34 Students 5th year	reference model	**Objective**	Develop and evaluate a 3D printed model for training in pediatric dentistry and compare it with the reference model used in our body teacher.
			Conclusion	Finally, by offering the teacher the possibility of modifying the model according to his educational objective, these 3D models offer great freedom from a didactic point of view while giving the patient a more central place in the education of future practitioners.is one of the main benefits of manufacturing 3D printed models. based on radiological examinations of real patients
			Advantages	• Students consider 3D models to provide a more realistic experience • Possible that this contribution of realism is one of the main benefits of manufacturing 3D printed models • Based on radiological examinations of real patients

			Limitations	The lack of simulation of contacts proximal was a significant deficit in the current 3D printed technique possible ways of improving these models, for example, by changing the quality of resins to improve the milling sensation or the design to obtain a better proximal area
CANTÍN; MUÑOZ; OLATE, (2015)	34 students	tooth natural	**Objective**	Present educational material that would allow dentistry students to learn easily identify the morphological characteristics of permanent teeth
			Conclusion	It is important to continue looking for alternative and integrative teaching techniques that allow the development of basic and professional sciences. Virtual and printed teeth are intended to be a valuable learning tool that can be used in addition to or instead of extracted teeth and are expected to represent an improvement over plastic teeth. The association of RP models with virtual 3D models is a viable and accessible technique that helps and enriches the teaching-learning process
			Advantages	• Ability to create complex geometric precision and good surface finish. • It is easy to create teaching blocks with a variety of cavity types and numbers, sizes and positions. • Used in pre-clinical dental education to develop the student's visual recognition skills and fine hand-eye coordination.
			Limitations	A disadvantage to viewing the data acquired and processed for 3D reconstruction is that 3D software and suitable hardware are required. However, with 3D printing, all these complications disappear and the generation of 3D models can be applied in any institution, without the need to set up a computer lab or have digital equipment for all students to use.
(VENKATAGANAKARTHIK; GANAPATHY; VISALAKSHI, 2019)	112 students	NR	**Objective**	This study aims to assess the knowledge about stereolithography (SLA) and its applications among dental students
			Conclusion	In this study, among dental students, the results were quite evident that 76% were not aware of stereolithography and its uses. Considering all the advantages of it, it should be used more frequently
			Advantages	NR
			Limitations	NR

Not Report (NR); Supernumerary Teeth (SNT); Acrylonitrile Butadiene Styrene (ABS); Polylactic Acid (PLA); Cone Beam Computed Tomography (CBCT); StereoLithoGraphy (SLA); Selective Laser Sintering (SLS); Direct Light Processing (DLP); Fused Deposition Modeling (FDM/FFF); Rapid Prototyping (RP); Dental Anatomy Spatial Representation Ability (DASRA)

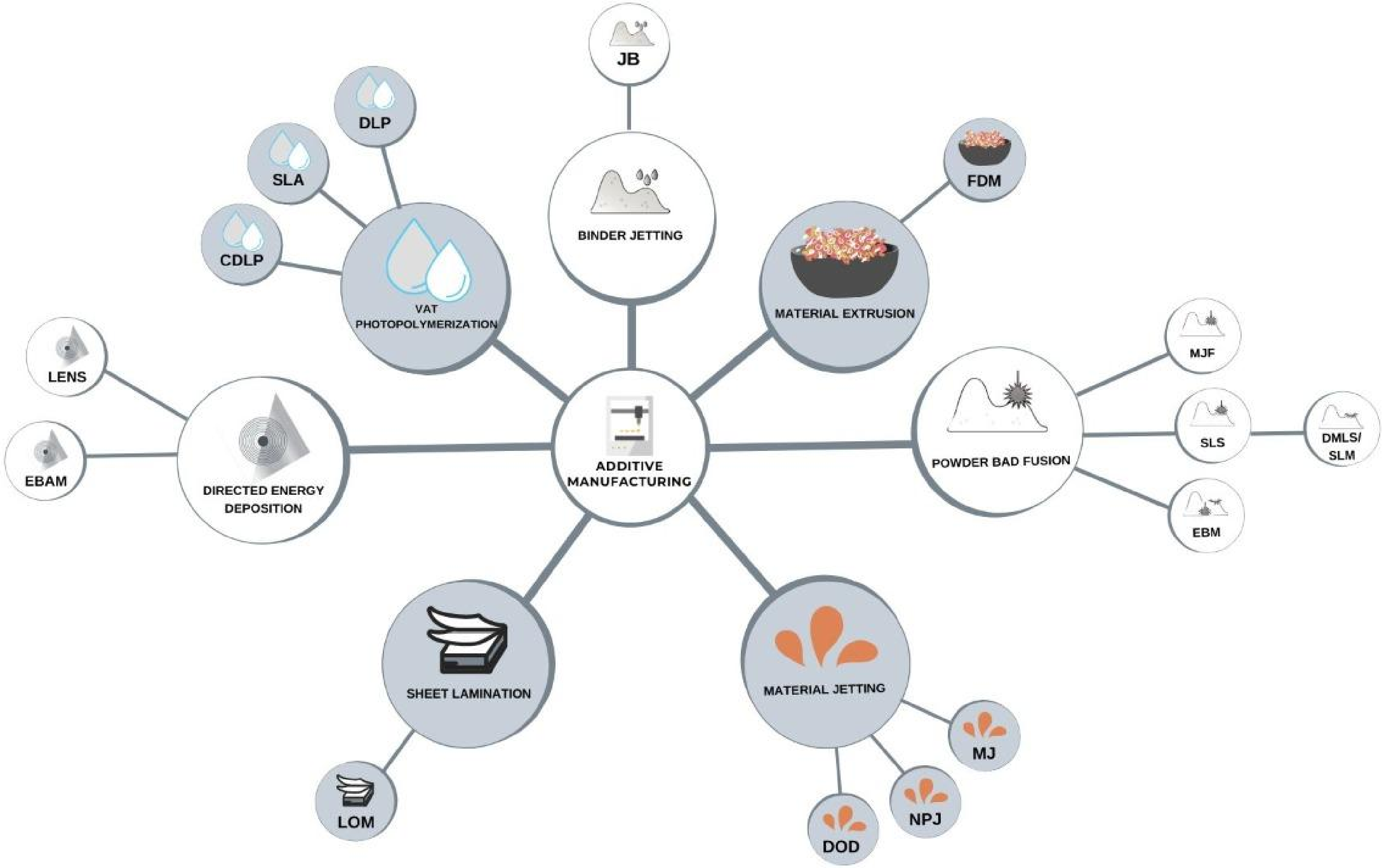
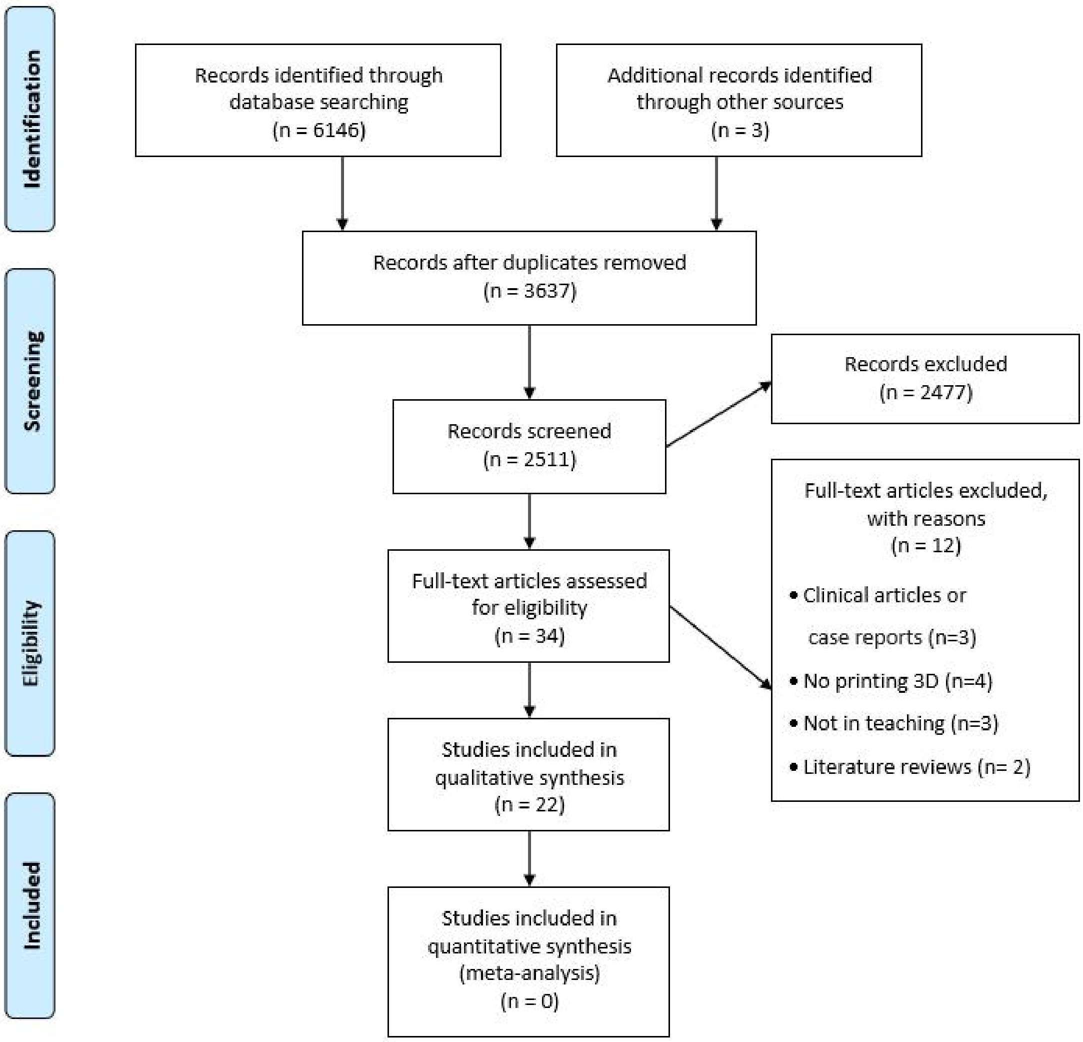


Figure 1 Additive Manufacturing Technologies

Figures

PRISMA 2009 Flow Diagram

3D PRINTING FOR DENTISTRY EDUCATION - A SCOPING REVIEW



From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). *P*referred *R*eporting *I*tems for *S*ystematic Reviews and *M*eta-*A*nalyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit www.prisma-statement.org.

Figure 2 Search flow (as described in the PRISMA statement).

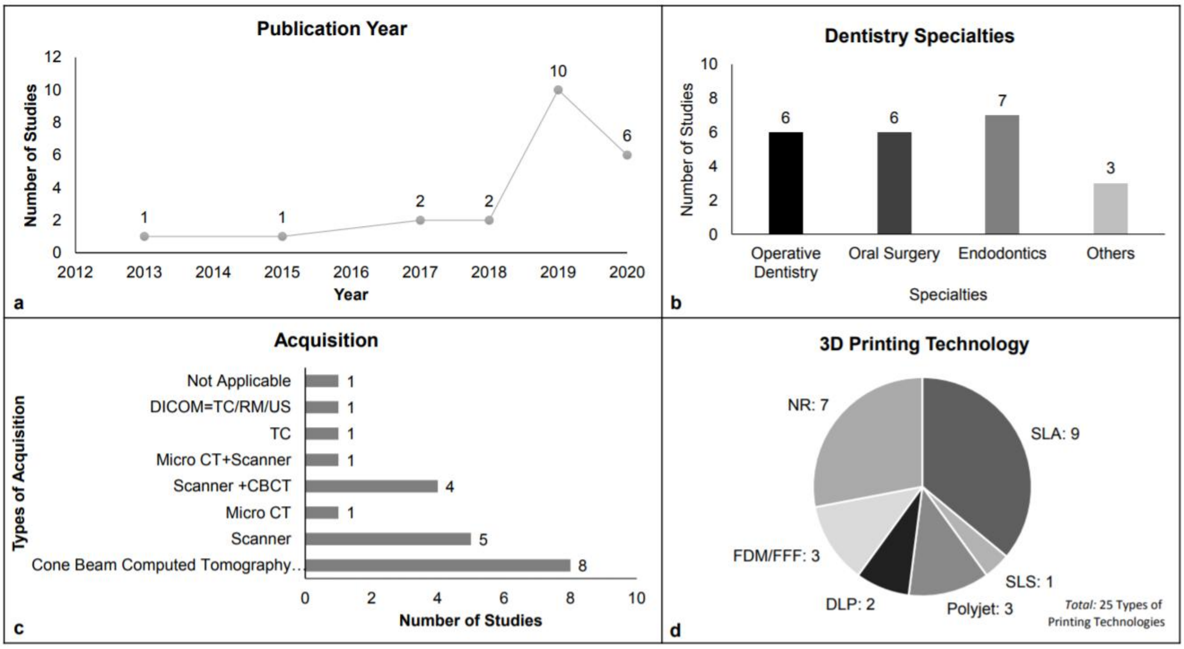


Figure 3 Number of publication year (a); Number of dentistry specialties (b); Types of aquisition (c); Types of printing technologies, in this figure the total is 25 types, as a study evaluated 4 printers (d).
Not Report (NR); Supernumerary Teeth (SNT); Acrylonitrile Butadiene Styrene (ABS); Polylactic Acid (PLA); Cone Beam Computed Tomography (CBCT); StereoLithoGraphy (SLA); Selective Laser Sintering (SLS); Direct Light Processing (DLP); Fused Deposition Modeling (FDM/FFF); Rapid Prototyping (RP); Dental Anatomy Spatial Representation Ability (DASRA)

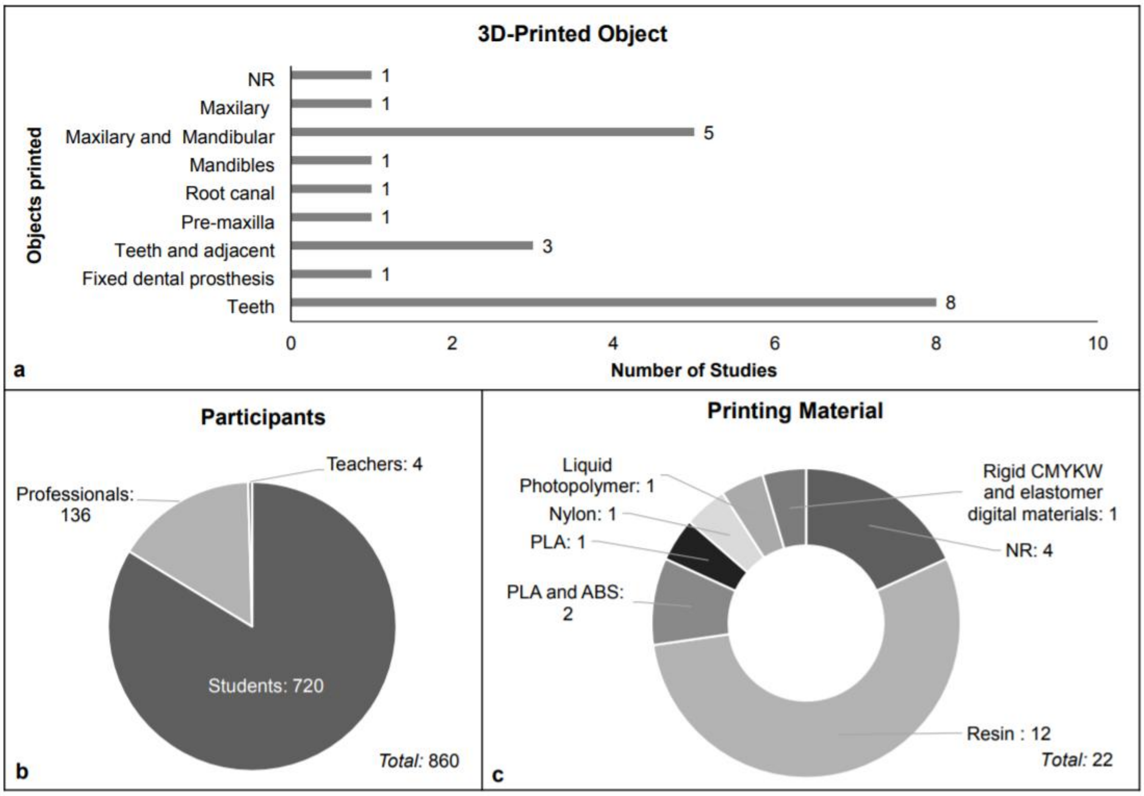


Figure 4 Types of objects printed (a); Total of participants (b); Type of printing Material (c). Not Report (NR); Supernumerary Teeth (SNT); Acrylonitrile Butadiene Styrene (ABS); Polylactic Acid (PLA); Cone Beam Computed Tomography (CBCT); StereoLithoGraphy (SLA); Selective Laser Sintering (SLS); Direct Light Processing (DLP); Fused Deposition Modeling (FDM/FFF); Rapid Prototyping (RP); Dental Anatomy Spatial Representation Ability (DASRA)

5 Considerações finais

O conceito da utilização da tecnologia de impressão tridimensional no ensino odontológico se mostrou bem avaliado e eficiente no desenvolvimento profissional usuários, sendo considerado um método auxiliar, podendo vir a corroborar positivamente no processo ensino-aprendizagem. Dentre as estruturas mais impressas estão os dentes e a maxila em conjunto com a mandíbula os quais foram principalmente utilizados para simulação e treinamento de estudantes envolvendo as diferentes áreas da odontologia. O método de aquisição das imagens foi preferencialmente a tomografia computadorizada de feixe cônico (CBCT). Em relação à tecnologia de impressão mais utilizada foi a StereoLithoGraphy (SLA), e o material mais considerado para impressão foi a resina manufaturada aditiva.

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