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EFEITO DO ESTÁGIO DE RIZOGÊNESE E DIREÇÃO DA SIMULAÇÃO IN SILICO DE TRAUMA NAS TENSÕES E DESLOCAMENTO DE INCISIVO CENTRAL PERMANENTE

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Efeito do Estágio de rizogênese e direção da simulação in silico de trauma na concentração de tensões do incisivo central permanente

Dissertação apresentada ao Programa ao Programa de Pós-graduação em Odontologia do Centro Universitário de Anápolis – UniEVANGÉLICA, para obtenção do Título de Mestre em Odontologia na Área Clínica Odontológica.

Orientador: Prof. Dr. Marco Aurélio de Carvalho
Co-orientador: Prof. Dr. Brunno Santos de Freitas Silva

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Aprovado em 31 de março de 2021.

Banca examinadora

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Prof. Dr. Marco Aurélio de Carvalho

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Prof. Dr. Orlando Aguirre Guedes

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Prof. Dr. Dimorvan Bordin

DEDICATÓRIA

Ao meu esposo Antônio dedico este trabalho, resultado da confiança, apoio e investimento em mim depositado e hoje compartilha da minha alegria. Muito obrigada!!

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"*Graças a Deus, não sou o que era antes*".

Marthin Luther King

SUMÁRIO

LISTA DE ABREVIATURAS

CDI	Centro de Diagnóstico e Imagem
D	Dentina
E	Esmalte
I	Incisal
LP	Ligamento Periodontal
MEF	Método dos Elementos Finitos
OC	Osso Cortical
OT	Osso Trabecular
RC	Rizogênese Completa
RIA	Rizogênese Incompleta no Terço Apical
RIM	Rizogênese Incompleta no Terço Médio
TCFC	Tomografia Computadorizada por Feixe Cônico
V	Vestibular

RESUMO

O objetivo deste estudo foi realizar uma análise tridimensional de elementos finitos de incisivos centrais superiores permanentes em diferentes estágios de desenvolvimento radicular sob diferentes configurações de trauma. Os fatores de estudo incluíram duas condições de trauma (V, vestibular; I, incisal) nos incisivos centrais permanentes superiores, apresentando três diferentes estágios de desenvolvimento radicular (RC, rizogênese completa; RIA; rizogênese incompleta no terço apical da raiz; e RIM, rizogênese incompleta no terço médio da raiz) para produzir seis modelos. O modelo de rizogênese completo foi obtido com um exame de tomografia computadorizada de feixe cônico de um dente extraído. Os dois modelos de rizogênese incompleta foram modelados com base em exames semelhantes de pacientes. O trauma foi simulado pela aplicação de uma carga estática de 300 N na borda incisal ou perpendicular à superfície vestibular do dente. Para a análise quantitativa os critérios de deslocamento e tensão de von Mises equivalente (σvM) foram obtidos para osso alveolar, ligamento periodontal, papila apical e dentina. Uma escala σvM com código de cores foi usada para a análise qualitativa. Os resultados deste estudo indicaram que a direção do trauma exerce maior influência na tensão do que a fase de formação da raiz. O trauma vestibular resultou em maior concentração de tensão no osso e no ligamento periodontal, principalmente no RC-V. Menor tensão foi encontrada no ligamento periodontal à medida que a formação da raiz progrediu (diminuição de 8% de RIA-V para RC-V e 11% de RIM-V para RC-V). Os modelos de rizogênese incompleta mostraram maiores valores tesão máxima σvM na dentina em comparação com a rizogênese completa (aumento de 52% de RC-V para RIA-V e 56% de RC-V para RIM-V). O trauma vestibular gerou maiores valores de tensão independente do estágio de rizogênese. Os dentes com raízes totalmente formadas apresentaram maior concentração de tensões no osso alveolar e no ligamento periodontal em comparação com os dentes imaturos, sendo que este último apresentou altas tensões na coroa dentária.

PALAVRAS-CHAVE: trauma dentário; método do elemento finito; rizogênese incompleta; rizogênese completa.

ABSTRACT

The aim of the present study was to perform a three-dimensional finite element analysis of permanent maxillary central incisors in different stages of root development under different trauma settings. The study factors included two trauma conditions (B, buccal; I, incisal) on upper permanent central incisors showing three different stages of root development (CR, complete rhizogenesis; IRA; incomplete rhizogenesis in the apical third of the root; and IRM, incomplete rhizogenesis in the middle third of the root) to yield six models. The complete rhizogenesis model was obtained with a cone-beam computed tomography examination of an extracted tooth. The two incomplete rhizogenesis models were modeled on the basis of similar examinations of patients. Trauma was simulated by applying a 300 N static load on the incisal edge or perpendicular to the buccal surface of the tooth. The displacement and equivalent von Mises (σvM) stress criteria were obtained for alveolar bone, periodontal ligament, apical papilla, and dentin for the quantitative analysis. A σvM color-coded scale was used for qualitative analysis. The results of this investigation showed that the trauma direction had a greater influence on the stress than the root-formation stage. Buccal trauma resulted in higher stress concentration in the bone and periodontal ligament , especially in B-CR. Lower stress was found on the periodontal ligament as the root formation progressed (decrease of 8% from B-IRA to B-CR and 11% from B-IRM to B-CR). The incomplete rhizogenesis models showed higher σvM stress peak values in dentin in comparison with complete rhizogenesis (increase of 52% from B-CR to B-IRA and 56% from B-CR to B-IRM). Buccal trauma yielded greater stress values regardless of the stage of rhizogenesis. Teeth with fully formed roots showed a higher stress concentration in the alveolar bone and periodontal ligament in comparison with immature teeth, with the latter presenting high stresses in the tooth crown.

KEYWORDS: dental trauma; immature tooth; incomplete rhizogenesis; permanent tooth; finite element analysis.

1. INTRODUÇÃO

O trauma dental é o termo utilizado para descrever as injúrias nos tecidos dentários e periodontais, incluindo as estruturas de sustentação e proteção (Clark & Levin, 2019). Dentre os agravos que ocorrem em consequência ao trauma são figurados a fratura coronária, fratura corono-radicular, fratura radicular, concussão, subluxação, luxação lateral, luxação intrusiva, luxação extrusiva e avulsão (Andreasen *et al*., 2002). Algumas dessas intercorrências podem ocasionar dor, reabsorção radicular, edema, fístula, anquilose, mobilidade, infecção, perda de vitalidade pulpar, descoloração e perda do dente (Sharif *et al*., 2015). Por conseguinte, esses distúrbios podem afetar o indivíduo de formas diferentes, impactando na função, estética e até emocionalmente (Borges *et al*., 2017).

O trauma dental em crianças e adolescentes tem sido extensivamente estudado durante as últimas décadas, relatando taxas de prevalência que varia de 6% a 58% em diferentes populações. No Brasil, a prevalência varia muito, desde 10% a 58% (Traebert, Claudino, 2012). As possíveis explicações para essa variação incluem diferenças de lugares / ambientes, critérios de diagnósticos e métodos de exame (Damé-Teixeira, Severo, Susin, 2013). A comparação entre os estudos realizados é uma tarefa difícil, uma vez que poucas pesquisas epidemiológicas são similares. As pesquisas têm diferentes metodologias e populações (Traebert, Claudino, 2012).

Os dentes mais acometidos pelo trauma são os incisivos centrais superiores decíduos e os incisivos centrais superiores permanentes (Zhang *et al*., 2014). O trauma dos dentes permanentes anteriores pode resultar não só em danos estéticos e funcionais, mas também, pode prejudicar a performance social do indivíduo adulto (Rajab, 2003). Estudos em crianças e adolescentes, sendo esta a população mais vulnerável ao trauma dental, demonstram que a faixa etária mais acometida por acidentes envolvendo esse elemento está entre 8 e 9 anos de idade (Rocha & Cardoso, 2001). Algumas investigações indicam que o prognóstico dos dentes permanentes acometidos por trauma pode ser extremamente variável, dependendo do tipo de trauma e da força aplicada na estrutura dentária. Inclusive, que o protocolo de manejo dessas intercorrências é dependente das estruturas que foram lesadas (Tsilingaridis *et al*., 2012).

Existem evidências de que o dente com o ápice aberto (rizogênese incompleta) apresenta considerável capacidade de recuperação após a exposição ao trauma. Até mesmo que esses dentes têm maior chance de manter a vitalidade pulpar, o que pode garantir a continuidade do desenvolvimento radicular e um melhor prognóstico (Diangelis *et al*., 2012). Todavia, atualmente são escassas as informações sobre a influência do trauma em dentes permanentes com diferentes estágios de formação da raiz. Inclusive, são limitados os estudos que avaliam como esse estágio de formação da raiz pode influir na deformação e tensão das estruturas de suporte e do próprio órgão dentário. Clinicamente, o traumatismo dentário é uma das principais emergências em odontologia. Porém, as características biomecânicas precisas do traumatismo dentário e suas repercussões nos tecidos adjacentes são amplamente desconhecidas, com poucas evidências experimentais.

Entende-se que o estudo do trauma em dentes com diferentes estágios de rizogênese possa ser importante na compreensão do seu mecanismo, como também, na avaliação do efeito que essas diferentes situações de maturação dentária possam ter no prognóstico e no manejo clínico dos dentes traumatizados. No entanto, a verificação da consequência do trauma no órgão dentário e nas estruturas de suporte é impraticável do ponto de vista experimental, tendo implicações éticas significativas (Vilela *et al*., 2019).

O método dos elementos finitos (MEF) foi desenvolvido como uma ferramenta de engenharia para analisar as condições de deformação e tensão em estruturas complexas (Verissimo *et al*., 2016). É um método bem estabelecido para avaliar o comportamento biomecânico onde testes experimentais não são possíveis. Esse método consiste em uma análise matemática que realiza a discretização de um meio contínuo em pequenos elementos, conservando as mesmas características do meio original, e assim, tornando possível a criação de modelos digitais de estruturas complexas (Trivedi, 2014). Ou seja, trata-se de uma simulação computacional que torna viável a análise de cargas e tensões de diferentes estruturas e forças, sendo sua utilização oportuna para o estudo do trauma dental (Vilela *et al*., 2019) e da fratura dentária (Takeshita *et al*., 2016). Desse modo, o objetivo do presente estudo foi avaliar o efeito do estágio de rizogênese do incisivo central superior permanente na concentração de tensões em consequência do trauma dental.

2. MATERIAL E MÉTODOS

a. 2.1 Tipologia do estudo

Trata-se de um estudo experimental ao qual utilizou ferramentas computacionais de análise numérica visando simular e avaliar a distribuição de tensões, sendo esse método conhecido como Método dos Elementos Finitos (MEF) em três dimensões.

b. 2.2 População e amostra

Foram selecionados exames de TCFC do banco de imagens do Centro de Diagnóstico por Imagem (CDI) do Curso de Odontologia do Centro Universitário de Anápolis – UniEVANGÉLICA com a finalidade de se obter modelos de incisivos centrais superiores em diferentes estágios de rizogênese. Num montante de 1.253 exames de TCFC disponíveis no mencionado arquivo de imagens, 6 (seis) exames foram selecionados para servirem como referência, sendo esta seleção por conveniência. Todos as imagens utilizadas neste estudo foram adquiridas em um tomógrafo Ortopantomograph^{TM} OP300 (*Instrumentarium Dental^{TM}, Charlotte, NC, EUA*) sob o protocolo “padrão” de aquisição de imagem. O modelo de dente com a formação completa da raiz foi obtido com o escaneamento tomográfico de um dente incisivo central superior extraído.

c. 2.3 Critérios de inclusão e exclusão

Foram selecionados exames de TCFC de pacientes entre 7 a 10 anos de idade, em que a coroa do incisivo central superior já estivesse completamente erupcionada, e em diferentes estágios da rizogênese. Foram excluídos exames com distorções dimensionais, má qualidade da imagem e problemas de posicionamento do paciente. Adicionalmente, foram excluídos os exames de TCFC em que os incisivos centrais superiores apresentarem lesões do órgão dentário (cárie, calcificação pulpar e fratura), anomalias (dilaceração, taurodontia, macrodontia, microdontia, fusão, geminação, *dens in dente* e reabsorção), lesão periapical, perda óssea horizontal e defeitos ósseos verticais.

2.4 Procedimentos do estudo

Para a realização das simulações pelo MEF foi necessária a execução de algumas etapas: construção do modelo, solução do problema e análise dos resultados. Essas três fases são também denominadas, respectivamente, por: pré-processamento, processamento e pós-processamento. O pré-processamento consiste na modelagem das geometrias de interesse, assim como na verificação de possíveis inconsistências dimensionais ou geométricas em função de alterações causadas pelos processos de importação da imagem. Neste estágio também são definidas as propriedades mecânicas dos materiais (Módulo de Young, coeficiente de Poisson e densidade) e os tipos de elementos a serem utilizados na geração das malhas.

O Módulo de Young utilizado neste protocolo definiu a inclinação da curva tensão-deformação até o limite de proporcionalidade, sendo uma medida de rigidez da estrutura (material) em sua região elástica. Já o Coeficiente de Poisson teve por objetivo caracterizar a relação entre as deformações longitudinais e transversais (alongamento ou contração) geradas quando um corpo for submetido a uma força axial de tração ou compressão. As propriedades mecânicas acima elencadas, e que foram utilizadas neste projeto de pesquisa, foram obtidas em estudos previamente publicados, estando os seus valores dispostos no **Quadro 1.**

Quadro 1. Propriedade mecânica do esmalte (E), dentina (D), ligamento periodontal (LP), osso trabecular (OT) e osso cortical (OC) definida na etapa de pré-processamento.

Propriedade/Estrutura	***E***	***D***	***LP***	***OT***	***OC***
Módulo de Young (MPa)	84100*	18600**	50***	1400****	13700****
Coeficiente de Poisson	0.30*	0.30**	0.45***	0.31****	0.33****
Densidade	2.14*	2.97**	0.95***	0.70****	2.00****

Fonte: *Zarone et al., 2006 ; **Sano et al., 1994; ***Rees e Jacobsen, 1997; ****Carter e Hayes,1977.

Em seguida, foi gerada a malha de Elementos Finitos. Finalizando essa fase de pré-processamento, foram delimitadas as condições de contorno, incluindo as restrições de movimento e carregamento, para assim, traduzir o fenômeno da maneira mais fidedigna possível.

Já o processamento é a etapa que se dá após a criação do modelo experimental, levando em consideração as condições estabelecidas durante o pré-processamento, consistindo no processamento numérico do problema estrutural que será solucionado computacionalmente. Nesta etapa, foram obtidos os resultados dos campos de tensão e deformação.

A etapa de pós-processamento consistiu na análise dos resultados do modelo obtido, fornecendo a visualização dos campos de tensões e deslocamentos. Nesta fase, os dados qualitativos e quantitativos foram analisados por meio da visualização gráfica dos campos de tensões (tensão equivalente de von Misses e tensão de tração). Para execução da modelagem tridimensional e análise pelo MEF foram utilizados, respectivamente, os programas computacionais *SolidWorks* 2013 (SolidWorks Corp., Concord, Massachusetts, EUA) e Ansys (ANSYS Workbench 14, Ansys Inc., Canonsburg, Pensylvania, EUA), em um computador Avell G1513 Fox-7, com processador Intel® Core™ i7-8750H Coffee Lake, 9 MB Cache (2.2 GHz até 4.1 GHz com Intel® Turbo Boost); memória RAM 16GB (2x 8GB - Dual Channel) Memória DDR4 (2666 MHZ); placa de vídeo dedicada NVIDIA® GeForce® GTX 1050 Ti GPU (4 GB GDDR5 dedicada); armazenamento HD 1TB - 5400 RPM SATA III; monitor 15.6" WVA FULLHD 16:9 (1920x1080p) LED; sistema operacional Windows Home 10 (Portátil Equipam entos de Informática LTDA, Joinville, Santa Catarina, Brasil). O trabalho foi realizado nas dependências do Centro Universitário UniEVANGÉLICA por meio do acesso remoto pelo aplicativo *TeamViewer* (*TeamViewer* GmbH, Göppingen, Alemanha) ao computador da instituição parceira, através da colaboração com a Profa. Dra. Altair Del Bel Cury do Laboratório de Elementos Finitos da Faculdade de Odontologia da Universidade Estadual de Campinas (LEF-FOP-UNICAMP).

2.5 Modelagem das estruturas

A proposta do presente estudo foi de elaborar um modelo tridimensional (3D) de incisivo central superior em diferentes estágios de rizogênese (formação da raiz), juntamente ao ligamento periodontal, osso trabecular, osso cortical e papila apical, e verificar a concentração de tensões após o trauma dentário. O modelo foi elaborado a partir de referências de exames por imagem associado ao desenho manual em 3D (**Figura 1**). Com essa finalidade, conforme descrito previamente neste protocolo, foram selecionados exames de tomografia computadorizada de feixe cônico (TCFC) de pacientes entre 7 e 10 anos de idade em que a coroa do incisivo central superior que já estivesse completamente erupcionada (apresentando a junção cemento-esmalte 2 mm acima da crista óssea alveolar) (**Figura 2**).

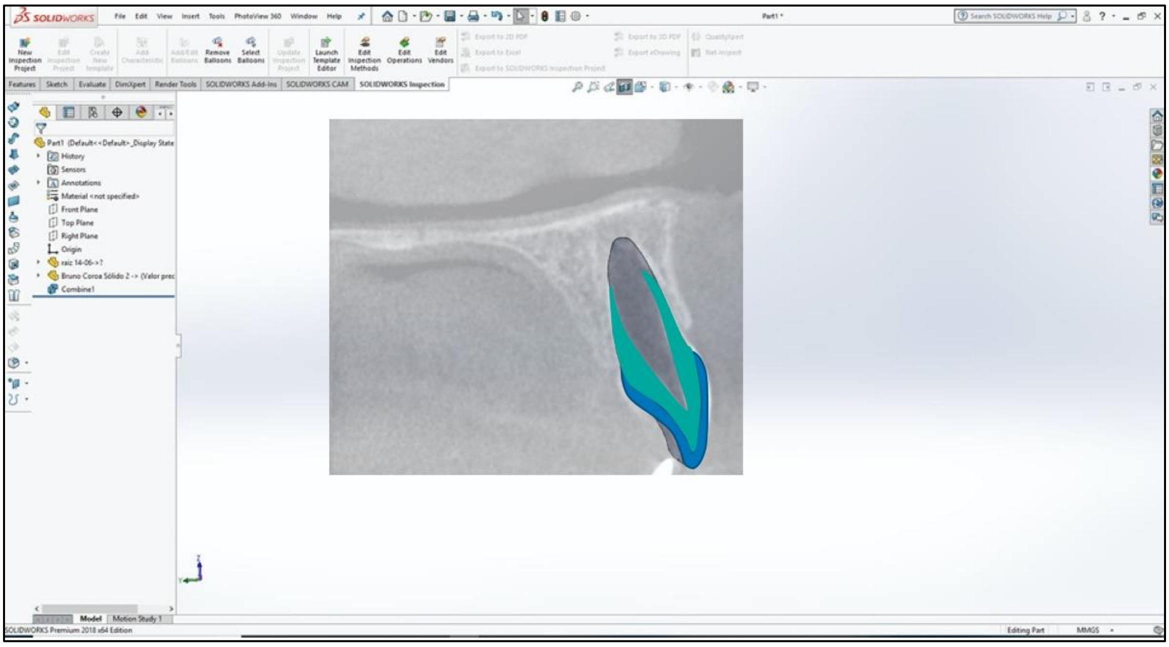

Figura 1. Ilustração da etapa de desenho manual realizada no programa computacional *SolidWorks* 2013 (SolidWorks Corp., Concord, Massachusetts, EUA) a partir da referência do exame de TCFC (Fonte: Próprio autor).

Com o objetivo de criar um modelo em diferentes estágios da rizogênese, foram utilizados exames em ao menos 3 (três) fases diferentes da formação da raiz, assim representadas: 1) Raiz completamente formada; 2) Rizogênese incompleta no terço apical; e 3) Rizogênese incompleta no terço médio da raiz (**Figura 3 e 4**). Para o modelo de raíz completamente formada foi utilizado um exame de TCFC obtido a partir de um dente extraído.

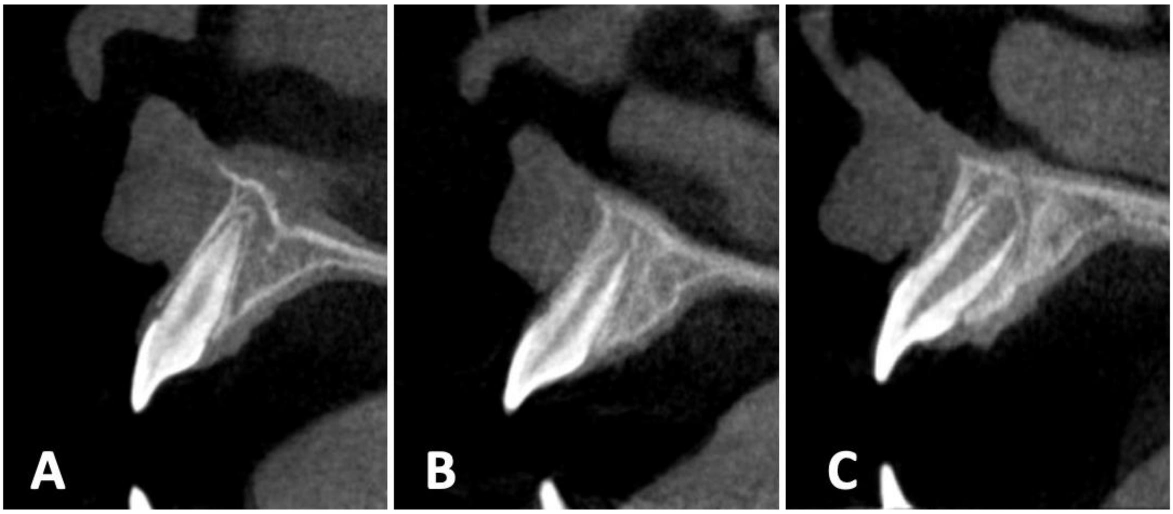

Figura 2. Cortes transversais de TCFC exibindo um incisivo central superior nos três diferentes estágios de formação da raiz simulados nesse estudo (Fonte: Exames do banco de imagens do CDI do Curso de Odontologia da UniEVANGÉLICA – Utilização das imagens autorizada por escrito pelos responsáveis para utilização com finalidade de ensino).

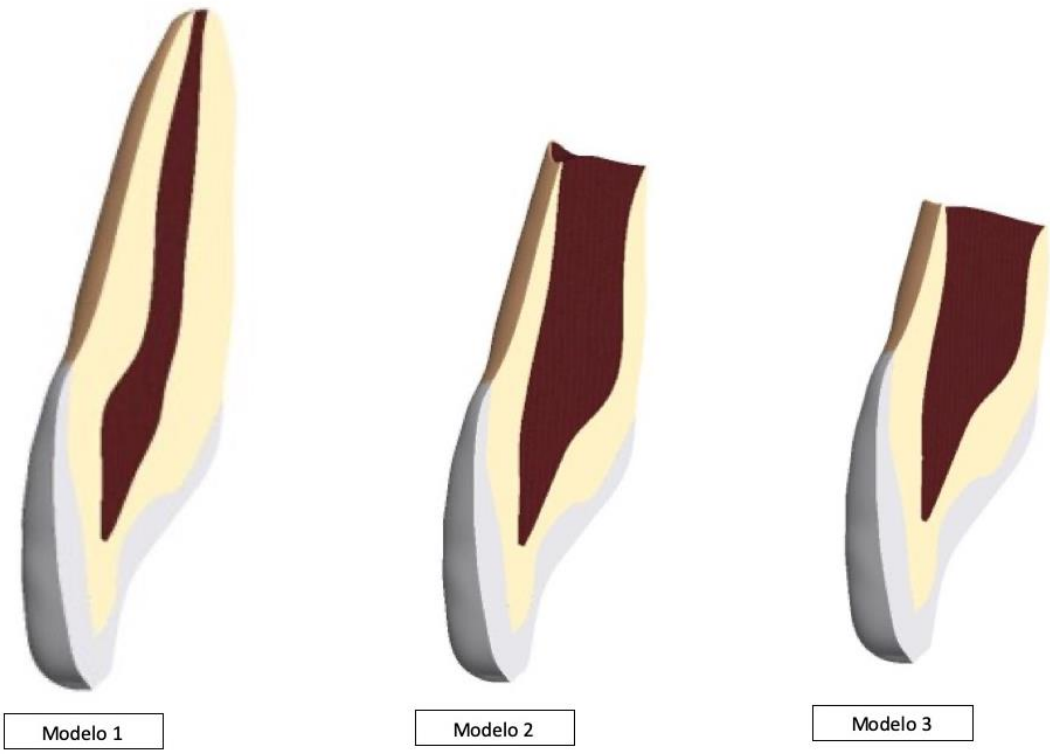

Figura 3. Vista da secção de modelos tridimensionais dos dentes em diferentes estágios de formação da raiz. (Fonte: Próprio autor)

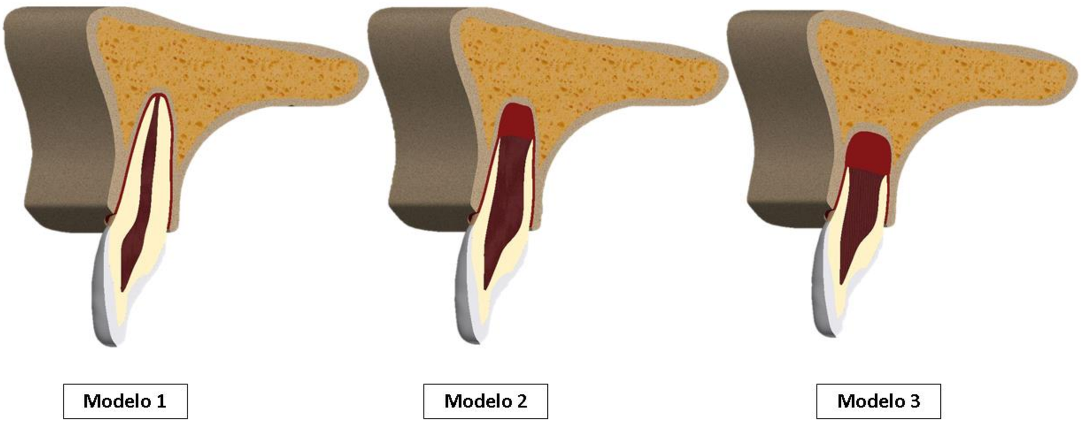

Figura 4. Vista de secção das estruturas que compõe os modelos do estudo: Osso cortical, osso medular, ligamento periodontal, papila apical, polpa dental, dentina, esmalte nos diferentes estágios de rizogênese. Exemplo da figura, grupo G1/G4 (rizogênese completa). (Fonte: Próprio autor).

Cortes transversais de tomografia computadorizada setorizadas (em 2 dimensões), obtidas a partir dos arquivos DICOM, foram utilizados como referência para as dimensões do modelo, sendo as espessuras do esmalte, dentina, osso trabecular, osso cortical e papila apical definidas por meio do valor médio obtidos em 3 (três) exames. Para a espessura do ligamento periodontal convencionou-se o valor uniforme de 0.25 mm, sendo este um valor intermediário estabelecido com base em estudos histológicos dessa estrutura (Consolaro & Furquim, 2011). Portanto, as imagens de TCFC não foram utilizadas para obtenção dos valores de espessura do ligamento periodontal, devido a possibilidade de imprecisão nos valores dimensionais (Pauwels *et al*., 2011). Os exames que foram utilizados neste estudo foram obtidos com protocolos padrão de aquisição (**Quadro 2**) com o tamanho do *voxel* variando entre 0.125 a 0.3.

Quadro 2. Protocolo “padrão” de aquisição de imagens disponíveis no tomógrafo Ortopantomograph™ OP300 (*Instrumentarium Dental™, Charlotte, NC, EUA*) e utilizados para obtenção dos exames selecionados neste estudo.

Voxel	***FOV***	***Corrente***	***Potência***	***Tempo de Exposição***
0.125	6x8 cm	6.3 mA	90 kVp	6.1 seg.
0.2	6x4 cm	8.0 mA	90 kVp	2.3 seg.
0.3	6x8 cm	8.0 mA	90 kVp	2.3 seg.

Fonte: Manual do fabricante do aparelho Ortopantomograph™ OP300 (Instrumentarium Dental™, Charlotte, NC, EUA) disponível em: http://www.3d-roentgen.ch/pdf/Instrumentarium_OP300_3D_2011_1.pdf

Os modelos obtidos a partir dos desenhos traçados com o auxílio de exames de TCFC foram exportados para um programa específico de análise por elementos finitos (ANSYS Workbench 14, Ansys Inc., Canonsburg, Pensylvania, EUA). Curvas cúbicas foram traçadas através das coordenadas obtidas, recriando os contornos de tecido para a MEF.

Com a finalidade de simular a ação de um impacto frontal e outro um vertical sobre o incisivo central superior nos três diferentes estágios da rizogênese, foram estabelecidos 6 modelos experimentais conforme observado no **Quadro 3**: 1) Raiz completamente formada com impacto horizontal; 2) Rizogênese incompleta no terço apical com impacto horizontal; 3) Rizogênese incompleta na altura do terço médio da raiz com impacto horizontal; 4) Raiz completamente formada com impacto vertical; 5) Rizogênese incompleta no terço apical com impacto vertical; 6) Rizogênese incompleta na altura do terço médio da raiz com impacto vertical.

Quadro 3. Delineamento experimental dos 6 modelos do estudo.

Estágio de rizogênese	Impacto	
	Vestibular	Incisal
Rizogênese completa	RC-V (G1)	RC-I (G4)
Rizogênese incompleta no terço apical	RIA-V (G2)	RIA-I (G5)
Rizogênese incompleta no terço médio	RIM-V (G3)	RIM-I (G6)

d.

2.6 Geração das malhas

Nesta etapa, os modelos sólidos 3D, de forma individual, foram exportados para o programa computacional de análise por MEF Ansys (ANSYS Workbench 14, Ansys Inc., Canonsburg, Pensylvania, EUA), sendo as malhas das estruturas geradas separadamente. As estruturas presentes nos modelos foram consideradas homogêneas, isotrópicas, linearmente elásticas e contínuas. Conforme descrito anteriormente neste protocolo, foram incorporadas as malhas a propriedades mecânicas correspondentes a cada material, seguida pela discretização em um número finito de elementos interconectados por pontos nodais (**Figura 5**). O tamanho dos elementos finitos foi determinado pela análise de convergência de 5%.

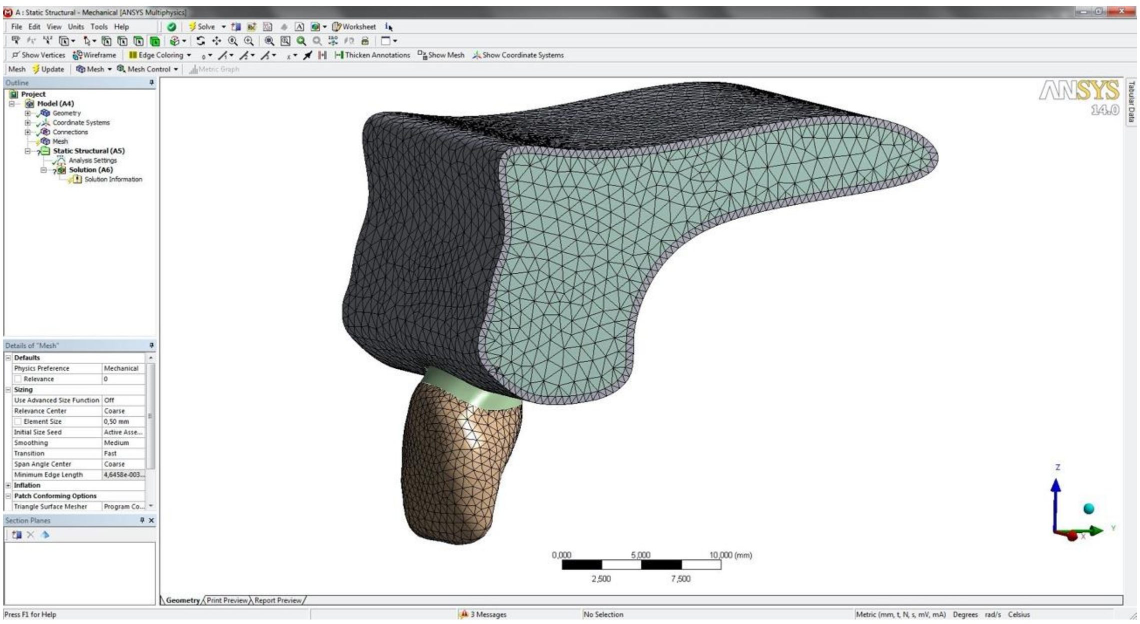

Figura 5. Malhamento das estruturas em software de análise por elementos finitos Ansys (ANSYS Workbench 14, Ansys Inc., Canonsburg, Pensylvania, EUA). (Fonte: Próprio autor).

2.7 Condições de contorno

As condições de contorno foram definidas em conformidade com o protocolo descrito por Vilela *et al*. (2019). Assim, todas as interfaces foram consideradas coladas, impedindo a penetração, deslizamento ou afastamento das superfícies (**Figura 6**). A exceção foi aplicada apenas na simulação de impacto no objeto. Um objeto quadrado foi criado para simular o impacto com uma superfície plana como o asfalto. Os “nós” no topo da estrutura óssea foram fixados rigidamente nas direções x (horizontal) e y (vertical).

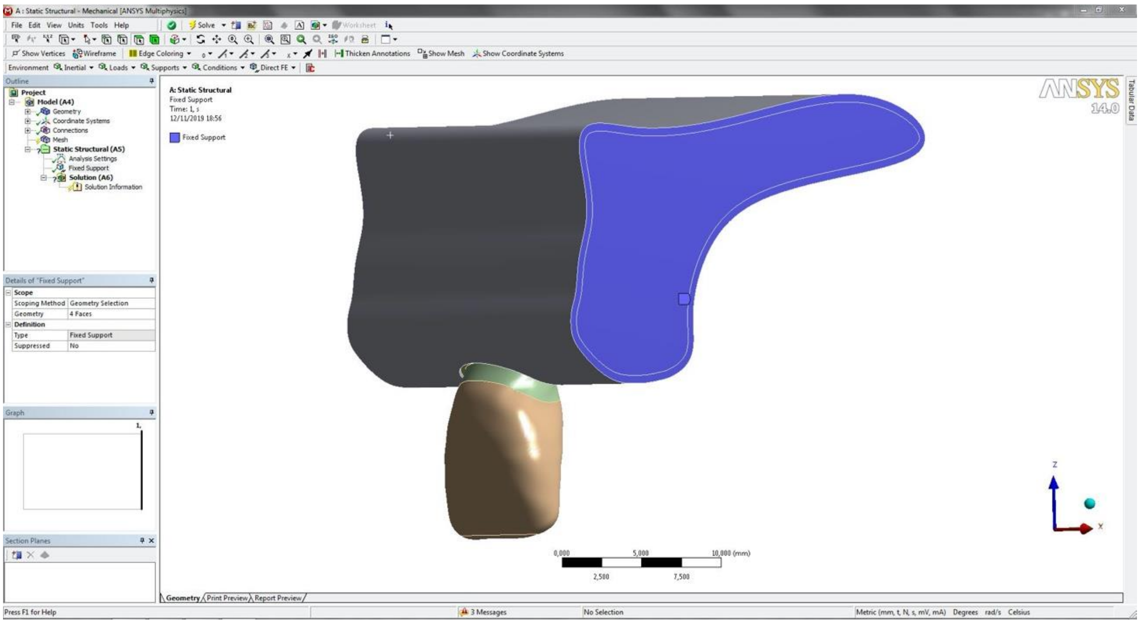

Figura 6. Suporte fixo nas faces medial e lateral do segmento de maxila. (Fonte: Próprio autor).

2.8 Pós-processamento

O resultado do processamento foi avaliado qualitativamente, pela comparação visual das imagens e os gradientes de cores geradas pelo programa computacional de simulação, e quantitativamente, onde foram avaliados os valores de tensões máxima geradas como resposta biomecânica do sistema.

2.9 Aspectos éticos

O presente estudo se encontra de acordo com a Resolução 466/2012 do Conselho Nacional de Saúde e sendo submetido e aprovado pelo Comitê de Ética e Pesquisa (CEP) da UniEVANGÉLICA sob o número 3.857.577 (ANEXO 1).

3. CAPÍTULO 1

Artigo 1: Artigo nas normas do periódico científico Dental Traumatology (Qualis/CAPES A2) (ANEXO 2). Normalizado e revisado pela empresa Editage (ANEXO 3). Carta de apresentação encontra-se no Apêndice “A”.

A three-dimensional finite element analysis of permanent maxillary central incisors in different stages of root development and trauma settings

Running title: Finite element analysis of permanent maxillary central incisors

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Abstract

Background/Aim: To perform a three-dimensional finite element analysis of permanent maxillary central incisors in different stages of root development under different trauma settings. **Material and methods:** The study factors included two trauma conditions (B, buccal; I, incisal) on upper permanent central incisors showing three different stages of root development (CR, complete rhizogenesis; IRA; incomplete rhizogenesis in the apical third of the root; and IRM, incomplete rhizogenesis in the middle third of the root) to yield six models. The complete rhizogenesis model was obtained with a cone-beam computed tomography examination of an extracted tooth. The two incomplete rhizogenesis models were modeled on the basis of similar examinations of patients. Trauma was simulated by applying a 300 N static load on the incisal edge or perpendicular to the buccal surface of the tooth. The displacement and equivalent von Mises (σvM) stress criteria were obtained for alveolar bone, periodontal ligament, apical papilla, and dentin for the quantitative analysis. A σvM color-coded scale was used for qualitative analysis. **Results:** The trauma direction had a greater influence on the stress than the root-formation stage. Buccal trauma resulted in higher stress concentration in the bone and periodontal ligament , especially in B-CR. Lower stress was found on the periodontal ligament as the root formation progressed (decrease of 8% from B-IRA to B-CR and 11% from B-IRM to B-CR). The incomplete rhizogenesis models showed higher σvM stress peak values in dentin in comparison with complete rhizogenesis (increase of 52% from B-CR to B-IRA and 56% from B-CR to B-IRM). **Conclusions:** Buccal trauma yielded greater stress values regardless of the stage of rhizogenesis. Teeth with fully formed

roots showed a higher stress concentration in the alveolar bone and periodontal ligament in comparison with immature teeth, with the latter presenting high stresses in the tooth crown.

Key words: dental trauma, immature tooth, incomplete rhizogenesis, permanent tooth, finite element analysis

1. Introduction

Dental trauma can cause physical, esthetic, and emotional problems for the patient and is, therefore, a matter of great concern for dental practitioners.[1] In both primary[2] and permanent dentitions,[3,4] maxillary central incisors are the teeth most affected by trauma. The occurrence of trauma can cause a variety of physical damages to the tooth structure, dental crown, root and pulp, and its supporting tissues, such as the periodontal ligament (PDL) and alveolar bone.[5] Some of these injuries can result in pain, root resorption, edema, fistulas, ankylosis, mobility, infection, loss of pulp vitality, discoloration, and tooth loss,[6] reinforcing the importance of dental trauma studies to verify the situations in which these injuries can happen.

Considering the permanent dentition, most patients experiencing dental trauma are aged 6 to 13 years,[5] with boys being more prone to events causing dental trauma.[3] Within this distinctive age range, the upper central incisors show different stages of root development,[7] which may influence the outcomes for traumatized dental and surrounding tissues. Despite the great number of observational and *in silico* investigations on dental trauma, the biomechanical characteristics of dental traumatic injuries and their reactions with dental supportive tissues,[8] especially for teeth with an open apex,[9] have been addressed in very few studies.

Finite element analysis (FEA) has emerged as an engineering tool to analyze stresses and deformation conditions in complex structures.[10] This method is based on a mathematical analysis using discretization of a continuous structure into smaller elements, preserving the characteristics of the original structure and providing simplified digital models of complex structures.[11] In other words, it is a computer simulation (*in silico* technique) that enables the resolution of different mechanical challenges involving complex structures, allowing stress-and-strain analyses of different components of the models, and is therefore very appropriate for studies of dental trauma[12] and dental fracture[13] based on clinical scenarios.

Studies of trauma in teeth showing different stages of rhizogenesis may enlighten the understanding of clinical outcomes, since the resultant differences in dental maturation may affect the prognosis and clinical management of traumatized teeth. However, evaluation of the outcomes of dental trauma to the dental organ and support structures in an *in vivo* model is impossible and involves major methodological and ethical implications.[12] FEA is a viable alternative to analyze the stresses and deformations resulting from dental trauma in different stages of root formation. Thus, the aim of the present study was to perform a three-dimensional (3D) FEA of permanent maxillary central incisors in different stages of root development subjected to buccal and incisal trauma.

2. Materials and methods

Experimental Design

Ethical approval for the study was obtained from the Institutional Review Board under protocol number 3.857.577. This *in silico* experimental study performed using 3D FEA consisted of trauma simulations under two force conditions (B, buccal trauma; I, incisal trauma) on upper permanent central incisors showing three different stages of root development (CR, complete rhizogenesis; IRA, incomplete rhizogenesis in the apical third; and IRM, incomplete rhizogenesis in the middle third of the root), yielding a total of six study conditions: B-CR, B-IRA, B-IRM, I-CR, I-IRA, and I-IRM (Figure 1).

Model construction

To obtain the complete 3D model of rhizogenesis, a cone-beam computed tomography (CBCT) examination of an extracted upper central incisor was performed. The digital imaging and communications in medicine (DICOM) file was exported to an open-source medical imaging software (InVesalius, Renato Archer Information and Technology Center, Campinas, Brazil) for surface/geometric reconstruction in solid-display stereolithographic (STL) file format. The STL file was then imported into a computer-aided design software (SolidWorks 2013, SolidWorks Corp., Concord, Massachusetts, USA) for model construction.[14]

To obtain the two incomplete rhizogenesis models, images from six CBCT examinations of patients aged 7 to 12 years were selected from the image bank of the dental radiology clinic of the university and used as guides for obtaining the IRA and IRM models. The crowns of the upper central incisors had already completely erupted (cementoenamel junction was at least 2 mm above the alveolar bone crest) in a similar occlusal pattern (Figure 2). All CBCT images were obtained with an Ortopantomograph™ OP300 (Instrumentarium DentalTM, Charlotte, NC, EUA) tomograph under the following acquisition parameters: isotropic 0.2-mm voxel; field of view (FOV), 6 × 8 cm; tube current, 8.0 mA; tube voltage, 90 kVp; and acquisition time, 2.3 s.

The two incomplete rhizogenesis models (IRA and IRM) were designed in SolidWorks from the complete rhizogenesis model based on the anatomical references of the CBCT exams. The 3D models consisted of the upper permanent incisor in three different stages of root formation (enamel, dentin, and pulp), the PDL, trabecular bone, cortical bone, and apical papilla. The enamel, dentin, trabecular bone, cortical bone, and apical papilla thickness were defined by the mean value obtained in three exams for each of the two stages of incomplete rhizogenesis. For the PDL thickness, a uniform value of 0.25 mm was considered on the basis of a histological study of this structure.[15]

Numerical Analysis

The 3D models were exported to a specific FEA program (ANSYS Workbench 14, Ansys Inc., Canonsburg, Pennsylvania, USA) for numerical analysis. The material mechanical properties were obtained from previous studies as described in Table 1.[12,16–18] All the materials were considered linearly elastic, homogenous, and isotropic.

The mesh was generated by using quadratic tetrahedral elements. After 5% convergence analysis,[19] the element size was set as 0.5 mm. The number of elements and nodes for each model is described in Table 2. Contact between teeth and related structures was considered to indicate bonding. The boundary conditions were defined by fixing the mesial and distal exterior surfaces of the bone segment in all directions.

Since falls are the major cause of dental trauma in immature permanent incisors,[3] frontal (buccal) and vertical (incisal) traumas were simulated with a hard and flat object like asphalt.[12] For the trauma simulations, a 300 N static load was applied on the incisal edge parallel to the tooth long axis for the incisal trauma, and a 300 N static load was applied perpendicular to the buccal surface of the central incisor for the buccal trauma.[9]

The displacement and equivalent von Mises (σvM) stress criteria were obtained for alveolar bone, PDL, apical papilla, and dentin for quantitative analysis. A σvM color-coded scale was used for dentin and alveolar bone in the qualitative analysis.

3. Results

The peak values of σvM stresses are presented in Table 3, and the peak values of displacement are provided in Table 4. The qualitative analysis of σvM stress distribution is visualized in Figures 3 and 4 using a linear color scale, with the warmer colors (red) indicating higher stress values and the cooler colors (blue) representing lower values.

According to this FEA, the direction of the trauma had a greater influence on the magnitude and concentration of the stress than the stage of root formation, since the buccal trauma resulted in a greater magnitude of stress regardless of the rhizogenesis stage. The buccal trauma resulted in higher stress concentrations in the buccal and lingual bone and PDL, especially in B-CR, in which the root was fully formed (Table 1 and Figure 3). In fact, the longer the root, the greater the stress on the adjacent cortical bone, since the lever action was increased on the alveolus (increase of 15% from B-IRA to B-CR and 3% from B-IRM to B-CR). On the other hand, the stress on the PDL reduced with root formation (decrease of 8% from B-IRA to B-CR and 11% from B-IRM to B-CR). The incomplete rhizogenesis models showed higher σvM stress peak values in dentin in comparison with the complete rhizogenesis model (increase of 52% from B-CR to B-IRA and 56% from B-IRM to B-CR), which were concentrated mainly at the coronal portion of the roots. These immature teeth models also showed greater stress in the apical papilla in the less developed root (increase of 35% from B-IRA to B-IRM).

In displacement evaluations, for buccal trauma, greater values were obtained for the surrounding cortical bone when the root was fully formed (increase of 18% from B-IRA or B-IRM to B-CR). On the other hand, greater displacement on the dentin was observed in the immature roots (increase of approximately 12% from B-CR to B-IRA and 10% from B-CR to B-IRM).

Incisal trauma yielded lower values of σvM stresses in all analyzed structures in comparison with the buccal trauma. Considering the dental papilla, a slight difference was observed between I-IRA and I-IRM, with the latter showing 6% greater stress values in this particular structure.

4. Discussion

Dental trauma is a term used to describe an injury to the teeth and the supportive tissues.[20] Traumatic events are associated with a broad series of dental complications that can vary dramatically according to the magnitude of the trauma and the affected dental or periodontal structures (enamel, dentin, pulp, PDL, alveolar bone, and gingiva). The combined or isolated responses of these tissues influence the outcome of the teeth and, consequently, the selection of the clinical management approach.[20] Differences in dental maturation status may also influence the prognosis of traumatized teeth, particularly in different stages of rhizogenesis. For this reason, and since these traumatic injuries occur with great frequency in permanent immature upper central incisors, this study aimed to perform a 3D FEA in models representing different stages of root development. For this purpose, six different models were subjected to simulated buccal or incisal trauma.

In the present study, the FEA showed that buccal trauma is related to a greater stress concentration, regardless of the different stages of rhizogenesis. A fully formed root was associated with a greater stress concentration on the PDL and the adjacent bone and greater displacement, with the latter being an expected event from buccal trauma.[21] These findings emphasize that buccal trauma in permanent mature upper central incisors is more likely to cause damage to the periodontium, which could result in concussion, subluxation, or luxation injuries and pulp necrosis. In other words, mature teeth could experience more complications due to dental trauma. Observational studies have also shown that dental trauma in permanent teeth with fully formed roots shows causes problems than trauma in immature teeth, especially in relation to pulp vitality.[22] This could be explained by the fact that the greater blood supply provided through open apices of immature teeth facilitates pulp recovery, thereby preventing pulp necrosis.[23] In contrast, the closure of the apical foramen in mature teeth increases the risk of pulp necrosis to cause concussion, subluxation,[24] and lateral [22] or intrusive luxation.[25]

This study also yielded some additional findings that could explain the better prognosis of immature permanent incisors after a traumatic injury. In the present *in silico* analysis, in comparison with teeth containing fully formed roots, immature teeth models showed a higher stress concentration in the coronal portion of the tooth (enamel and dentin) with a lower concentration of tension in the PDL and alveolar bone, which indicated a higher risk of crown fracture and a lower risk of damage to the periodontium. How can this assumption reflect a better prognosis for immature teeth? Theoretically, the shortened roots and thin dentin walls of an immature tooth favor the concentration of stresses in the tooth itself, and not in the adjacent structures, which can be beneficial for the periodontium and the dental pulp.[24] Additionally, the greater resilience of the bone in young patients with immature teeth,[26] and the presence of substantial amounts of soft tissue in the open apex (apical papilla) may favor the dissipation of traumatic forces. Consistent with this hypothesis, the present analysis corroborated the possibility of dissipation of traumatic forces via the apical papilla, since this simulation demonstrated greater stress in the apical papilla proportional to the stage of root development. However, this finding and the predisposition of immature permanent teeth to crown fracture should be interpreted with caution, because there is no conclusive information in the literature regarding the possible differences in the prevalence of luxation and dental fractures between immature or mature teeth.[27,28]

Intrusive luxation is one of the most problematic types of dental injuries, and the stage of root development can influence the management and prognosis of such injuries.[29] The current study simulated an incisal trauma to understand the effects of this kind of trauma in teeth showing different stages of rhizogenesis. In assessments with incisal trauma, the stress concentration in the dental papilla was greater when the root of the tooth was shorter. This result is difficult to properly interpret, since there is no evidence that immature teeth show a poorer prognosis in relation to intrusive luxation. In fact, immature teeth present the most favorable outcome in response to this kind of intrusive trauma. Immature teeth may show less damage to the PDL and alveolar bone,[25] which was also observed in the present FEA study. These results indicate that the apical papilla may absorb the impact of incisal trauma, explaining the minor damage to the tissues adjacent to the tooth with an open apex. Nevertheless, there is a need for additional studies not only to understand the biomechanical behavior of these traumatized teeth when an incisal trauma is applied, but also to establish more reliable data outlining the influence of different stages of root development on the prognosis.

In the present study, FEA was used to estimate the biomechanical responses of a traumatic load in a permanent upper central incisor in different stages of root development and the surrounding structures. Since in vivo assessments of dental trauma are impossible due to ethical reasons, FEA is a suitable method to assess the effect of trauma in these dental models.[8,11] FEA was performed with three different models of permanent upper central incisors that were subjected to simulated buccal or incisal trauma. The 3D models were manually traced based on the anatomical references of 6 CBCT examinations of patients aged 7 to 12 years with teeth with different stages of rhizogenesis. Due to the complexity of these models, manual or automatic segmentation of the CBCT scans was not performed. The 3D model of immature tooth included the following components: enamel, dentin, pulp, PDL, apical papilla, trabecular bone and cortical bone. The thickness of these structures was defined by the mean value obtained in three CBCT examinations for each of the three stages of root development. This strategy for obtaining models ensured that the simulations were close to *in vivo* situations, thereby ensuring that the anatomical conditions in this study were close to those noted in the age group showing a high prevalence of dental trauma in the permanent incisors. Due to the lack of studies assessing the biomechanical conditions associated with traumatic injuries in teeth under different stages of root development, this FEA may improve the understanding of the complications related to dental trauma. However, the 3D models may not fully represent the real-world conditions.

This study performed a static analysis due to the complexity of the present model and the lower computational cost of static analyses in comparison with dynamic analyses.[8] Although dynamic analyses have already been used in other studies of dental trauma[30,31] and because it seems more appropriate in models with a short traumatic loading, it has recently been demonstrated that the inertia of the dental structure does not affect the results of the trauma simulation, with the static analysis presenting the same results as the dynamic analysis.[8] Therefore, static analysis seems to be the most suitable method for the present study model.

Considering the fact that FEA is a reliable method for studies of stresses and strains and that the present tooth model was anatomically close to the conditions in the age group showing greater susceptibility to trauma, more studies should focus on the effects of buccal and incisal traumas on tooth structure and prognosis.

5. Conclusion

Buccal trauma resulted in greater stress values regardless of the stage of rhizogenesis. Teeth with fully formed roots showed higher stress concentration in the alveolar bone and PDL in comparison with immature teeth, which showed high stresses in the tooth crown. Incomplete rhizogenesis of teeth is related to greater stress concentration in enamel and dentin in comparison with that in teeth with fully formed roots. The incisal trauma resulted in greater stress to the dental papilla, proportional to the stage of root development.

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TABLES

Table 1 – Mechanical and physical properties of enamel, dentin, periodontal ligament (PDL), trabecular bone (TB), cortical bone (CB) and apical papilla (AP)

Mechanical/Physical properties	Enamel	Dentin	PDL	TB	CO	AP
Young's Modulus (MPa)	84,100	18,600	50	1,400	13,700	50
Poisson's ratio	0.30	0.30	0.45	0.31	0.33	0.45
Density (Kg/m^3)	2.14	2.97	0.95	0.70	2.00	0.95

Table 2 – Number of elements and nodes for each condition evaluated in the study

Model	Elements	Nodes
I-CR	1,455,162	2,187,272
B-CR	1,444,817	2,170,678
I-IRA	858,975	1,284,798
B-IRA	842,810	1,259,807
I-IRM	773,407	1,159,332
B-IRM	757,242	1,134,341

B, buccal; I, incisal; CR, complete rhizogenesis; IRA; incomplete rhizogenesis in the apical third of the root; and IRM, incomplete rhizogenesis in the middle third of the root

Table 3 – Peak values of equivalent von Mises Stress (σvM) in MPa for the components for each model evaluated in the study

	I-CR	**B-CR**	**I-IRA**	**B-IRA**	**I-IRM**	**B-IRM**
Cortical bone	67.84	112.73	63.54	97.91	68.99	109.18
Apical papilla	-	-	1.94	2.13	2.08	2.87
PDL	60.79	73.49	57.36	79.88	65.03	82.82
Dentin	68.92	88.65	81.25	134.82	82.88	138.25

PDL, periodontal ligament; B, buccal; I, incisal; CR, complete rhizogenesis; IRA; incomplete rhizogenesis in the apical third of the root; and IRM, incomplete rhizogenesis in the middle third of the root

Table 4 – Peak values of displacement in μm for the components in each model evaluated in the study

	I-CR	B-CR	I-IRA	B-IRA	I-IRM	B-IRM
Cortical bone	18.24	40.26	18.65	34.17	19.22	33.97
Apical Papilla	-	-	23.82	19.94	36.52	54.12
PDL	379	514	444	610	436	591
Dentin	2,200	4,226	2,506	4,753	2,460	4,665

PDL, periodontal ligament; B, buccal; I, incisal; CR, complete rhizogenesis; IRA; incomplete rhizogenesis in the apical third of the root; and IRM, incomplete rhizogenesis in the middle third of the root

FIGURES

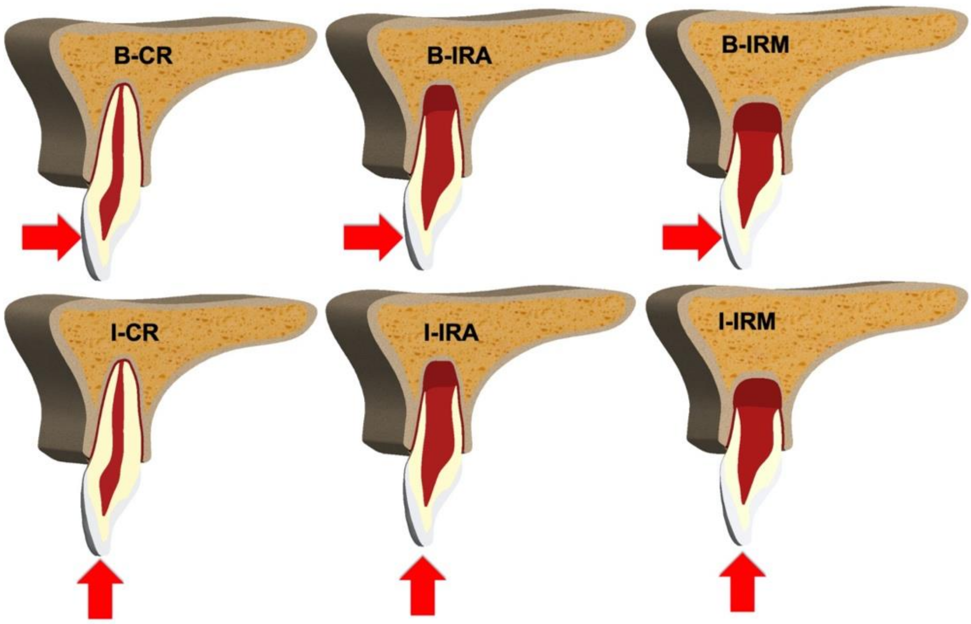

Figure 1. Six experimental conditions evaluated in the study, from the factorial combination of three rhizogenesis stages (CR, complete rhizogenesis; IRA, incomplete rhizogenesis in the apical third; and IRM, incomplete rhizogenesis in the middle third of the root) and two trauma settings (B, buccal trauma; I, incisal trauma).

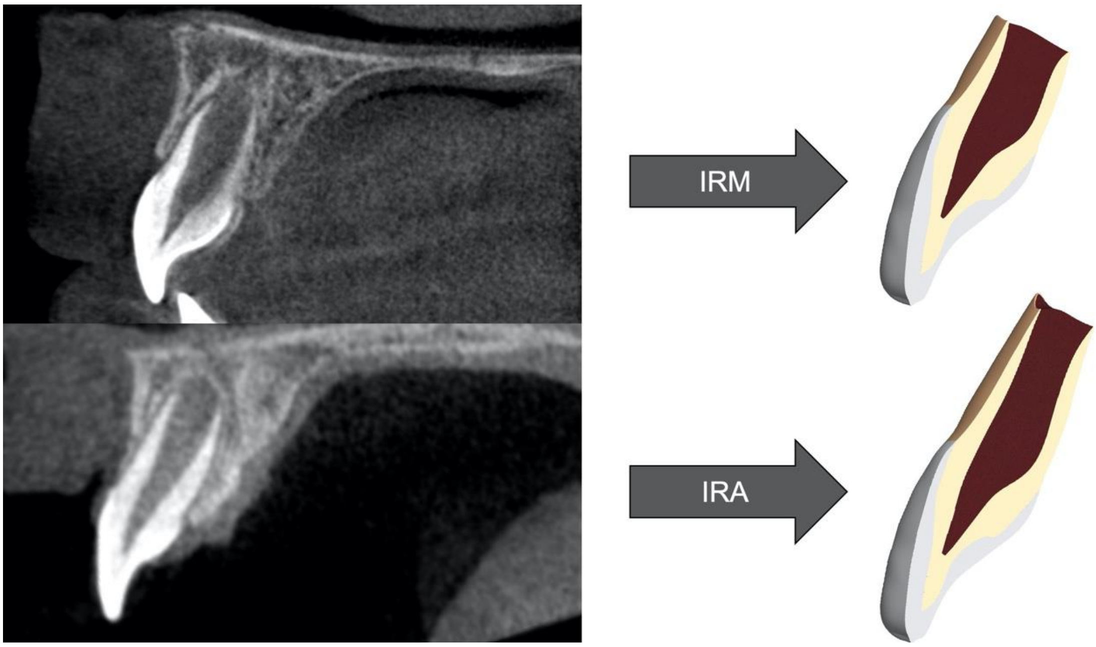

Figure 2. Six images from CBCT exams were used to guide the construction of the two incomplete rhizogenesis models (IRA and IRM). IRA, incomplete rhizogenesis in the apical third of the root; and IRM, incomplete rhizogenesis in the middle third of the root.

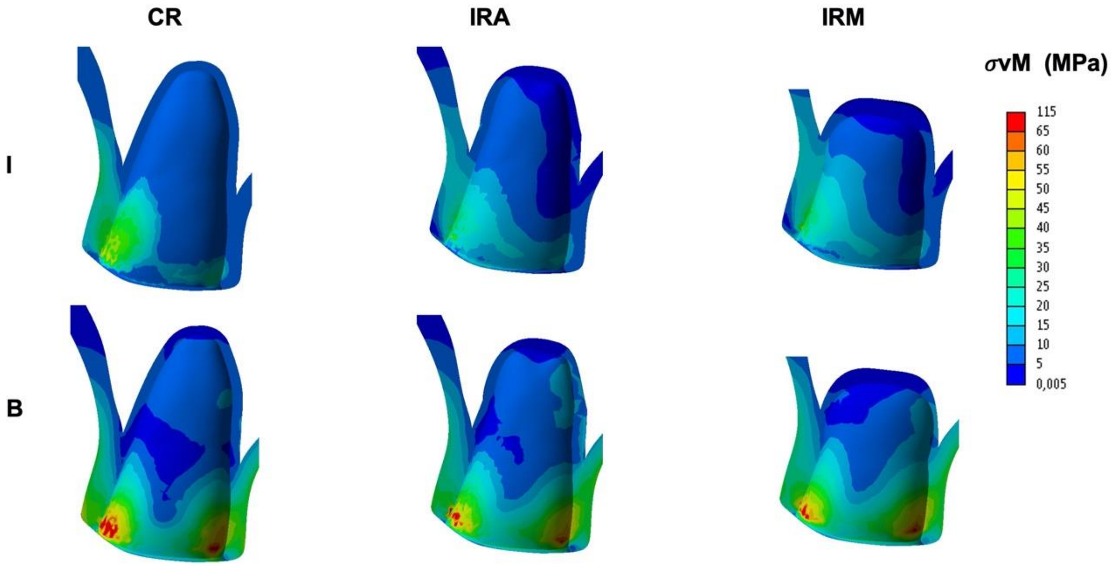

Figure 3. Equivalent von Mises stress distribution on surrounding cortical bone. B, buccal trauma; I, incisal trauma; CR, complete rhizogenesis; IRA, incomplete rhizogenesis in the apical third of the root; and IRM, incomplete rhizogenesis in the middle third of the root.

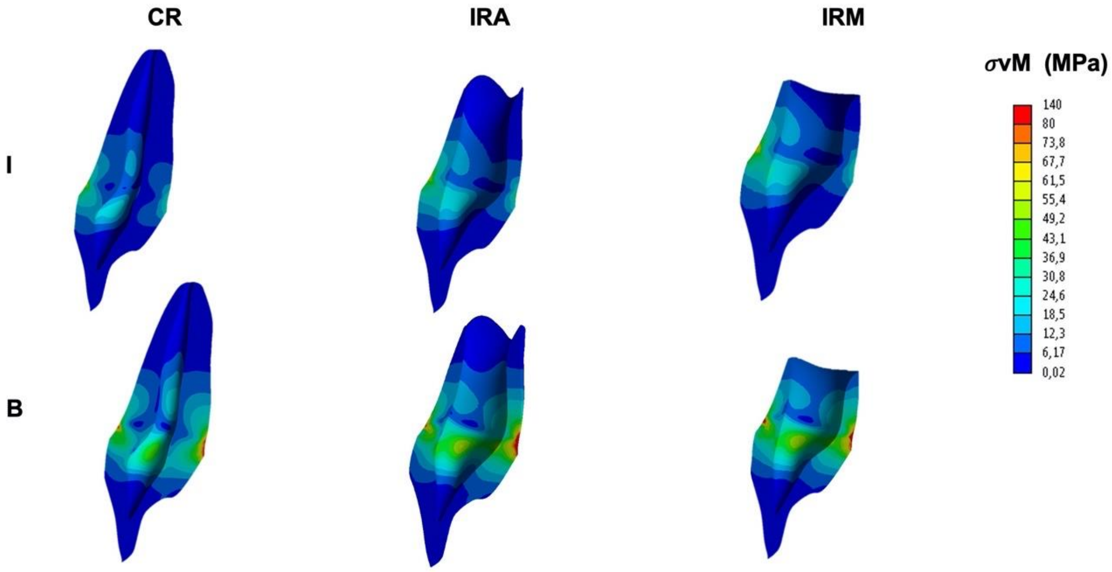

Figure 4. Equivalent von Mises stress distribution on dentin. B, buccal trauma; I, incisal trauma; CR, complete rhizogenesis; IRA, incomplete rhizogenesis in the apical third of the root; and IRM, incomplete rhizogenesis in the middle third of the root.

4. CONSIDERAÇÕES FINAIS

O trauma vestibular resultou em maiores valores de tensão independentemente do estágio de rizogênese. Dentes com raízes totalmente formadas apresentaram maior concentração de tensões no osso alveolar e ligamento periodontal em comparação com dentes imaturos, que apresentaram altas tensões na coroa dentária. A rizogênese incompleta dos dentes está relacionada à maior concentração de tensões no esmalte e dentina em comparação com os dentes com raízes totalmente formadas. O trauma incisal resultou em maior tensão à papila dentária, proporcional ao estágio de desenvolvimento radicular.

Considerando o fato de que a análise por elementos finitos é um método confiável para estudos de tensões e deformações, entende-se que estudos adicionais com enfoque clínico devam ser conduzidos, tendo como finalidade confirmar os achados observados na presente simulação, como também, verificar o impacto do trauma no prognóstico de dentes em diferentes estágios de formação da raiz.

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ANEXO 1

Parecer consubstanciado do CEP-UniEVANGÉLICA:

CENTRO UNIVERSITÁRIO DE ANÁPOLIS - UNIEVANGÉLICA

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Efeito do estágio de rizogênese do incisivo central permanente na concentração de tensões

Pesquisador: Brunno Santos de Freitas Silva

Área Temática:

Versão: 1

CAAE: 26335619.1.0000.5076

Instituição Proponente: Centro Universitário de Anápolis - UniEVANGÉLICA

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 3.857.577

Apresentação do Projeto:

O trauma dental é o termo utilizado para descrever as injúrias nos tecidos dentários e periodontais, incluindo as estruturas de sustentação e proteção (1). Dentre os agravos que ocorrem em consequência ao trauma são figurados a fratura coronária, fratura corono-radicular, fratura radicular, concussão, subluxação, luxação lateral, luxação intrusiva, luxação extrusiva e avulsão (2). Algumas dessas intercorrências podem ocasionar dor, reabsorção radicular, edema, fístula, anquilose, mobilidade, infecção, perda de vitalidade pulpar, descoloração e perda do dente (3). Por conseguinte, esses distúrbios podem afetar o indivíduo de formas diferentes, impactando na função, estética e até emocionalmente (4). Os dentes mais acometidos pelo trauma são os incisivos centrais superiores decíduos e os incisivos centrais superiores permanentes (5). O trauma dos dentes permanentes anteriores pode resultar não só em danos estéticos e funcionais, mas também, pode prejudicar a performance social do indivíduo adulto (6). Estudos em crianças e adolescentes, sendo esta a população mais vulnerável ao trauma dental, demonstram que a faixa etária mais acometida por acidentes envolvendo esse elemento está entre 8 e 9 anos de idade (7). Algumas investigações indicam que o prognóstico dos dentes permanentes acometidos por trauma pode ser extremamente variável, dependendo do tipo de trauma e da força aplicada na estrutura
dentária. Inclusive, que o protocolo de manejo dessas intercorrências é dependente das estruturas que foram lesadas (8).Existem evidências de que o dente com o ápice aberto (rizogênese incompleta) apresenta considerável capacidade de recuperação após a exposição ao trauma. Até

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mesmo que esses dentes têm maior chance de manter a vitalidade pulpar, o que pode garantir a continuidade do desenvolvimento radicular e um melhor prognóstico (9).

No entanto, a verificação da consequência do trauma no órgão dentário e nas estruturas de suporte é impraticável do ponto de vista experimental, tendo implicações éticas significativas (10).O método dos elementos finitos (MEF) foi desenvolvido como uma ferramenta de engenharia para analisar as condições de estresse e tensão em estruturas complexas (11). Esse método consiste em uma análise matemática que realiza a discretização de um meio contínuo em pequenos elementos, conservando as mesmas características do meio original, e assim, tornando possível a criação de modelos digitais de estruturas complexas (12). Ou seja, trata-se de uma simulação computacional que torna viável a análise de cargas e tensões de diferentes estruturas e forças, sendo sua utilização oportuna para o estudo do trauma dental (10) e da fratura dentária (13). Desse modo, o objetivo do

presente estudo é de avaliar o efeito do estágio de rizogênese do incisivo central superior permanente na concentração de tensões em consequência do trauma dental.

Hipótese:

O trauma dos incisivos centrais superiores permanentes pode resultar em lesões no órgão dentário e nos seus tecidos de suporte, sendo o prognóstico desses dentes dependente das estruturas acometidas pela injúria traumática (14). Sabe-se que os dentes com rizogênese incompleta têm menor chance de apresentar necrose pulpar após o trauma dental, e dessa forma, trazem consigo um melhor prognóstico (9). A direção e a força do trauma exercem grande influência no tipo de lesão presente no dente e no periodonto de sustentação (1), entretanto, não se sabe se o estágio de formação da raiz dental também possa influenciar no tipo de dano estabelecido nessas estruturas. Apesar de investigações sobre esse

tema serem pertinentes do ponto de vista clínico, entende-se ser inviável a realização de estudos experimentais que tenham como escopo o trauma dental. Dessa forma, o MEF se apresenta como uma alternativa viável para se analisar a concentração de tensões decorrentes do traumatismo dental em diferentes estágios de formação da raiz. Diante da variedade de agravos relacionados ao trauma dental, acredita-se que as tensões

geradas durante o trauma do incisivo central superior possam ser influenciadas pelo estágio de rizogênese.

Metodologia Proposta:

Tipologia do estudo:Trata-se de um estudo experimental ao qual utilizará ferramentas computacionais de análise numérica visando simular e avaliar a distribuição de tensões, sendo esse método conhecido como Método dos Elementos Finitos (MEF) em três dimensões. População e amostra:Serão selecionados exames de TCFC do banco de imagens do Centro de Diagnóstico por Imagem (CDI) do Curso de Odontologia do Centro Universitário de Anápolis – UniEVANGÉLICA com a finalidade de se obter modelos de incisivos centrais superiores em diferentes estágios de rizogênese. Num montante de 1.253 exames de TCFC disponíveis no mencionado arquivo de imagens, 9 (nove) exames serão selecionados para servirem como referência, sendo esta seleção por conveniência. Todos as imagens que serão utilizadas neste estudo foram adquiridas em um tomógrafo OrtopantomographTM OP300 (Instrumentarium DentalTM, Charlotte, NC, EUA) sob o protocolo "padrão" de aquisição de imagem. Procedimentos a serem realizados:Para a realização das simulações pelo MEF será necessária a execução de algumas etapas: construção do modelo, solução do problema e análise dos resultados. Essas três fases são também denominadas, respectivamente, por: pré-processamento,processamento e pós-processamento. O pré-processamento consiste na modelagem das geometrias de interesse, assim como na verificação de possíveis inconsistências dimensionais ou geométricas em função de alterações causadas pelos processos de importação da imagem. Neste estágio também são definidas as propriedades mecânicas dos materiais (Módulo de Young, coeficiente de Poisson e densidade) e os tipos de elementos a

serem utilizados na geração das malhas. O Módulo de Young utilizado neste protocolo definirá a inclinação da curva tensão-deformação até o limite de proporcionalidade, sendo uma medida de rigidez da estrutura (material) em sua região elástica. Já o Coeficiente de Poisson terá por objetivo caracterizar a relação entre as deformações longitudinais e transversais (alongamento ou contração) geradas quando um corpo for submetido a uma

força axial de tração ou compressão. As propriedades mecânicas acima elencadas, e que serão utilizadas neste projeto de pesquisa, foram obtidas em estudos previamente publicados, estando os seus valores dispostos no Quadro 1 (constante apenas no arquivo do projeto).Em seguida, será gerada a malha de Elementos Finitos. Finalizando essa fase de pré-processamento, delimitar-se-á as condições de contorno, incluindo as restrições

de movimento e carregamento, para assim, traduzir o fenômeno da maneira mais fidedigna possível. Já o processamento é a etapa que se dá após a criação do modelo experimental, levando em consideração as condições estabelecidas durante o pré-processamento, consistindo no processamento numérico do problema estrutural que será solucionado computacionalmente. Nesta etapa, serão obtidos os resultados dos campos de tensão e deformação. POR LIMITAÇÃO DO CAMPO DE PREENCHIMENTO, A DESCRIÇÃO NA ÍNTEGRA DOS PROCEDIMENTOS DE PESQUISA FOI

INCLUÍDA APENAS ARQUIVO DO PROJETO.

Critério de Inclusão:

Serão selecionados exames de TCFC de pacientes entre 7 a 10 anos de idade, em que a coroa do incisivo central superior já esteja completamente erupcionada, e em diferentes estágios da rizogênese. A amostra selecionada será dividida inicialmente em 3 (três) grupos, contendo 3 (três) exames em cada um, conforme a fase de formação da raiz.

Critério de Exclusão:

Não serão relacionados na amostra exames com distorções dimensionais, má qualidade da imagem e problemas de posicionamento do paciente. Adicionalmente, serão excluídos os exames de TCFC em que os incisivos centrais superiores apresentarem lesões do órgão dentário (cárie, calcificação pulpar e fratura), anomalias (dilaceração, taurodontia, macrodontia, microdontia, fusão, geminação, dens in dente e reabsorção), lesão
periapical, perda óssea horizontal e defeitos ósseos verticais.

Objetivo da Pesquisa:

Objetivo Primário:

Analisar a influência do estágio de rizogênese do incisivo central superior permanente na concentração de tensões decorrentes do trauma dental.

Objetivo Secundário:

• Criar modelos tridimensionais de um incisivo central superior permanente em diferentes fases de formação da raiz a partir de exames de tomografia computadorizada de feixe cônico;• Criar modelos tridimensionais do osso alveolar (porção cortical e trabecular) e da papila apical de acordo com o estágio de formação da raiz a partir de exames de tomografia computadorizada de feixe cônico;• Elaborar os modelos por elementos finitos tridimensionais;• Testar por meio de simulação a aplicação de forças traumáticas horizontais nos modelos em diferentes estágios da rizogênese;• Testar por meio de simulação a aplicação de forças traumáticas verticais nos modelos em diferentes estágios da rizogênese;•
Analisar a concentração de tensões decorrentes do trauma nas estruturas dentárias e periodontais

Avaliação dos Riscos e Benefícios:

Riscos:

Os riscos atribuídos a este estudo são relacionados à divulgação da identidade dos pacientes e possíveis danos aos exames de TCFC. Entretanto, esses riscos serão minimizados, e a confidencialidade dos dados garantida, por meio da anonimização da identidade do paciente em todas as imagens utilizadas no estudo por meio da supressão deste dado nas reconstruções

extraídas dos arquivos DICOM. Declara-se complementarmente que, somente o pesquisador responsável por este estudo terá acesso aos dados dos pacientes constantes nos arquivos DICOM originais, garantindo plenamente o sigilo quanto a identificação do participante. Os dados serão divulgados em forma estatística descritiva, sem a identificação do participante da pesquisa.
O risco biológico relacionado à dose de radiação absorvida pelo paciente durante a aquisição das imagens de TCFC não é assumido como um risco atribuído a realização desta pesquisa. Os citados exames não foram realizados com desígnio de pesquisa, se tratando apenas de exames do arquivo do banco de imagens do CDI – UniEVANGÉLICA realizados sob indicação clínica específica.
Benefícios:
De acordo com a alínea "n" do item III.2 da Resolução Nº466/2012 do Conselho Nacional de Saúde, os benefícios de uma pesquisa podem ser de ordem direta ou indireta ao participante, desde que seja a ele assegurado os benefícios resultantes do projeto, em termos de retorno social, acesso aos procedimentos, produtos ou agentes da pesquisa. No presente estudo, entende-se que os benefícios são de ordem indireta, por ser uma
simulação em computador de um acidente (trauma dentário) que de fato não ocorreu na amostra estudada. Configura-se aqui, como benefícios desta pesquisa, uma maior compreensão da influência do estágio de formação da raiz (rizogênese) nos danos causados por um trauma dentário. Entende-se que uma melhor compreensão deste processo possa auxiliar no manejo e na avaliação do prognóstico dessas situações que podem emergir da prática clínica odontológica.

Comentários e Considerações sobre a Pesquisa:
Pesquisa com relevância científica e social a ser realizada pelo Curso de Odontologia do Centro Universitário de Anápolis - UniEVANGÉLICA. Trata-se de estudo que busca analisar a influência do estágio de rizogênese do incisivo central superior permanente na concentração de tensões decorrentes do trauma dental utilizando-se de exames de imagens que compõe o banco de dados do setor de diagnóstico por imagem do próprio curso. Os pesquisadores solicitaram e justificaram dispensa do TCLE.

Considerações sobre os Termos de apresentação obrigatória:
De acordo com as recomendações previstas pela RESOLUÇÃO CNS N.466/2012 e demais complementares o protocolo permitiu a realização da análise ética. Todos os documentos listados foram analisados.

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Recomendações:

Não se aplica

Conclusões ou Pendências e Lista de Inadequações:

Não foram encontrados óbices éticos.

Considerações Finais a critério do CEP:

O pesquisador responsável atende todas as orientações da construção de um projeto de pesquisa e da Resolução CNS no. 466/2012 e complementares.

Solicitamos ao pesquisador responsável o envio do RELATÓRIO FINAL a este CEP, via Plataforma Brasil, conforme o cronograma de execução apresentado.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_1479472.pdf	28/11/2019 15:24:32		Aceito
Projeto Detalhado / Brochura Investigador	ProjetoRizogeneseMEF.pdf	28/11/2019 15:21:01	Brunno Santos de Freitas Silva	Aceito
Folha de Rosto	FolhaDeRosto.pdf	28/11/2019 15:19:22	Brunno Santos de Freitas Silva	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	DispensaDoTermoDeConsentimentoLivreEsclarecido.pdf	27/11/2019 23:38:02	Brunno Santos de Freitas Silva	Aceito

Situação do Parecer:

Aprovado

Necessita Apreciação da CONEP:

Não

ANAPOLIS, 27 de Fevereiro de 2020

Assinado por:
Cristiane Martins Rodrigues Bernardes
(Coordenador(a))

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ANEXO 2

Normas da revista Dental Traumatology:

Author Guidelines

Sections

1. SUBMISSION

Authors should kindly note that submission implies that the content has not been published or submitted for publication elsewhere except as a brief abstract in the proceedings of a scientific meeting or symposium.

Once the submission materials have been prepared in accordance with the Author Guidelines, manuscripts should be submitted online at https://mc.manuscriptcentral.com/dt

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2. AIMS AND SCOPE

Dental Traumatology is an international peer-reviewed journal which aims to convey scientific and clinical progress in all areas related to adult and pediatric dental traumatology. It aims to promote communication among clinicians, educators, researchers, administrators and others interested in dental traumatology. The journal publishes original scientific articles, review articles in the form of comprehensive reviews or mini reviews of a smaller area, short communication about clinical methods or techniques, Letters to the Editor and case reports. The journal focuses on the following areas ***as they relate to dental trauma:***

- Epidemiology and Social Aspects
- Periodontal and Soft Tissue Aspects
- Endodontic Aspects
- Pediatric and Orthodontic Aspects
- Oral and Maxillofacial Surgery / Transplants/ Implants
- Esthetics / Restorations / Prosthetic Aspects
- Prevention and Sports Dentistry
- Epidemiology, Social Aspects, Education and Diagnostic Aspects.

3. MANUSCRIPT CATEGORIES AND REQUIREMENTS

Original Research Articles in all areas related to adult and pediatric dental traumatology are of interest to Dental Traumatology. Examples of such areas are Epidemiology and Social Aspects, Periodontal and Soft Tissue Aspects, Endodontic Aspects, Pediatric and Orthodontic Aspects, Oral and Maxillofacial Surgery/Transplants/Implants, Esthetics/Restorations/Prosthetic Aspects, Prevention and Sports Dentistry, Epidemiology, Social Aspects, Education and Diagnostic Aspects.

Review Papers: *Dental Traumatology* commissions specific topical review papers and mini reviews of small areas of interest. The journal also welcomes uninvited reviews.

Reviews should be submitted via the online submission site and are subject to peer-review.

Comprehensive Reviews should be a complete coverage of a subject discussed with the Editor-in-Chief prior to submission. Comprehensive review articles should include a description of the search strategy of the relevant literature, the inclusion criteria, exclusion criteria, method for evaluation of papers, level of evidence, etc.

Mini Reviews cover a smaller area and may be written in a more free format.

Case Reports: Dental Traumatology may accept Case Reports that illustrate unusual and clinically relevant observations or management. Case reports should demonstrate something new or unique, and they should not present common clinical scenarios. Case reports should be kept brief (within 3-4 printed pages) and need not follow the usual division into Material and Methods etc. There should be an Abstract written as a short paragraph. The Abstract should not be structured with specific sections (i.e. do not use aims, methods, results, conclusions). The Introduction should be kept short. Thereafter the case is described followed by a short Discussion. Case reports should have adequate follow-up to demonstrate the outcome of the treatment provided or the long-term prognosis of the presented problem. Typically, cases with treatment should have at least 4-5 years follow-up radiographs, photographs, etc. to show the outcome. Case reports are subject to peer review.

Short Communications of 1-2 pages may be accepted for publication. These papers need not follow the usual division into Material and Methods, etc., but should have an Abstract. They should contain important new information to warrant publication and may reflect improvements in clinical practice such as introduction of new technology or practical approaches. They should conform to high scientific and high clinical practice standards. Short communications are subject to peer review.

Letters to the Editor may be considered for publication if they are of broad interest to dental traumatology. They may deal with material in papers already published in Dental Traumatology or they may raise new issues, but they should have important implications for dental traumatology.

Meetings: advance information about and reports from international meetings are welcome, but should not be submitted via the online submission site – these should be sent directly to the Editorial Office: EDToffice@wiley.com

4. PREPARING THE SUBMISSION
Cover Letters

Cover letters are not mandatory; however, they may be supplied at the author’s discretion.

Parts of the Manuscript

The manuscript should be submitted in separate files: title page; main text file; figures.

Title Page

The title page should contain:

1. A short informative title containing the major key words. The title should not contain abbreviations (see Wiley's best practice SEO tips) and should not be a question about the aim. The title should not be a statement of the results or conclusions;
2. A short running title of less than 60 characters;
3. The full names of the authors;
4. The author's institutional affiliations where the work was conducted, with a footnote for the author’s present address if different from where the work was conducted;
5. Acknowledgments.

Authorship

Please refer to the journal’s authorship policy the Editorial Policies and Ethical Considerations section for details on eligibility for author listing.

Acknowledgments

Contributions from anyone who does not meet the criteria for authorship should be listed, with permission from the contributor, in an Acknowledgments section. Financial and material support should also be mentioned. Thanks to anonymous reviewers are not appropriate.

Conflict of Interest Statement

Authors will be asked to provide a conflict of interest statement during the submission process. For details on what to include in this section, see the section ‘Conflict of Interest’ in the Editorial Policies and Ethical Considerations section below. Submitting authors should ensure they liaise with all co-authors to confirm agreement with the final statement.

Main Text File

As papers are double-blind peer reviewed, the main text file should not include any information that might identify the authors.

The main text file should be presented in the following order:

1. Title, abstract, and key words;
2. Main text;
3. References;
4. Tables (each table complete with title and footnotes);
5. Figure legends.

Do not use any sub-headings within the above sections.

The text in the main document should be double-spaced.

Figures and supporting information should be supplied as separate files.

Abstract

The abstract is limited to 300 words in length and should contain no abbreviations. The abstract should be included in the manuscript document uploaded for review as well as inserted separately where specified in the submission process. The abstract should convey a brief background statement plus the essential purpose and message of the paper in an abbreviated form. For Original Scientific Articles, the abstract should be structured with the following headings: Background/Aim, Material and Methods, Results, and Conclusions. For other article types (e.g. Case Reports, Reviews Papers, Short Communications) headings are not required and the Abstract should be in the form of a paragraph that briefly summarizes the paper.

Keywords

Please provide 3-6 keywords. Keywords should be carefully chosen to ensure they reflect the content of the manuscript.

Main Text of Original Articles

- As papers are double-blind peer reviewed, the main text file should not include any information that might identify the authors.
- The main text should be divided into the following sections: Introduction, Material and Methods, Results and Discussion.
    - ***Introduction:*** This section should be focused, outlining the historical or logical origins of the study. It should not summarize the results and

exhaustive literature reviews are inappropriate. Give only strict and pertinent references and do not include data or conclusions from the work being reported. The introduction should close with an explicit, but brief, statement of the specific aims of the investigation or hypothesis tested. Do not include details of the methods in the statement of the aims.

  - ***Materials and Methods:*** This section must contain sufficient detail such that, in combination with the references cited, all clinical trials and experiments reported can be fully reproduced. As a condition of publication, authors are required to make materials and methods used freely available to academic researchers for their own use. Describe your selection of observational or experimental participants clearly. Identify the method, apparatus and procedures in sufficient detail. Give references to established methods, including statistical methods, describe new or modified methods. Identify precisely all drugs used by their generic names and route of administration.

    If a method or tool is introduced in the study, including software, questionnaires, and scales, the author should state the license this is available under and any requirement for permission for use. If an existing method or tool is used in the research, the authors are responsible for checking the license and obtaining the permission. If permission was required, a statement confirming permission should be included in the Methods and Materials section.
  - ***Results*** should clearly and simply present the observations/results without reference to other literature and without any interpretation of the data. Present the results in a logical sequence in the text, tables and illustrations giving the main or most important findings first. Do not duplicate data in graphs and tables.
  - ***Discussion*** usually starts with a brief summary of the major findings. Repetition of parts of the Introduction or of the Results sections should be avoided. Statements and interpretation of the data should be appropriately supported by original references. A comment on the potential clinical relevance of the findings should be included. The Discussion section should end with a brief conclusion, but the conclusion should not be a repeat of the results and it should not extrapolate beyond the findings of the study. Link the conclusions to the aim of the study. Do not use sub-headings in the Discussion section, The Discussion should flow from one paragraph to the next in a cohesive and logical manner.

- **Randomised control clinical trials** should be reported using the Preferred Reporting Items for Randomized Trials in Endodontics (PRIRATE) 2020 guidelines. A PRIRATE checklist and flowchart (as a Figure) should also be completed and included in the submission material. The PRIRATE 2020 checklist and flowchart can be downloaded from: http://pride-endodonticguidelines.org/pirate/

  It is recommended that authors consult the following papers, which explains the rationale for the PRIRATE 2020 guidelines and their importance when writing manuscripts:

-
    - Nagendrababu V, Duncan HF, Bjørndal L, Kvist T, Priya E, Jayaraman J, Pulikkotil SJ, Pigg M, Rechenberg DK, Vaeth M, Dummer P. PRIRATE 2020 guidelines for reporting randomized trials in Endodontics: a consensus-based development. Int Endod J. 2020 Mar 20. doi: 10.1111/iej.13294. (https://onlinelibrary.wiley.com/doi/abs/10.1111/iej.13294)
    - Nagendrababu V, Duncan HF, Bjørndal L, Kvist T, Priya E, Jayaraman J, Pulikkotil SJ, Dummer P. PRIRATE 2020 guidelines for reporting randomized trials in Endodontics: Explanation and elaboration. Int Endod J. 2020 April 8. doi: 10.1111/iej.13304 (https://onlinelibrary.wiley.com/doi/abs/10.1111/iej.13304)

Main Text of Review Articles

- As papers are double-blind peer reviewed, the main text file should not include any information that might identify the authors.
- The main text should comprise an introduction and a running text structured in a suitable way according to the subject treated. A final section with conclusions may be added.
- The main text should be double-spaced.

Main Text of Case Studies

Case reports should be written using the Preferred Reporting Items for Case reports in Endodontics (PRICE) 2020 guidelines. A PRICE checklist and flowchart (as a Figure) should also be completed and included in the submission material. The PRICE 2020 checklist and flowchart can be downloaded from: http://pride-endodonticguidelines.org/price/.

It is recommended that authors consult the following papers, which explains the rationale for the PRICE 2020 guidelines and their importance when writing manuscripts:

- Nagendrababu V, Chong BS, McCabe P, Shah PK, Priya E, Jayaraman J, Pulikkotil SJ, Setzer FC, Sunde PT, Dummer PMH. PRICE 2020 guidelines for reporting case reports in Endodontics: a consensus-based development. Int Endod J. 2020 Feb 23. doi: 10.1111/iej.13285. (https://www.ncbi.nlm.nih.gov/pubmed/32090342)
- Nagendrababu V, Chong BS, McCabe P, Shah PK, Priya E, Jayaraman J, Pulikkotil SJ, Dummer PMH. PRICE 2020 guidelines for reporting case reports in Endodontics: Explanation and elaboration. Int Endod J. (https://onlinelibrary.wiley.com/doi/abs/10.1111/iej.13300)

References

All references should be numbered consecutively in order of appearance and should be as complete as possible. In text citations should be superscript numbers. Journal titles must be abbreviated; correct abbreviations may be found in the following: MEDLINE, Index Medicus, or CalTech Library.

Submissions are not required to reflect the precise reference formatting of the journal (use of italics, use of capital letters, bold etc.). However it is important that all key elements of each reference are included. Please see below for examples of reference content requirements.

For more information about this reference style, please see the Vancouver Reference Style Guide.

Reference examples follow:

Journal Articles

Lam R, Abbott PV, Lloyd C, Lloyd CA, Kruger E, Tennant M. Dental trauma in an Australian Rural Centre. Dent Traumatol 2008; 24: 663-70.

Text book chapters

Andreasen J, Andreasen F. Classification, etiology and epidemiology. IN: Andreasen JO, Andreasen FM, eds. Textbook and Color Atlas of Traumatic Injuries to the Teeth. 3rd Edn. Munksgaard, Copenhagen. 1994;151-80.

Thesis or Dissertation

Lauridsen, E. Dental trauma – combination injuries. Injury pattern and pulp prognosis for permanent incisors with luxation injuries and concomitant crown fractures. Denmark: The University of Copenhagen. 2011. PhD Thesis.

Corporate Author

European Society of Endodontology. Quality guidelines for endodontic treatment: consensus report of the European Society of Endodontology. Int Endod J 2006:39;921-30.

American Association of Endodontists. The treatment of traumatic dental injuries. Available at: URL: 'http://www.aae.org/uploadedfiles/publications_and_research/newsletters/endodontics_colleagues_for_excellence_newsletter/ecfe_summer2014%20final.pdf'. Accessed September 2015.

Tables

Tables should be self-contained and complement, not duplicate, information contained in the text. They should be supplied as editable files, not pasted as images. Legends should be concise but comprehensive – the table, legend, and footnotes must be understandable without reference to the text. All abbreviations must be defined in footnotes. Footnote symbols: †, ‡, §, ¶, should be used (in that order) and *, **, *** should be reserved for P-values. Statistical measures such as SD or SEM should be identified in the headings.

Figure Legends

Legends should be concise but comprehensive – the figure and its legend must be understandable without reference to the text. Include definitions of any symbols used and define/explain all abbreviations and units of measurement.

Figures

Although authors are encouraged to send the highest-quality figures possible, for peer-review purposes, a wide variety of formats, sizes, and resolutions are accepted.

Click here for the basic figure requirements for figures submitted with manuscripts for initial peer review, as well as the more detailed post-acceptance figure requirements.

Color Figures. Figures submitted in color will be reproduced in colour online. Please note, however, that it is preferable that line figures (e.g. graphs and charts) are supplied in black and white so that they are legible if printed by a reader in black and white.

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General Style Points

The following points provide general advice on formatting and style.

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- As *Dental Traumatology* is an international journal with wide readership from all parts of the world, the **FDI Tooth Numbering system** MUST be used. This system uses two digits to identify teeth according to quadrant and tooth type. The first digit refers to the quadrant and the second digit refers to the tooth type – for example: tooth 11 is the maxillary right central incisor and tooth 36 is the mandibular left first molar. Alternatively, the tooth can be described in words. Other tooth numbering systems will not be accepted.
- **Numbers:** Numbers under 10 are spelt out as words, and not shown as numerals, except for: measurements with a unit (8mmol/l); age (6 weeks old), or lists with other numbers (11 dogs, 9 cats, 4 gerbils).
- **When referring to a figure**, spell the word out (e.g. Figure 2 shows the patient's injuries on initial presentation). When referring to a figure at the end of

a sentence, enclose it in parentheses - e.g. *The patient's maxillary central incisor was repositioned and splinted* (Figure 5).

- **Page numbering:** During the editorial process, reviewers and editors frequently need to refer to specific portions of the manuscript, which is difficult unless the pages are numbered. Hence, authors should number all of the pages consecutively at the bottom of the page.
- Scientific papers should not be written in the 1st person – that is, avoid using "we", "our", etc. As examples, use words such as the 'current study", "the results", "samples were tested", instead of "our study", "our results", "we tested", etc.
- Care must be taken with the use of tense (usually the past tense is the most appropriate).
- Care must be taken with the use of singular and plural words.
- **Trade Names:** Chemical substances should be referred to by the generic name only. Trade names should not be used. Drugs should be referred to by their generic names. If proprietary drugs have been used in the study, refer to these by their generic name, mentioning the proprietary name and the name and location of the manufacturer in parentheses.

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Peer Review and Acceptance

The acceptance criteria for all papers are the quality and originality of the research and its significance to journal readership. Manuscripts are double-blind peer reviewed, hence, the names of the reviewers will not be disclosed to the author(s) who have submitted the paper and the name(s) of the author(s) will not be disclosed to the reviewers.

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Papers will only be sent to review if the Editor-in-Chief determines that the paper meets the appropriate quality and relevance requirements.

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Suppliers of materials should be named and their location (town, state/county, country) included.

Sequence Data

Nucleotide sequence data can be submitted in electronic form to any of the three major collaborative databases: DDBJ, EMBL, or GenBank. It is only necessary to submit to one database as data are exchanged between DDBJ, EMBL, and GenBank on a daily basis. The suggested wording for referring to accession-number information is: ‘These sequence data have been submitted to the DDBJ/EMBL/GenBank databases under accession number U12345’. Addresses are as follows:

- DNA Data Bank of Japan (DDBJ): www.ddbj.nig.ac.jp
- EMBL Nucleotide Archive: ebi.ac.uk/ena
- GenBank: www.ncbi.nlm.nih.gov/genbank

Proteins sequence data should be submitted to either of the following repositories:

- Protein Information Resource (PIR): pir.georgetown.edu
- SWISS-PROT: expasy.ch/sprot/sprot-top

Conflict of Interest

The journal requires that all authors disclose any potential sources of conflict of interest. Any interest or relationship, financial or otherwise that might be perceived as influencing an author's objectivity is considered a potential source of conflict of interest. These must be disclosed when directly relevant or directly related to the work that the authors describe in their manuscript. Potential sources of conflict of interest include, but are not limited to: patent or stock ownership, membership of a company board of directors, membership of an advisory board or committee for a company, and consultancy for or receipt of speaker's fees from a company. The existence of a conflict of interest does not preclude publication. If the authors have no conflict of interest to declare, they must also state this at submission. It is the responsibility of the corresponding author to review this policy with all authors and collectively to disclose with the submission ALL pertinent commercial and other relationships.

Dental Traumatology requires Conflict of Interest forms from all authors. The corresponding author must upload completed CoI forms for all authors when submitting the manuscript.

You can **download the Conflict of Interest Disclosure Form here**.

Funding

Authors should list all funding sources in the Acknowledgments section. Authors are responsible for the accuracy of their funder designation. If in doubt, please check the Open Funder Registry for the correct nomenclature:
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Authorship

The list of authors should accurately illustrate who contributed to the work and how. All those listed as authors should qualify for authorship according to the following criteria:

1. Have made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; and
2. Been involved in drafting the manuscript or revising it critically for important intellectual content; and
3. Given final approval of the version to be published. Each author should have participated sufficiently in the work to take public responsibility for appropriate portions of the content; and
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Dental Traumatology expects that data supporting the results in the paper will be archived in an appropriate public repository. Authors are required to provide a data availability statement to describe the availability or the absence of shared data. When data have been shared, authors are required to include in their data availability statement a link to the repository they have used, and to cite the data they have shared. Whenever possible the scripts and other artefacts used to generate the analyses presented in the paper should also be publicly archived. If sharing data compromises ethical standards or legal requirements then authors are not expected to share it.

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8. POST PUBLICATION

Access and sharing

When the article is published online:

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- The link to the published article can be shared through social media.

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- The corresponding author and co-authors can nominate up to ten colleagues to receive a publication alert and free online access to the article.

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ANEXO 3

Certificado de revisão da língua inglesa e normas do periódico escolhido:

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Editor's report

I have provided feedback on your manuscript through specific comments along with ratings for relevant sections. The key below the table explains my ratings. I hope you find my feedback useful.

Section	Rating
Title An effective title is concise while being representative.	★★★

Abstract ★★★

A good abstract explains the aims of the research, how these were met, and the main findings.

Introduction ★★★

This section should set the context for the study, clearly state the research objective, and establish the significance of the study.

Materials and methods ★★★

This section should completely describe all methods, techniques, and instruments used. This includes ethical considerations.

Results and discussion ★★★

These sections should present the data and findings in a clear and unbiased manner, and address the objective or research question stated in the introduction.

Conclusions ★★★

A good concluding section notes the limitations of the study. It should mention the scope for further research as well as the implications/application of the study.

Tables and figures ★★★

The tables and figures should present data clearly, should be referenced in and correspond with the text.

★★★ This section required only a few revisions.
★★ Most parts of this section required revision.
★ The entire section required significant revision. Please go through my comments/changes carefully.

Comments

SCOPE

Since the target journal publishes research on dental trauma, your paper matches the scope of the target journal.

NOVELTY OF THE STUDY

The aim of the study, i.e., the attempt to use FEA to assess the biomechanical characteristics of dental traumatic injuries and their effects on the supporting tissues, is well-defined. Since you have also clarified the state of the literature on this topic, no additional changes are required to clarify the novelty of the study.

RELEVANCE AND CONTRIBUTION OF THE STUDY

This study provides useful data outlining how FEA can be used as proxy for actual in vivo analyses of dental trauma and clarified the influence of these injuries on various dental tissues. Therefore, your paper presents relevant research that might be of clinical value.

SUBMISSION READINESS

The manuscript has been checked for language, clarity, grammar, and flow. I have made changes wherever necessary to ensure that the language quality of the paper is ready for submission.

Title

The title was clear and needed no major revisions.

Abstract

The abstract provides an independent summary of the study. However, it required extensive revisions to meet the journal's word limit.

Introduction

The introduction is sufficiently brief and concise. It provides the context for the study and outlines the need for the current study. Citations have also been added wherever appropriate. However, it needs some minor deletions to meet the journal's word limit.

Methods

The methods section contains all the important details for researchers to reproduce the study.

Results

The results are presented well. No additional changes are required in it.

Discussion

This section discusses the results in sufficient detail and adequately links them to published literature. Please consider providing the limitations of the study, which is looked upon favorably during peer review.

Quick tip

Guideline

Redundancy, that is, the unnecessary repetition of words or ideas, should be avoided in academic writing.

Explanation

In academic writing, ideas need to be conveyed as concisely as possible and redundant expressions should be avoided.

For example, the word "per," which typically implies "for each," is used to express rates and ratios. In the sentence "The speed of the vehicle was 90 miles per 1 hour," the use of "per" implies that the vehicle covered a distance of 90 miles in one hour. Therefore, the number "1" is redundant.

Correct sentence: "The speed of the vehicle was 90 miles per hour."

APÊNDICE “A”

Carta de apresentação do artigo (Cover Letter) para submissão ao periódico científico escolhido:

September 24, 2020

Professor Paul V. Abbott AO BDSc, MDS, FRACDS (Endo)
Editor-in-Chief
Dental Traumatology

Dear Professor Abbott:

I wish to submit an original article for publication in *Dental Traumatology*, titled “A three-dimensional finite element analysis of permanent maxillary central incisors in different stages of root development and trauma settings.” The paper was coauthored by Ana Cláudia Dezzen-Gomide, Marco Aurélio de Carvalho, Priscilla Cardoso Lazari-Carvalho, Helder Fernandes de Oliveira, Altair A Del Bel Cury and Fernanda Paula Yamamoto-Silva.

Although numerous studies have performed observational and in silico investigations of dental trauma, the biomechanical characteristics of dental traumatic injuries and their reactions with dental supportive tissues, especially for teeth with an open apex, have not been adequately addressed in the literature. This study attempted to address this gap in the literature by performing a three-dimensional (3D) finite element analysis (FEA) of permanent maxillary central incisors in different stages of root development subjected to buccal and incisal trauma. We believe that our study makes a significant contribution to the literature because the findings highlight the importance of the trauma direction in the effects on dental tissues and also highlight how these effects differ depending on the stage of root development.

Further, we believe that this paper will be of interest to the readership of your journal because the use of FEA for such analyses represents a viable alternative to in vivo assessments, and the findings presented herein will be useful for the management of dental traumatic injuries in the age group that is most susceptible to these injuries.

This manuscript has not been published or presented elsewhere in part or in entirety and is not under consideration by another journal. The study design was approved by the appropriate ethics review board. We have read and understood your journal’s policies, and we believe that neither the manuscript nor the study violates any of these. There are no conflicts of interest to declare.

Thank you for your consideration. I look forward to hearing from you.

Sincerely,

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