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RESISTÊNCIA À FRATURA DE PRÉ-MOLARES TRATADOS ENDODONTICAMENTE VARIANDO INCLINAÇÃO DE CARGA, ATIVAÇÃO E VOLUME DE HIPOCLORITO DE SÓDIO A 2,5%

PONTA GROSSA
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Tese apresentada para a obtenção do título de Doutor em Odontologia, na Universidade Estadual de Ponta Grossa. Área de concentração: Clínica Integrada – Linha de Pesquisa: Etiologia, diagnóstico e tratamento das doenças bucais.

Orientador: Prof. Dr. Alfonso Sánchez Ayala.

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MARIANNA MAFUZO WENDLING

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Tese apresentada ao Programa de Pós-graduação Stricto sensu em Odontologia da Universidade Estadual de Ponta Grossa, como requisito parcial à obtenção do título de Doutor em Odontologia, área de concentração em Clínica Integrada, linha de pesquisa de Etiologia, diagnóstico, e tratamento das doenças bucais.

Ponta Grossa, 25 de março de 2024.

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Profª. Drª. Ana Paula Gebert de Oliveira Franco
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Dedico este trabalho aos meus pais Anderson e Adriane,

Ao meu irmão Caio.

DADOS CURRICULARES

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RESUMO

Wendling, M.M **Resistência à fratura de pré-molares tratados endodonticamente variando inclinação de carga, ativação e volume de hipoclorito de sódio a 2,5%.** [Tese] Doutorado em Odontologia. Ponta Grossa: Universidade Estadual de Ponta Grossa; 2024.

OBJETIVO: Avaliar a influência da agitação e volumes de hipoclorito de sódio 2,5% na resistência dental na oclusão (90º) e lateralidade (30º). MATERIAL E MÉTODOS: 80 pré-molares foram preparados endodonticamente usando lima 40/0.05 ProDesign Logic 2 (Easy Equipamentos Odontológicos, Belo Horizonte, Brasil) e divididos em quatro grupos. Cada grupo (n=20) receberam um protocolo químico. Grupo 1: Irrigação convencional (15 mL); Grupo 2: Irrigação convencional (30 mL); Grupo 3: EasyClean (15 mL); Grupo 4: EasyClean (30 mL). As amostras foram montadas e divididas em angulações de 90° e 30° (n=10) para os testes de compressão e os fatores que contribuem para a fratura foram analisados, incluindo carga de fratura, estresse, deformação e deslocamento. RESULTADOS: duas ANOVA 2-vias foram conduzidas para os fatores irrigação e volume, examinando os desfechos em 90º e 30º. A média de fratura para volume em 90º foi 731 N ± 245 para 30 mL e 445 N ± 137 para 15 mL. Os valores de estresse foram 0.242 N/mm^2 ± 0.0882 para 30 mL e 0.138 N/mm^2 ± 0.0508 para 15 mL. Deformação e deslocamento não apresentaram significância (p=0.137), assim como o fator irrigação (p=0.831). A média de fratura para volume em 30º foi 828 N ± 189 para 30 mL e 700 N ± 223 para 15 mL. Os valores de *stress* foram 0.281 N/mm^2 ± 0.0641 para 30 mL e 0.238 N/mm^2 ± 0.0756 para 15 mL. Deformação e deslocamento não obtiveram significância (p=0.972). O fator Irrigação não apresentou significância quanto a carga de fratura e estresse (p=0.308). Enquanto deformação, foi 11.38 % ± 3.55 para EasyClean e 9.06 % ± 2.27 para irrigação convencional, e deslocamento foi 2.84 mm ± 0.887 para EasyClean e 2.26 mm ± 0.568 para irrigação convencional. Para ANOVA 3-vias, volume e carga foram estatisticamente significativos para os valores de carga de fratura e estresse (p<0,001), enquanto irrigação não houve influência (p=0.960 e p=0.585, respectivamente). A irrigação mostrou-se estatisticamente significativa para deformação e deslocamento (p=0.009), enquanto volume não obteve influência (p=0.357 e p=0.346, respectivamente). CONCLUSÃO: A carga oclusal aumentou o risco de fratura, enquanto maior volume e agitação com EasyClean não enfraqueceram os dentes.

Key Words: Análise do Estresse Dentário; Endodontia; Força Compressiva; Irrigantes do Canal Radicular; Hipoclorito de Sódio; Tratamento do Canal Radicular.

ABSTRACT

Wendling, M.M. **Fracture resistance of endodonticly treated premolars varying load, activation and volume of 2.5% sodium hypochlorite.** [Thesis] Doctor in Dentistry. Ponta Grossa: State University of Ponta Grossa; 2024.

Introduction: The influence of agitation and volumes of 2,5% sodium hypochlorite on dental resistance at occlusion (90º) and laterality (30º) loads. METHODS: Eighty premolars were prepared using a 40/0.05 ProDesign Logic 2 file (Easy Equipamentos Odontológicos, Belo Horizonte, Brazil) and divided into four groups. Each group (n=20) received a unique chemical protocol. Group 1: Conventional irrigation (15 mL); Group 2: Conventional irrigation (30 mL); Group 3: EasyClean (15 mL); Group 4: EasyClean (30 mL). The specimens were mounted and divided into 90° and 30° angles (n=10) for compression tests, and the factors contributing to fracture were analyzed, including fracture load, stress, strain, and displacement. RESULTS: Two tests of two-way ANOVA analyses were conducted for the irrigation and volume factors, examining outcomes at 90º and 30º. The mean volume fracture load at 90º was 731 N ± 245 for 30 mL and 445 N ± 137 for 15 mL. The stress values were 0.242 N/mm^2 ± 0.0882 for 30 mL and 0.138 N/mm^2 ± 0.0508 for 15 mL. Strain and displacement showed no significance (p=0.137), as well as irrigation factor (p=0.831). The mean volume fracture load at 30º was 828 N ± 189 for 30 mL and 700 N ± 223 for 15 mL. The stress values were 0.281 N/mm^2 ± 0.0641 for 30 mL and 0.238 N/mm^2 ± 0.0756 for 15 mL. Strain and displacement showed no significance (p=0.972). The irrigation factor, fracture load and stress did not show significance (p=0.308). The strain values were 11.38 % ± 3.55 for EasyClean and 9.06 % ± 2.27 for conventional irrigation, while the displacement was 2.84 mm ± 0.887 for EasyClean and 2.26 mm ± 0.568 for conventional irrigation. For the 3-way ANOVA, volume and load were found to be statistically significant for fracture load and stress values (p<0.001), while irrigation had no influence (p=0.960 and p=0.585, respectively). Irrigation was found to be statistically significant for strain and displacement (p=0.009), while volume had no influence (p=0.357 and p=0.346, respectively). CONCLUSION: Occlusal load tended to increase the risk of fracture, while larger volume and agitation with EasyClean did not weaken the teeth.

Key Words: Compressive Strength; Endodontics; Dental Stress Analysis; Root Canal Irrigants; Root Canal Therapy; Sodium Hypochlorite.

LISTA DE FIGURAS

LISTA DE GRÁFICOS

LISTA DE TABELAS

LISTA DE ABREVIATURAS

ANOVA	Análise de variância
CT	Comprimento de trabalho
EDTA	Ácido etilenodiaminoteracético
mL	Mililitro (s)
mm	Milímetro (s)
mm^2	Milímetro (s) quadrado (s)
mW/cm2	Miliwatts por centímetro (s) quadrado (s)
N	Newton (s)
NaOCl	Hipoclorito de sódio
SAF	Self-Adjusting File

SUMÁRIO

1 INTRODUÇÃO

A fratura dentária é um fenômeno multifatorial, ocorrendo frequentemente em dentes tratados endodonticamente em uma frequência que varia de 3,7% a 25%.[1] Está associada a vários fatores de risco para fratura dentária, como aumento do canal radicular, propriedades dos irrigantes endodônticos, perda da estrutura dentária, canais ovais, atividade parafuncional e pressão excessiva aplicada durante a obturação do canal.[1–3] Os dentes tratados endodonticamente também são geralmente considerados mais suscetíveis à carga oclusal do que os dentes vitais.[1]

Nos últimos anos, houve um aumento na variedade e qualidade das ligas de níquel-titânio usadas em instrumentos rotatórios devido à sua redução do tempo de trabalho e previsibilidade, evitando iatrogenias.[4,5] Enquanto isso, devido à morfologia como canais laterais, istmos, deltas apicais e achatamento, esses instrumentos são incapazes de alcançar todas as superfícies, deixando entre 10% e 80% da área intocada.[6–9] Dada essa restrição, é crucial complementar a instrumentação mecânica e aumentar os efeitos antimicrobianos usando agentes irrigadores como o hipoclorito de sódio (NaOCl).[6,9,10]

O hipoclorito de sódio é o agente irrigante mais comumente usado na endodontia devido aos seus efeitos antibacterianos de amplo espectro[11–15] e sua capacidade de dissolver tecido orgânico.[11–13,15,16] No entanto, impacta negativamente sobre as características físicas e mecânicas da dentina devido à degradação de compostos orgânicos incluindo fibras de colágeno e causando alterações irreversíveis, como redução da resistência à flexão, módulo de elasticidade e microdureza, levando a um aumento da incidência de fraturas.[11,12,14,17–21]

Sabe-se que a eficácia do NaOCl é diretamente proporcional à quantidade de clorina disponível, e diminui rapidamente através da interação com tecidos e microrganismos, exigindo renovação constante.[12,16,19] Consequentemente, a fim conseguir a eficácia alta da limpeza, os volumes maiores de NaOCl devem distribuídos por toda parte do canal.[19] No entanto, o tempo de preparação com sistemas rotatórios implica em menor volume e renovação menos frequente dos irrigantes, o que reduz a eficácia antimicrobiana.[19,22]

Um novo sistema chamado EasyClean, desenvolvido pela Easy Equipamentos Odontológicos LTDA em Belo Horizonte, Brasil, foi introduzido para agitar soluções irrigantes e melhorar a limpeza de canais.[23,24] Consiste em um dispositivo de polímero projetado para operar usando cinemática reciprocante ou contínua, com um tamanho de 25/.04.[23,24] Obteve a mesma eficácia na remoção de *debris* que outros métodos de potencialização, como a irrigação passiva ultrassônica, o sistema EndoVac e Self-Adjusting File (SAF).[25,26]

A potencialização das soluções irrigadoras é um passo importante durante o tratamento endodôntico, que deve melhorar a limpeza do sistema de canais. No entanto, não se sabe se a agitação do hipoclorito de sódio tem influência na resistência dos dentes. Portanto, o objetivo deste estudo é avaliar a influência do EasyClean em diferentes volumes de NaOCl na resistência dental em cargas de lateralidade e oclusão. A hipótese foi que a agitação com EasyClean fica mais propensa à fratura, assim como o maior volume utilizado.

2 OBJETIVOS

2.1 OBJETIVO GERAL

Avaliar a resistência (resistência a fratura, estresse, deformação e deslocamento) em oclusão (90º) e lateralidade (30º) de pré-molares uniradiculares preparados endodonticamente com instrumentos de rotação contínua usando diferentes protocolos de irrigação com hipoclorito de sódio a 2,5%.

2.2 OBJETIVOS ESPECÍFICOS

- Comparar a potencialização do hipoclorito de sódio com EasyClean com a técnica tradicional de irrigação (seringa e agulha);
- Avaliar a variação dos volumes (15 mL e 30 mL) de hipoclorito de sódio;
- Avaliar a influência das incidências aplicadas em oclusão e lateralidade na resistência dental.

3 MATERIAL E MÉTODOS

Depois de aprovado pelo comitê de ética (Registro no. 45555621.2.0000.0105), uma amostra de conveniência contendo 80 pré-molares foram obtidos do banco de dentes da Universidade Estadual de Ponta Grossa. Somente dentes extraídos com um único canal, sem tratamento endodôntico prévio, fraturas ou rizogênese incompleta foram selecionados e armazenados em água destilada.

O tamanho da amostra final foi determinado usando *a priori: computed required sample size* com G*Power (3.1.9.6, Universidade Düsseldorf, Alemanha) para medidas repetidas bicaudal ANOVA, com quatro grupos independentes, visando uma potência de 0,80 e um erro alfa de 0,05. O tamanho do efeito de 0,310 resultou em um tamanho amostral de setenta e seis.

As cavidades de acesso foram abertas com uma broca esférica 1012 (KG Sorensen, Cotia, Brasil) e os canais foram localizados e explorados usando um arquivo K #10 (Dentsply Maillefer, Ballaigues, Suíça) (Figura 1A e 1B). Os comprimentos de trabalho (CT) foram estabelecidos a 1 mm aquém do ápice, e as raízes foram cobertas com cera para criar um sistema fechado, evitando o vazamento de soluções e simulando a presença dos tecidos apicais (Figura 1C).

As amostras foram divididas aleatoriamente em 4 grupos (n=20), cada um usando diferentes protocolos químicos, e agulha de ponta fechada 27G (Endo EZE Irrigator Tip, Ultradent, Indaiatuba, Brasil) foi colocada a até 2 mm de distância da CT.

Um único operador treinado realizou o preparo endodôntico utilizando a lima 40/0.05 Prodesign Logic 2 (Easy Equipamentos Odontológicos, Belo Horizonte, Brasil) ativado por motor elétrico (Silver Reciproc, VDW, Munique, Alemanha) em movimento rotativo no "Dr’s" programa pré-ajustado, seguindo as instruções do fabricante. A instrumentação foi realizada em terços com movimentos de entrada e saída até a CT, com a câmara pulpar preenchida com hipoclorito de sódio a 2,5%. A patência apical foi mantida durante todo o processo usando lima K #10 (Dentsply Maillefer, Ballaigues, Suíça).

3.1 PREPARO DO CANAL RADICULAR

Grupo 1 (Convencional 15 mL): Irrigação com 2,5 mL de NaOCl por 1 minuto a cada três bicadas do instrumento, totalizando 15 mL. A irrigação final foi realizada com

3 mL de 17% de EDTA por 3 minutos seguidos de 6 mL de NaOCl por 1 minuto. Entre as soluções de NaOCl e EDTA, 5 mL foi utilizado água destilada por 1 minuto.

Grupo 2 (Convencional 30 mL): Irrigação com 5 mL de NaOCl por 1 min a cada três bicadas do instrumento, totalizando 30 mL. A irrigação final foi semelhante à do grupo 1.

Grupo 3 (EasyClean 15 mL): Irrigação com 2,5 mL de NaOCl por 1 min após cada três bicadas do instrumento, totalizando 15 mL. A irrigação final foi realizada com 3 mL de 17% de EDTA por 3 minutos e 6 mL de NaOCl por 1 minuto. Cada solução final foi potencializada em 3 ciclos de 20 segundos usando EasyClean posicionado de comprimento de trabalho na função "RECIPROC ALL". Entre as soluções de NaOCl e EDTA, 5 mL foi utilizado água destilada por 1 minuto.

Grupo 4 (EasyClean 30 mL): Irrigação com 5 mL de NaOCl por 1 min após cada três bicadas do instrumento, totalizando 30 mL. A irrigação final foi semelhante à do grupo 3.

3.2 OBTURAÇÃO E RESTAURAÇÃO

Todas as amostras tiveram seus canais principais secos com cones de papel absorvente 40/0.05 (Tanari Industrial LTDA, Manacapuru, Brasil), preenchidos com guta-percha 40/0.05 (Tanari Industrial LTDA, Manacapuru, Brasil) e selados com cimento de óxido de zinco-eugenol (Endofill, Dentsply-Maillefer, Rio de Janeiro, Brasil). O excesso de obturação foi removido por meio de um calcador aquecido (Paiva, Golgran, São Caetano do Sul, Brasil) (Figura 2).

O esmalte e a dentina foram condicionados com ácido fosfórico a 37% por 30 e 15 segundos, respectivamente, e depois lavados com água por 30 segundos antes de serem secos suavemente. O adesivo fotopolimerizável Ambar (FGM Dental Products, Joinville, Brasil) foi aplicado ativamente usando um aplicador (FGM Dental Products, Joinville, Brasil), aplicado jato de ar suave e fotopolimerizado por 20 segundos a 1.100 mW/cm2 (Poly Wireless; Kavo, Joinville, Brasil). Todas as amostras foram restauradas com resina composta Z100 (3M/ESPE, St. Paul, EUA). (Figura 3).

3.3 MONTAGEM DE CORPOS DE PROVA E TESTE DE COMPRESSÃO

As superfícies radiculares foram recobertas com uma fina camada de cera, expondo 2 mm abaixo da junção cemento-esmalte, e então montadas verticalmente em resina acrílica auto-polimerizável (Vipi Flash, Vipi, Pirassununga, Brasil) no interior de cilindros de cloreto de polivinila com 25 mm de diâmetro e 25 mm de altura em (Figura 4). Após o tempo de endurecimento da resina acrílica, a cera foi removida e um material de impressão à base de silicone fluido (Perfil, Vigodent-Coltene, Rio de Janeiro, Brasil) foi usado para preencher o bloco de resina e o dente foi reinserido para simular o ligamento periodontal. Os excessos do material de moldagem foram removidos (Figura 5).

Os testes de compressão foram realizados utilizando a Máquina de Ensaio Universal (Autograph AG-I 10kN, SHIMADZU, Kyoto, Japão) (Figura 6). Uma ponta de aço inoxidável com um diâmetro de 1 mm foi posicionada no centro da superfície oclusal a 90º e 30º ao longo eixo, com velocidade de 1 mm/min (Figura 7). Os resultados foram coletados e valores foram obtidos para as quatro determinantes da resistência à fratura: carga de fratura (a força necessária para a deslocamento (o deslocamento vetorial do objeto em mm); e deformação (deformação sob tensão, medida em %).

3.4 ANÁLISE ESTATÍSTICA

Os dados foram explorados utilizando o *software* IBM® SPSS® Statistics (versão 25, IBM: NYSE, Armonk, NY, EUA) e todas as inferências foram realizadas com testes de duas caudas, considerando um nível de significância de 95% (α = 0,05) e um poder de teste de 80% (β = 0,2). Os pressupostos de normalidade e homocedasticidade das variáveis foram verificados utilizando-se o teste de Shapiro-Wilk e o teste de Levene, respectivamente.

Uma análise de variância de duas vias ANOVA foi realizada para avaliar o impacto dos fatores de irrigação e volume na variabilidade da resistência dental: carga de fratura, deslocamento, estresse e deformação para cada incidência de carga. Uma ANOVA de três vias também foi aplicada para analisar o comportamento das variáveis relacionadas ao impacto das cargas.

4 ARTIGO

4.1 FRACTURE RESISTANCE OF ENDODONTICALLY TREATED PREMOLARS VARYING LOAD, ACTIVATION AND VOLUME OF SODIO HYPOCHLORITE

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ABSTRACT

Introduction: The influence of agitation and volumes of sodium hypochlorite on dental resistance at occlusion (90º) and laterality (30º) loads. METHODS: Eighty premolars were prepared using a 40/0.05 ProDesign Logic 2 file (Easy Equipamentos Odontológicos, Belo Horizonte, Brazil) and divided into four groups. Each group (n=20) received a unique chemical protocol. Group 1: Conventional irrigation (15 mL); Group 2: Conventional irrigation (30 mL); Group 3: EasyClean (15 mL); Group 4: EasyClean (30 mL). The specimens were mounted and divided into 90° and 30° angles (n=10) for compression tests, and the factors contributing to fracture were analyzed, including fracture load, stress, strain, and displacement. RESULTS: Two tests of two-way ANOVA analyses were conducted for the irrigation and volume factors, examining outcomes at 90º and 30º. The mean volume fracture load at 90º was 731 N ± 245 for 30 mL and 445 N ± 137 for 15 mL. The stress values were 0.242 N/mm^2 ± 0.0882 for 30 mL and 0.138 N/mm^2 ± 0.0508 for 15 mL. Strain and displacement showed no significance (p=0.137), as well as irrigation factor (p=0.831). The mean volume fracture load at 30º was 828 N ± 189 for 30 mL and 700 N ± 223 for 15 mL. The stress values were 0.281 N/mm^2 ± 0.0641 for 30 mL and 0.238 N/mm^2 ± 0.0756 for 15 mL. Strain and displacement showed no significance (p=0.972). The irrigation factor, fracture load and stress did not show significance (p=0.308). The strain values were 11.38 % ± 3.55 for EasyClean and 9.06 % ± 2.27 for conventional irrigation, while the displacement was 2.84 mm ± 0.887 for EasyClean and 2.26 mm ± 0.568 for conventional irrigation. For the 3-way ANOVA, volume and load were found to be statistically significant for fracture load and stress values ($p<0.001$), while irrigation had no influence ($p=0.960$ and $p=0.585$, respectively). Irrigation was found to be statistically significant for strain and displacement ($p=0.009$), while volume had no influence ($p=0.357$ and $p=0.346$, respectively). CONCLUSION: Occlusal load tended to increase the risk of fracture, while larger volume and agitation with EasyClean did not weaken the teeth.

Key Words: Compressive Strength; Endodontics; Dental Stress Analysis; Root Canal Irrigants; Root Canal Therapy; Sodium Hypochlorite.

Introduction

Dental fracture is a multifactorial phenomenon, often occurring in endodontically treated teeth at a frequency ranging from 3.7% to 25%.[1] It is associated with several risk factors for dental fracture, such as enlargement of the root canal, properties of endodontic irrigants, loss of tooth structure, oval canals, parafunctional activity, tooth location and excessive pressure applied during root canal obturation.[1–3] Endodontically treated teeth are also generally considered to be more susceptible to occlusal load than vital teeth.[1]

In recent years, there has been an increase in the variety and quality of nickel-titanium alloys used in rotary instruments due to their reduction the working time and predictable avoiding iatrogenic risks.[4,5] Meanwhile, due to canal morphology such lateral canal, isthmuses, apical deltas and flattening, these instruments are unable to reach all surfaces, leaving between 10% and 80% of the area untouched.[6–9] Given such restriction, it is crucial to complement mechanical instrumentation and enhance the antimicrobial effects by using irrigating agents such as sodium hypochlorite (NaOCl).[6,9,10]

Sodium hypochlorite is the most commonly used irrigating agent in endodontics because of its broad-spectrum antibacterial effects[11–15] and its ability to dissolve organic tissue.[11–13,15,16] However, it negatively impacts the physical and mechanical features of dentin due to the degradation of organic compounds, including collagen fibers, causing irreversible changes such as a reduction in flexural strength, elastic modulus, and microhardness, leading to an increased incidence of fractures.[11,12,14,17–21]

It is known that the efficacy of NaOCl is directly proportional to the amount of available chlorine, and it rapidly decreases through interaction with tissues and microorganisms, requiring constant renewal.[12,16,19] Therefore, in order to achieve high cleaning effectiveness, larger volumes of NaOCl should be delivered into the root canals.[19] However, the preparation time with rotatory systems implies a lower volume and less frequent renewal of irrigants, which reduces antimicrobial effectiveness.[19,22]

A new system called EasyClean, developed by Easy Equipamentos Odontológicos LTDA in Belo Horizonte, Brazil, has been introduced to agitate irrigant solutions in order to enhance the cleansing of canals.[23,24] It consists of a polymer device designed to operate using reciprocating or continuous rotation kinematics with a size of 25/.04.[23,24] It had the same effectiveness in removing debris as other activation methods, such as ultrasonic irrigation, the EndoVac system, and the Self-Adjusting File (SAF).[25,26]

The activation of solutions it is an important step during endodontic treatment, which must improve the cleanliness of the canal system. However, it is unknow whether agitation of sodium hypochlorite has an influence on tooth resistance. Therefore, the aim of this pilot study is evaluating the influence of EasyClean in different volumes of NaOCl on dental resistance at laterality and occlusion loads. The hypothesis was that the agitation with EasyClean turns more prone to fracture, as well as the largest volume used.

Methods

After approval by the ethics committee (Registration no. 45555621.2.0000.0105), a convenience sample of eighty premolars was obtained from the Tooth Tissue Bank of State University of Ponta Grossa. Only extracted teeth with a single canal, no previous endodontic treatment, no fractures, and no open apex were selected and stored in distilled water.

The sample size was determined using a priori power calculation with G*Power (3.1.9.6, Universität Düsseldorf, Germany) for two-tailed repeated measures, between-subjects ANOVA with four independent groups, aiming for a power of 0.80 and an alpha error of 0.05. The effect size of 0.310 resulted in a sample size of seventy-six.

Access cavities were opened with a spherical burr 1012 (KG Sorensen, Cotia, Brazil) and the main canals were located and explored using a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) (Figure 1A and 1B). The working lengths (WL) were established 1 mm short of the apex, and the roots were covered with wax to create a closed-end system, preventing the leakage of solutions and simulating the presence of the apical tissues (Figure 1C).

The samples were randomly divided into 4 groups (n=20), each using different chemical protocols, and a 27G closed-ended needle (Endo EZE Irrigator Tip, Ultradent, Indaiatuba, Brazil) was placed up to 2 mm short of the WL.

A single trained operator performed endodontic preparation using a 40/0.05 ProDesign Logic 2 file (Easy Equipamentos Odontológicos, Belo Horizonte, Brazil) activated by an electric motor (Silver Reciproc, VDW, Munich, Germany) in rotary motion at the “Dr’s” pre-set program, following the manufacturer’s instructions. The instrumentation was performed in thirds with in-and-out movements up to the WL, and the pulp chamber was filled with 2.5% sodium hypochlorite. Apical patency was maintained throughout the entire process using a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland).

Root Canal Preparation

Group 1: Irrigation with 2.5 mL of NaOCl for 1 minute after every three pecks of the instrument, totaling 15 mL. Final irrigation was performed with 3 mL of 17% EDTA for 3 minutes followed by 6 mL of NaOCl for 1 minute. Alternating between NaOCl and EDTA solutions, 5 mL of distilled water for 1 minute. Group 2: Irrigation with 5 mL of NaOCl for 1 min after every three pecks of the instrument, totaling 30 mL. The final irrigation was similar to that of group 1.

Group 3: Irrigation with 2.5 mL of NaOCl for 1 min after every three pecks of the instrument, totaling 15 mL. Final irrigation was performed with 3 mL of 17% EDTA for 3 minutes and 6 mL of NaOCl for 1 minute. Each final solution was activated in 3 cycles of 20 seconds using EasyClean positioned at the working length set in the “RECIPROC ALL” function. Alternating between NaOCl and EDTA solutions, 5 mL of distilled water for 1 minute.

Group 4: Irrigation with 5 mL of NaOCl for 1 min after every three pecks of the instrument, totaling 30 mL. The final irrigation was similar to that of group 3.

Sealing and restoration

All samples had their main canals dried with 40/0.05 absorbent paper points (Tanari Industrial LTDA, Manacapuru, Brazil), filled with gutta-percha 40/0.05 (Tanari Industrial LTDA, Manacapuru, Brazil), and sealed with zinc oxide-eugenol sealer (Endofill, Dentsply-Maillefer, Rio de Janeiro, Brazil). The excess obturation was removed using a heated plugger tip (Paiva, Golgran, São Caetano do Sul, Brazil) (Figure 2).

Enamel and dentin were etched with 37% phosphoric acid for 30 and 15 seconds, respectively, and then rinsed with water for 30 seconds before being gently dried. A light-polymerizing adhesive called Ambar (FGM Dental Products, Joinville, Brazil) was actively applied using a micro brush (FGM Dental Products, Joinville, Brazil), gently air thinned, and light-cured for 20 seconds at 1,100 mW/cm2 (Poly Wireless; Kavo, Joinville, Brazil). All samples were restored with direct composite resin Z100 (3M/ESPE, St. Paul, USA). (Figure 3).

Mounting of Roots and Fracture Measurement

The root surfaces were covered with a thin layer of wax, exposing 2 mm below the cementoenamel junction, and then mounted vertically in self-cured acrylic resin (Vipi Flash, Vipi, Pirassununga, Brazil) inside 25 mm diameter and 25 mm high polyvinyl chloride cylinders (Figure 4). After the specified time for the removal of the acrylic resin and wax, a fluid silicone-based impression material (Perfil, Vigodent-Coltene, Rio de Janeiro, Brazil) was used to fill the resin block, and the tooth was reinserted to simulate the periodontal ligament. The excess impression material was removed (Figure 5).

The compression tests were conducted using the Universal Testing Machine (Autograph AG-I 10kN, SHIMADZU, Kyoto, Japan) (Figure 6). A stainless-steel tip with a 1 mm diameter was positioned at the center of the occlusal surface at 90° and 30° to the long axis of the tooth in each group, while running at a crosshead speed of 1 mm/min (Figure 7). The results were collected, and values were obtained for the four determinants of fracture strength: Fracture Load (the force required for fracture occurrence, recorded in Newtons); Stress (measured in N/mm^2); Displacement (the vectorial displacement of the object in mm); and Strain (the deformation under tension, measured in %).

Statistical Analysis

Data were explored using the IBM® SPSS® Statistics software (version 25, IBM: NYSE, Armonk, NY, USA), and all inferences were carried out with two-tailed tests, considering a significance level of 95% ($\alpha = 0.05$) and a test power of 80% ($\beta = 0.2$). The normality and homoscedasticity assumptions of variables was verified using the

Shapiro-Wilk test and Levene's Test, respectively. A two-way analysis of variance (ANOVA) was conducted to assess the impact of irrigation and volume factors on the variability of fracture load, displacement, stress and strain values for each load magnitude. A three-way ANOVA was also applied to analyze the behavior of variables related to the impact of loads.

Results

Results related to loads at 90º: A two-way ANOVA analysis shows a significant effect of volume values on fracture load and stress values ($p<0.001$). The 30 mL volume exhibited the highest stress (0.242 ± 0.0882) and fracture load (730.61 ± 245) compared to the 15 mL volume (0.138 ± 0.0508) and (445.39 ± 136.63), respectively (Graph 1). The agitation of NaOCl showed no significance ($p=0.831$). No variables were found to increase susceptibility to deformation in terms of strain and displacement: irrigation ($p=0.137$) and volume ($p=0.228$).

At a 30º load, the two-way ANOVA analysis revealed that volume variation significantly affected the values of fracture load and stress ($p=0.052$), while agitation showed no influence ($p=0.308$). The 30 mL volume exhibited higher stress (0.281 ± 0.0641) and fracture load (828 ± 189) compared to the 15 mL volume (0.238 ± 0.0756) and (700 ± 223) (Graph 2A and 2B). Regarding strain and displacement, volume had no influence ($p=0.972$). However, irrigation had a statistically significant effect ($p=0.022$). EasyClean agitation resulted in higher strain and displacement values (11.38 ± 3.55 and 2.84 ± 0.887, respectively) compared to conventional irrigation (9.06 ± 2.27 and 2.26 ± 0.568, respectively) (Graph 2C and 2D). Means and standard deviation of fracture load, stress, strain and displacement at 90º and 30º are represented in tables 1 and 2.

In addition to the variables: irrigation and volume, load was included to conduct a three-way ANOVA analysis. For the fracture load and stress values, irrigation had no influence ($p=0.960$ and $p=0.585$, respectively), while volume and load were statistically significant in determining the susceptibility to fracture in the samples ($p<0.001$). The occurrence of fracture load had a significant association with volume ($p=0.001$), with 30 mL showing higher values (779 ± 221) compared to 15 mL (573 ± 223) (Graph 3A). The 30 mL volume and 30º load interference resulted in higher stress levels (0.262 ± 0.0786 and 0.259 ± 0.0726, respectively) compared to the 15 mL volume (0.188 ± 0.0812) and 90º load occlusion (0.190 ± 0.0885) (Graph 3B). Regarding strain and displacement, volume had no influence (p=0.357 and p=0.346, respectively), as well as load (p=0.498). However, the irrigation had a statistically significant effect (p=0.009). EasyClean agitation resulted in higher strain and displacement values (10.93 ± 3.92 and 2.73 ± 0.980, respectively) compared to conventional irrigation (8.87 ± 2.67 and 2.22 ± 0.668, respectively) (Graph 3C and 3D).

Discussion

Resistance to fracture is an important factor in endodontics and future rehabilitative treatments. To maintain an adequate amount of available chlorine and achieve effective cleaning, it is necessary to increase the volume while keeping NaOCl constant. This compensates for the reduced treatment time when using rotary systems.[12,16,19] Our study showed that the lower volume reduced fracture strength. However, a single study using a higher concentration of 5.25% NaOCl in a smaller sample size found that the use of the largest volume had a greater impact on fracture strength.[16] Furthermore, wasn't take into account the retention time of NaOCl as in this article. Collagen fibers are triple helical structures encapsulated within hydroxyapatite crystals, over which NaOCl has no effect.[11] Therefore, there is an indirect effect on collagen, the low molecular size hypochlorite anion contributes to a slowly dissolution of encapsulated collagen fibers, being time dependent.[11]

In addition to using instruments and chemicals during endodontic therapy, it is necessary to activate the solution to ensure the flow and distribution of irrigant occurs into the intricacies of the root canal system.[9,21] In this study, was evaluated the impact of agitation on sodium hypochlorite, which has not been previously researched. Several techniques can be used to deliver irrigant to the entire root canal system, including the conventional syringe and needle method, Passive Ultrasonic Irrigation (PUI), sonic devices, Self-Adjusting File (SAF), XP Endo finisher, EasyClean, and others. EasyClean was chosen for its similar performance compared to PUI, EndoVac, and SAF instruments, besides having affordable price, requiring the use for three times for 20 seconds each, with renewal of solution to achieve the desired results.[25,27] The principle of EasyClen device is a mechanical agitation of solutions, aiming the displacement of products adhered to canal wall.[9]

Sodium hypochlorite has a proteolytic effect due to free chlorine available, which suffers reaction of saponification, oxidizing the collagen fibers of the dentin matrix to smaller peptide chains, contributing to the alteration of the dentin's mechanical properties such as a reduction in flexural strength, elastic modulus, and microhardness.[9,11,12] Thus, it is hypothetically assumed that increasing the volume and agitation of solutions amplifies undesirable effects on dental structure, reducing its resistance to fracture.[14,21,28] However, both increasing the volume and agitation with EasyClean were not determining factors in increasing the occurrence of dental fractures in this study. The effect of increased sodium hypochlorite concentration on the mechanical properties of dental structures remains controversial and unclear,[12,14] as evidenced by our results. However, higher concentration and volume influences positively on intracanal disinfection.[22] Therefore, more studies must be conducted to elucidate matters that have not yet been covered.

In most studies on the fracture resistance of endodontically treated teeth using various protocols, the dental crown was almost always excluded from the analysis.[7,8,18,19,29–31] Despite these works adhering to methodological principles and successfully controlling the occlusal variables (by artificially eliminating variations in tooth anatomy), it is challenging to consider these results relevant to a functional environment.[32] Mastication may be divided into three series: preparatory, involving the transport of the food bolus into the oral cavity and positioning of the food; reduction, where the food is comminuted; and pre swallowing, which is the oropharyngeal accumulation period. Beside opening and fast closing phases, the reduction series includes a slow closing phase, during which the relatively large forces required for crushing and grinding food are necessary.[33]

In normocclusion, the periodontal tissues experience less stress during clenching.[34] In contrast, patients with poorly positioned teeth, a flat occlusal surface, or occluding on a single contact experience a longer pause during the reduction series at maximum intercuspation position compared to those with inter-inner slope contacts.[35] This results in a need for a more sustained biting force to compensate for the relative biomechanical inefficiency of the intermaxillary relationship.[36] Therefore, the increased fracture resistance of the 90° load can be explained. The 1 mm diameter of the tip used in the mechanical test is smaller than a premolar cusp tip. This indicates that the force applied at a 90° angle represented a deficient occlusion in a single point between completely vertical teeth. On the other hand, the force of 30° represented the average buccolingual inclination between opposing premolars.

Within the limitations of this laboratorial in vitro study, no real environmental conditions, such absence of saliva and temperature. Therefore, caution must be exercised in the interpretation of the results Therefore, more studies should be conducted in order to overcome the limitations of this study and obtain greater scientific basis to improve clinical conduct.

Conclusions

From the results of this study, we found that using a larger volume and agitation with EasyClean did not lead to tooth weakening after root canal preparation. However, a punctual 90° loading increased the tendency to fracture.

REFERÊNCIAS

1. Haupt F, Wiegand A, Kanzow P. Risk factors for and clinical presentations indicative of vertical root fracture in endodontically treated teeth: a systematic review and meta-analysis. *J Endod*. 2023;49(8):940-952. doi:10.1016/j.joen.2023.06.004
2. Sugaya T, Nakatsuka M, Inoue K, Tanaka S, Miyaji H, Sakagami R, Kawamami M. Comparison of fracture sites and post lengths in longitudinal root fractures. *J Endod*. 2015;41(2):159-163. doi:10.1016/j.joen.2014.09.017
3. KISHEN A. Mechanisms and risk factors for fracture predilection in endodontically treated teeth. *Endod Topics*. 2006;13(1):57-83. doi:10.1111/j.1601-1546.2006.00201.x
4. Siqueira Junior JF, Rôças I das N, Marceliano-Alves MF, Pérez AR, Ricucci D. Unprepared root canal surface areas: causes, clinical implications, and therapeutic strategies. *Braz Oral Res*. 2018;32(suppl 1). doi:10.1590/1807-3107bor-2018.vol32.0065
5. LAM P, PALAMARA J, MESSER H. Fracture strength of tooth roots following canal preparation by hand and rotary instrumentation. *J Endod*. 2005;31(7):529-532. doi:10.1097/01.don.0000150947.90682.a0
6. Capar ID, Altunsoy M, Arslan H, Ertas H, Aydinbelge HA. Fracture strength of roots instrumented with self-adjusting file and the protaper rotary systems. *J Endod*. 2014;40(4):551-554. doi:10.1016/j.joen.2013.08.030
7. Rodrigues RCV, Zandi H, Kristoffersen AK, Enersen M, Mdala I, Ørstavik D, Rôças IN, Siqueira JF. Influence of the apical preparation size and the irrigant type on bacterial reduction in root canal–treated teeth with apical periodontitis. *J Endod*. 2017;43(7):1058-1063. doi:10.1016/j.joen.2017.02.004

8. Rath PP, Yiu CKY, Matinlinna JP, Kishen A, Neelakantan P. The effect of root canal irrigants on dentin: a focused review. *Restor Dent Endod*. 2020;45(3). doi:10.5395/rde.2020.45.e39

9. Boutsioukis C, Arias-Moliz MT. Present status and future directions – irrigants and irrigation methods. *Int Endod J*. 2022;55(S3):588-612. doi:10.1111/iej.13739

10. Ruiz-Linares M, Aguado-Pérez B, Baca P, Arias-Moliz MT, Ferrer-Luque CM. Efficacy of antimicrobial solutions against polymicrobial root canal biofilm. *Int Endod J*. 2017;50(1):77-83. doi:10.1111/iej.12598

11. Dotto L, Sarkis Onofre R, Bacchi A, Rocha Pereira GK. Effect of Root Canal irrigants on the mechanical properties of endodontically treated teeth: a scoping review. *J Endod*. 2020;46(5):596-604.e3. doi:10.1016/j.joen.2020.01.017

12. Dutner J, Mines P, Anderson A. Irrigation trends among american association of endodontists members: a web-based survey. *J Endod*. 2012;38(1):37-40. doi:10.1016/j.joen.2011.08.013

13. Tejada S, Baca P, Ferrer-Luque CM, Ruiz-Linares M, Valderrama MJ, Arias-Moliz MT. Influence of dentine debris and organic tissue on the properties of sodium hypochlorite solutions. *Int Endod J*. 2019;52(1):114-122. doi:10.1111/iej.12986

14. Khoroushi M, Ziaei S, Shirban F, Tavakol F. Effect of intracanal irrigants on coronal fracture resistance of endodontically treated teeth undergoing combined bleaching protocol: an in vitro study. *J Dent (Tehran)*. 2018;15(5):266-274.

15. Baechtold M, da Cunha L, Souza E, Gabardo M, de Oliveira K, Baratto-Filho F, Leonardi D. Effect of endodontic irrigation protocols on crown fracture resistance. *J Contemp Dent Pract*. 2018;19(7):768-772.

16. Souza EM, Quadros J de RP, Silva EJNL, De-Deus G, Belladonna FG, Maia-Filho EM. Volume and/or time of NaOCl influences the fracture strength of endodontically treated bovine teeth. *Braz Dent J*. 2019;30(1):31-35. doi:10.1590/0103-6440201902076

17. Sim TPC, Knowles JC, Ng YL, Shelton J, Gulabivala K. Effect of sodium hypochlorite on mechanical properties of dentine and tooth surface strain. *Int Endod J*. 2001;34(2):120-132. doi:10.1046/j.1365-2591.2001.00357.x

18. Tonini R, Salvadori M, Audino E, Sauro S, Garo ML, Salgarello S. Irrigating solutions and activation methods used in clinical endodontics: a systematic review. *Frontiers in Oral Health*. 2022;3. doi:10.3389/froh.2022.838043

19. Gazzaneo I, Vieira GCS, Pérez AR, Alves FRF, Gonçalves LS, Mdala I, Siqueira JF, Rôças IN. Root canal disinfection by single- and multiple-instrument systems: effects of sodium hypochlorite volume, concentration, and retention time. *J Endod*. 2019;45(6):736-741. doi:10.1016/j.joen.2019.02.017

20. Rodrigues CT, Duarte MAH, Guimarães BM, Vivan RR, Bernardineli N. Comparison of two methods of irrigant agitation in the removal of residual filling material in retreatment. *Braz Oral Res*. 2017;31(0). doi:10.1590/1807-3107bor-2017.vol31.0113

21. Kanaan CG, Pelegrine RA, da Silveira Bueno CE, Shimabuko DM, Valamatos Pinto NM, Kato AS. Can irrigant agitation lead to the formation of a smear layer? *J Endod*. 2020;46(8):1120-1124. doi:10.1016/j.joen.2020.05.007

22. Silva EJNL, Carvalho CR, Belladonna FG, Prado MC, Lopes RT, De-Deus G, Moreira EJL. Micro-ct evaluation of different final irrigation protocols on the removal of hard-tissue debris from isthmus-containing mesial root of mandibular molars. *Clin Oral Investig*. 2019;23(2):681-687. doi:10.1007/s00784-018-2483-1

23. Machado R, da Silva I, Comparin D, de Mattos BAM, Alberton LR, da Silva Neto UX. Smear layer removal by passive ultrasonic irrigation and 2 new mechanical methods for activation of the chelating solution. *Restor Dent Endod*. 2021;46(1). doi:10.5395/rde.2021.46.e11

24. Gomes BPFA, Aveiro E, Kishen A. Irrigants and irrigation activation systems in endodontics. *Braz Dent J*. 2023;34(4):1-33. doi:10.1590/0103-6440202305577

25. Duque JA, Duarte MAH, Canali LCF, Zancan RF, Vivan RR, Bernardes RA, Bramante CM. Comparative effectiveness of new mechanical irrigant agitating devices for debris removal from the canal and isthmus of mesial roots of mandibular molars. *J Endod*. 2017;43(2):326-331. doi:10.1016/j.joen.2016.10.009

26. Cecchin D, Soares Giaretta V, Granella Cadorin B, Albino Souza M, Vidal C de MP, Paula Farina A. Effect of synthetic and natural-derived novel endodontic irrigant solutions on mechanical properties of human dentin. *J Mater Sci Mater Med*. 2017;28(9):141. doi:10.1007/s10856-017-5960-1

27. Zandbiglari T, Davids H, Schäfer E. Influence of instrument taper on the resistance to fracture of endodontically treated roots. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*. 2006;101(1):126-131. doi:10.1016/j.tripleo.2005.01.019

28. Rippe MP, Santini MF, Bier CAS, Borges ALS, Valandro LF. Root canal filling: fracture strength of fiber-reinforced composite-restored roots and finite element analysis. *Braz Dent J*. 2013;24(6):619-625. doi:10.1590/0103-6440201301996

29. Kamalak A, Uzun I, Arslan H, Keleş A, Doğanay E, Keskin C, Akçay M. Fracture resistance of endodontically retreated roots after retreatment using self-adjusting file, passive ultrasonic irrigation, photon-induced photoacoustic streaming, or laser. *Photomed Laser Surg*. 2016;34(10):467-472. doi:10.1089/pho.2016.4121

30. Katona TR, Eckert GJ. The mechanics of dental occlusion and disclusion. *Clin Biomech (Bristol, Avon)*. 2017;50:84-91. doi:10.1016/j.clinbiomech.2017.10.009

31. Lund JP. Mastication and its control by the brain stem. *Crit Rev Oral Biol Med*. 1991;2(1):33-64. doi:10.1177/10454411910020010401

32. Lauret JF, Le Gall MG. The function of mastication: a key determinant of dental occlusion. *Pract Periodontics Aesthet Dent*. 1996;8(8):807-817; quiz 818.

33. Wang M, Mehta N. A possible biomechanical role of occlusal cusp-fossa contact relationships. *J Oral Rehabil*. 2013;40(1):69-79. doi:10.1111/j.1365-2842.2012.02333.x

34. Zhang H, Cui JW, Lu XL, Wang MQ. Finite element analysis on tooth and periodontal stress under simulated occlusal loads. *J Oral Rehabil*. 2017;44(7):526-536. doi:10.1111/joor.12512

35. Sender RS, Strait DS. The biomechanics of tooth strength: testing the utility of simple models for predicting fracture in geometrically complex teeth. *J R Soc Interface*. 2023;20(203):20230195. doi:10.1098/rsif.2023.0195

36. Wang MQ, Zhang M, Zhang JH. Photoelastic study of the effects of occlusal surface morphology on tooth apical stress from vertical bite forces. *J Contemp Dent Pract*. 2004;5(1):74-93.

Conflict of Interest Statement:

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FIGURAS/GRÁFICOS/TABELAS E LEGENDAS

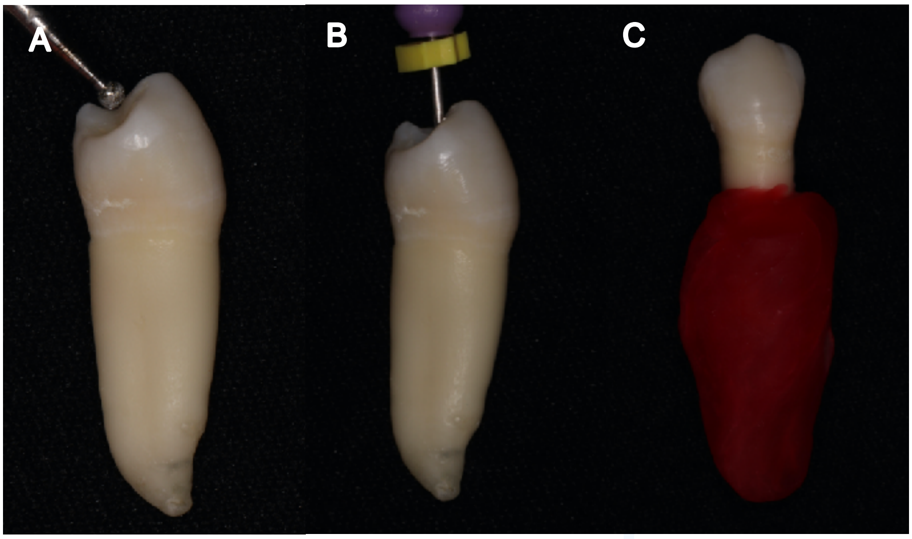


Figure 1. A- Access cavities using a spherical burr; B- Canal exploration with #10 K-file; C- Root coverage with wax.

Figura 1.A- Cavidades de acesso usando broca esférica; B- Exploração do canal com lima #10; C- Cobertura de raiz com cera
Fonte: Autor.

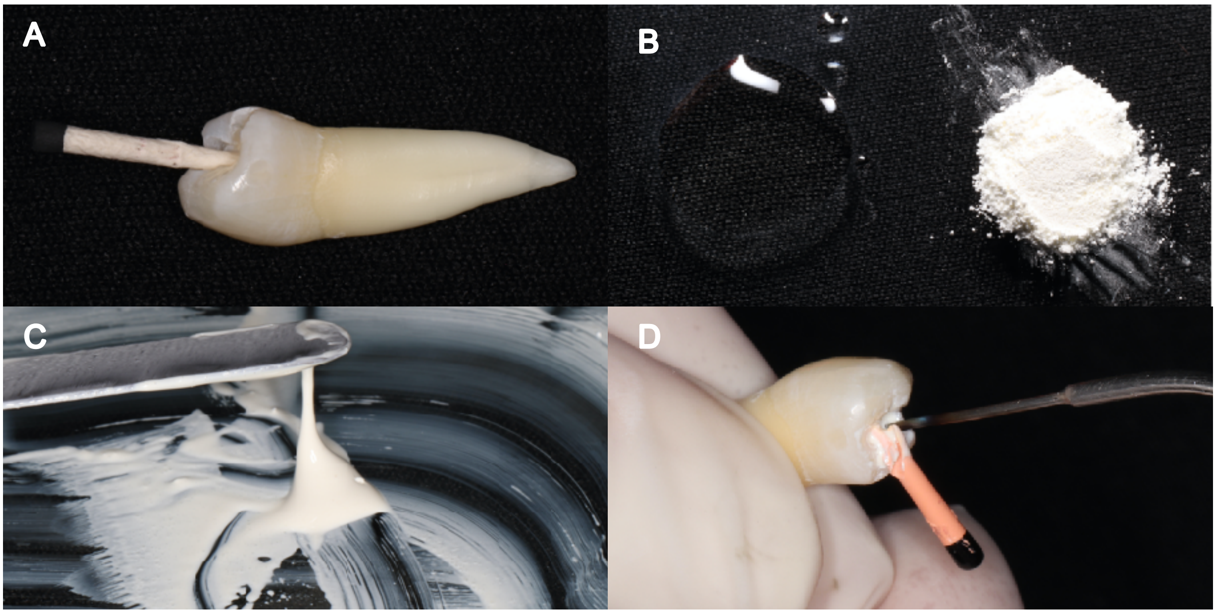


Figure 2. A- Canals dried with absorbent paper points; B and C – manipulation of zinc oxide-eugenol sealer; D- Gutta-percha excesses removal.

Figura 2. A- Canais secos com cones de papel absorvente; B e C - manipulação de cimento de óxido de zinco-eugenol; D- Remoção de excessos de guta-percha.
Fonte: Autor.

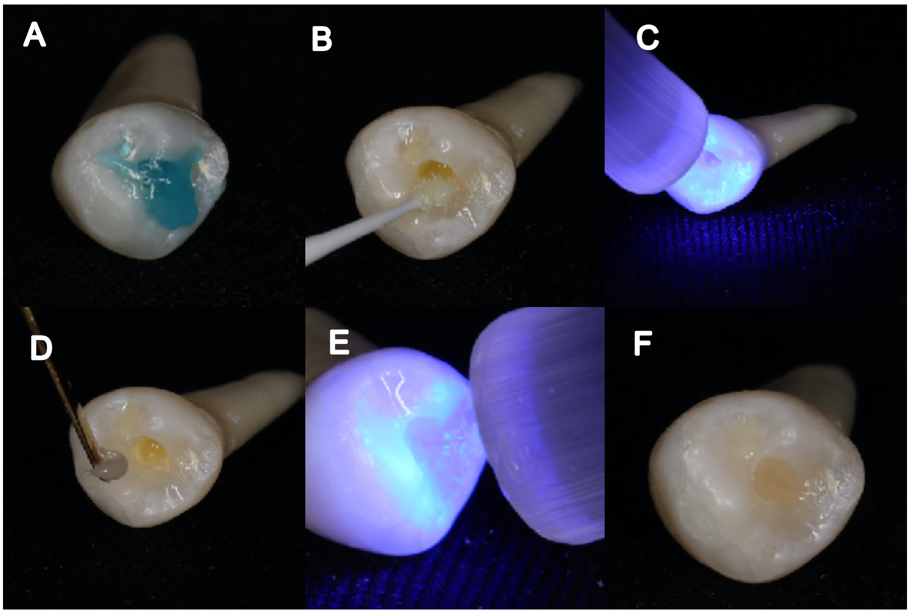


Figure 3. A- Acid etching; B- Adhesive system was applied; C- Adhesive system light-cured; D- Composite resin restauration; E- Z100 light-cured; F- Final result.

Figura 3. A- Ataque ácido; B- Aplicado sistema adesivo; C- Sistema adesivo fotopolimerizado; D- Restauração com resina composta Z100; E- Fotopolimerização da resina composta; F- Resultado final.
Fonte: Autor.

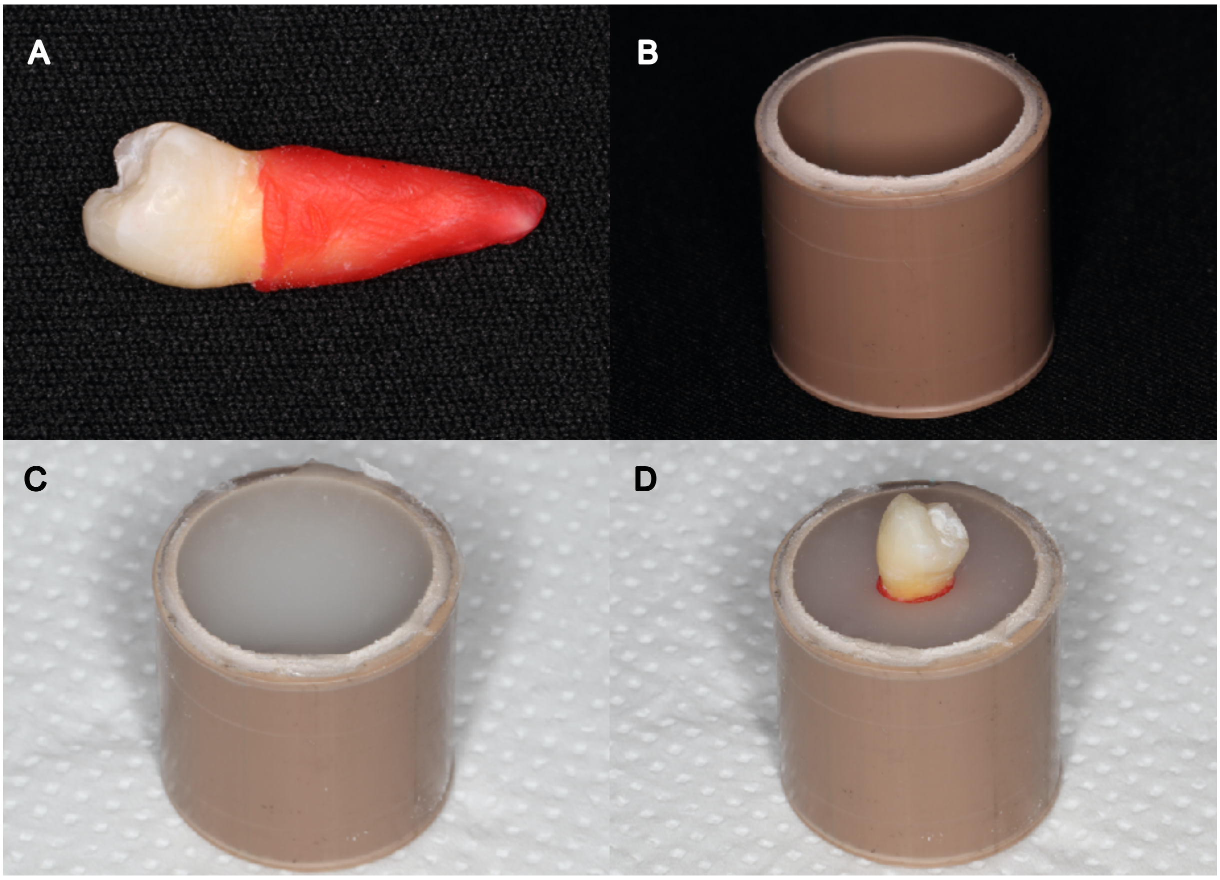


Figure 4. A- Root surfaces covered with a wax layer; B- Polyvinyl chloride cylinders; C- Self-cured acrylic resin filling; D- Mounted vertically.

Figura 4. A- Superfícies de raiz cobertas com camada de cera; B- Cilindros de PVC; C- Preenchimento com resina acrílica auto-polimerizável; D- Dentes inserido verticalmente
Fonte: Autor.

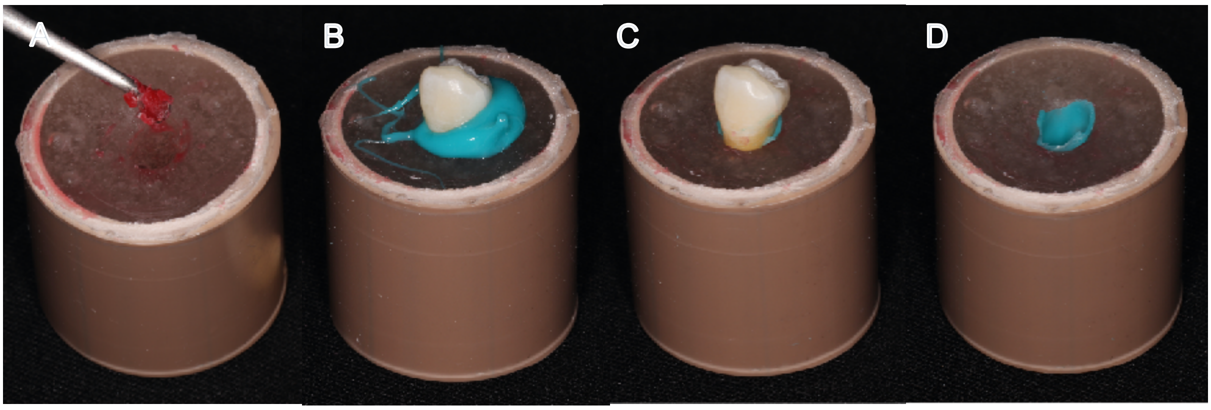


Figure 5. A- Wax Removal; B- Silicone-based impression material filling and tooth placement; C- Excesses removal; D- Final periodontal ligament simulation.

Figura 5. A- Remoção de cera; B- Preenchimento com material de impressão à base de silicone e colocação dos dentes; C- Remoção de excessos; D- Simulação final do ligamento periodontal
Fonte: Autor.

Figure 6. Universal Testing Machine (Autograph AG-I 10kN, SHIMADZU, Kyoto, Japan).

Figura 6. Máquina de teste universal (Autograph AG-I 10kN, SHIMADZU, Kyoto, Japão).
Fonte: Autor.

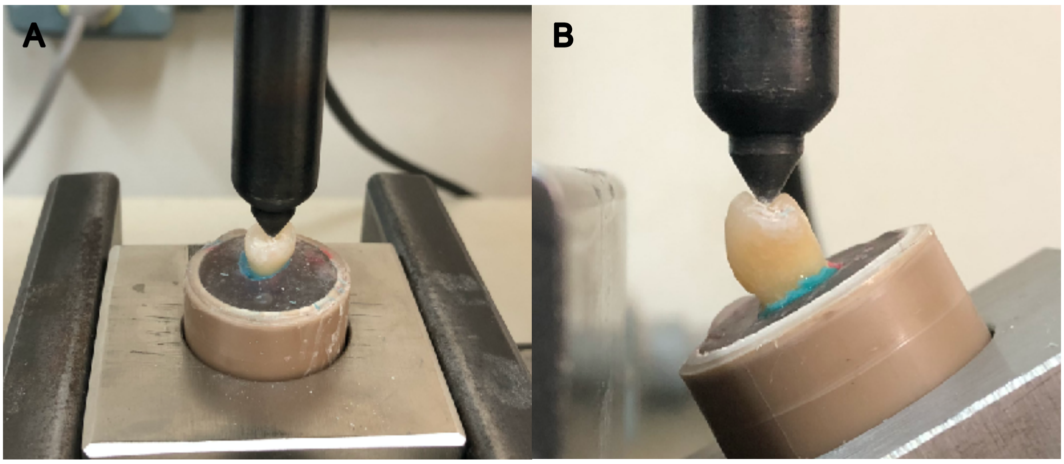
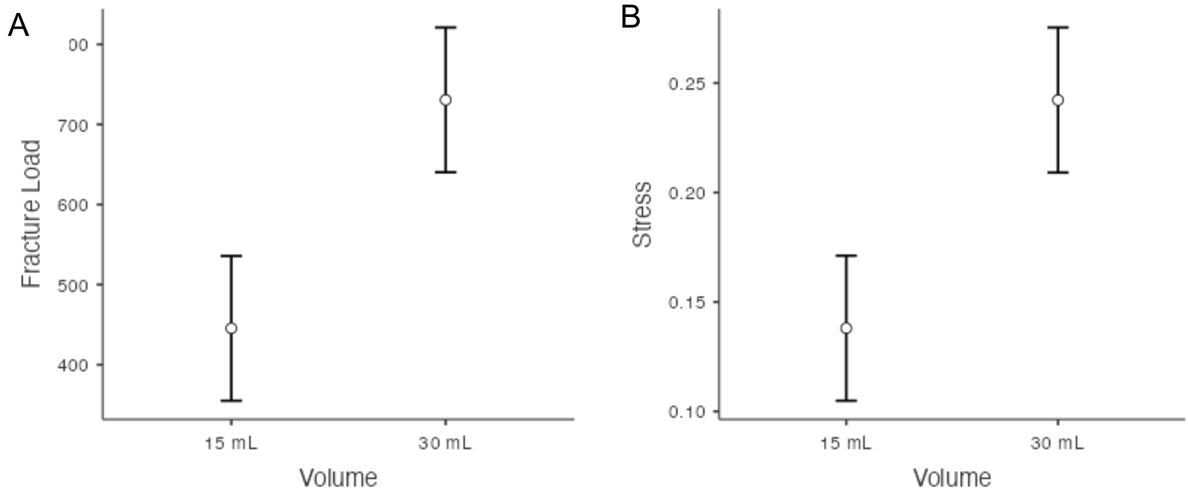


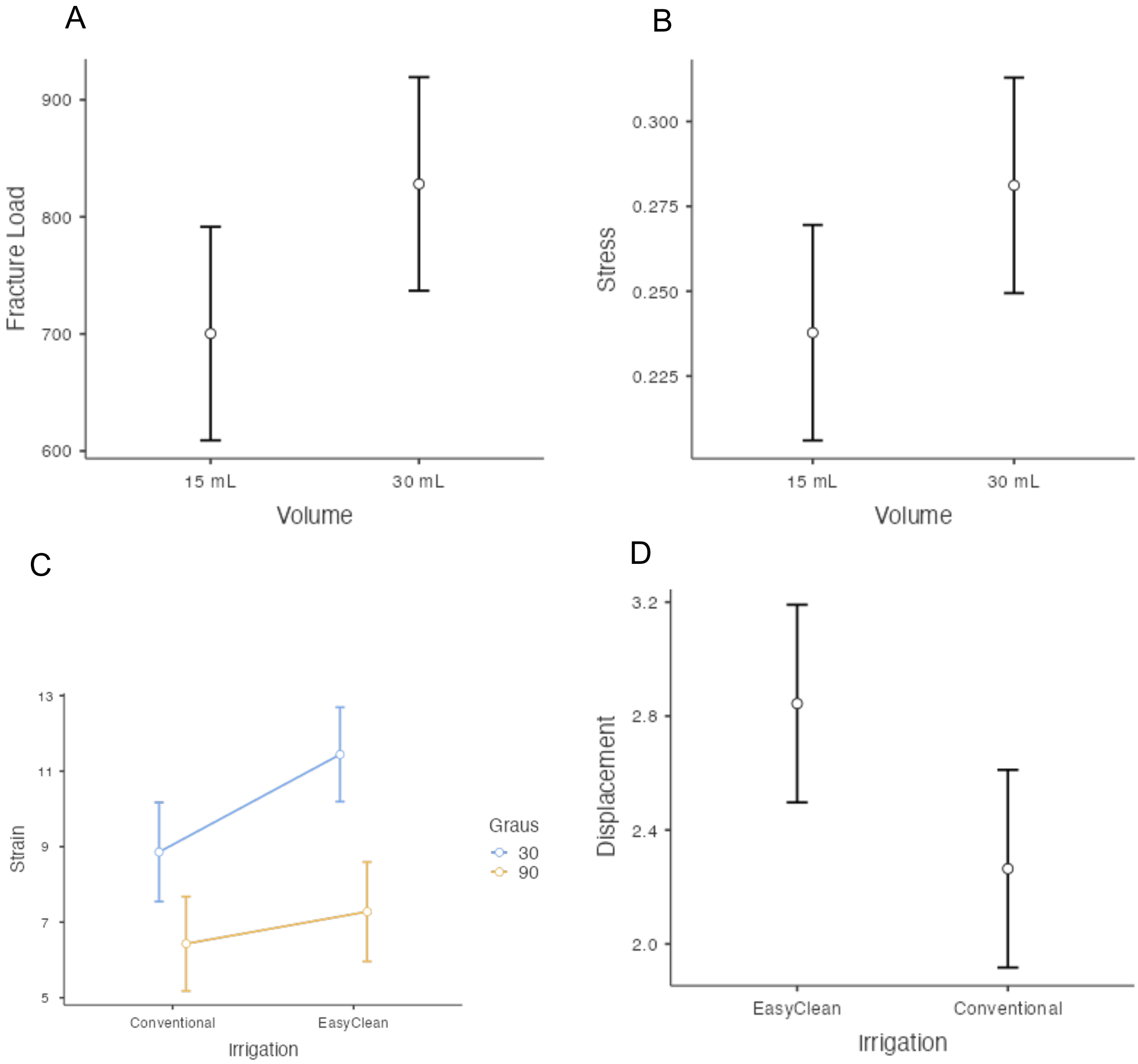
Figure 7. Stainless-steel at: A- 90º and B- 30º, to the long axis of the tooth.

Figura 7. Ponta de aço-inoxidável em: A- 90º e B- 30º, ao eixo longo do dente
Fonte: Autor.



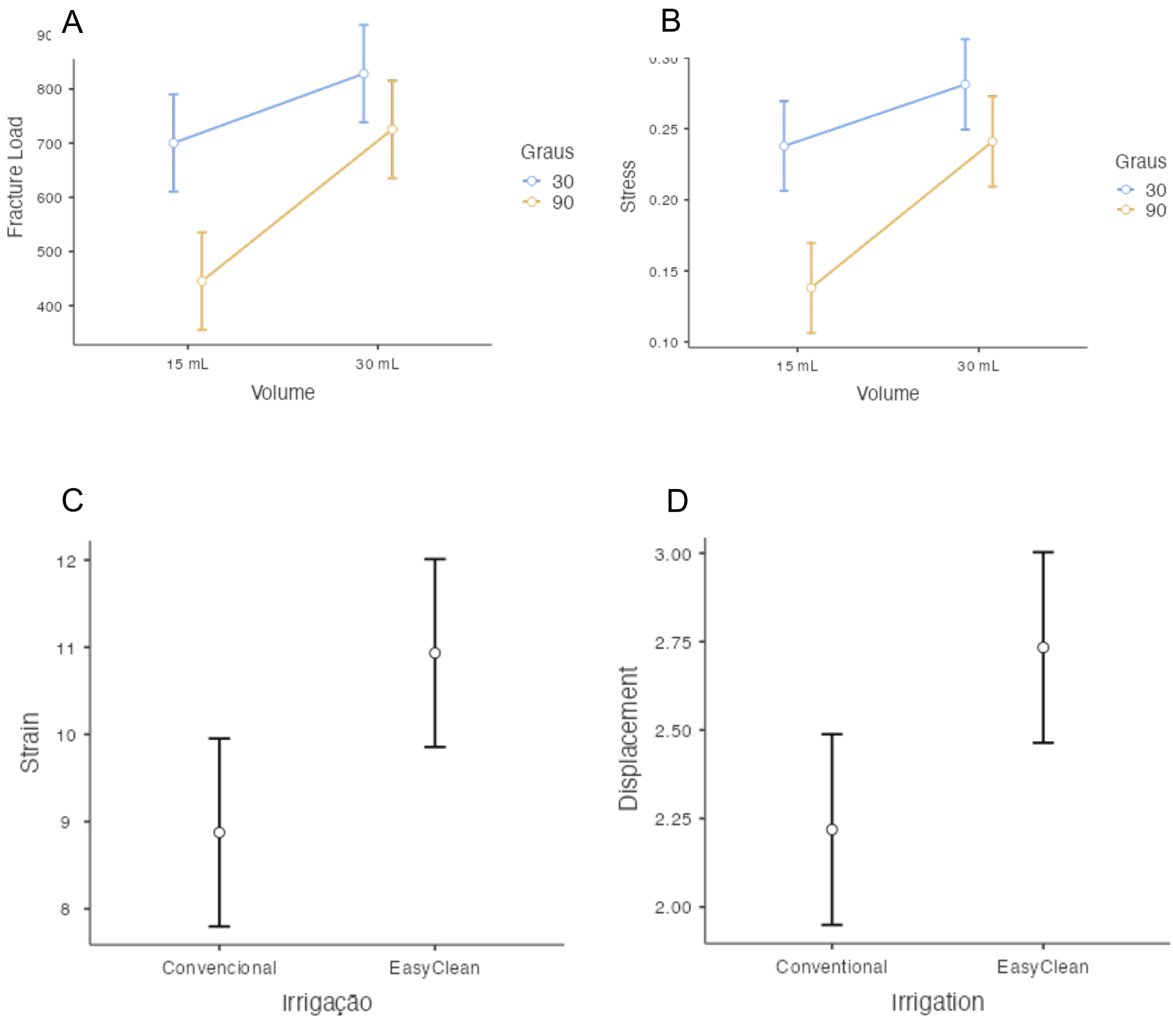
Graphic 1. Estimated marginal means at 90º for (A) Fracture Load (N) and (B) Stress (N/mm^2).

Gráfico 1. Médias marginais estimadas em 90º para (A) Carga para fratura (N) e (B) *Stress* (N/mm^2).
Fonte: Autor.



Graphic 2. Estimated marginal means at 30º for (A) Fracture Load (N), (B) Stress (N/mm^2), (C) Strain (%) and (D) Displacement (mm).

Gráfico 2. Médias marginais estimadas em 30º para (A) Carga para fratura (N), (B) *Stress* (N/mm^2), (C) Strain (%) e (D) Displacement (mm).
Fonte: Autor.



Graphic 3. Estimated marginal means at 90º and 30º for volume: (A) Fracture Load (N), (B) Stress (N/mm^2), and irrigation: (C) Strain (%) and (D) Displacement (mm).

Gráfico 3. Médias marginais estimadas em 90º e 30º para volume: (A) Carga para fratura (N), (B) *Stress* (N/mm^2) e irrigação: (C) Strain (%) e (D) Displacement (mm). Fonte: Autor.

Table 1. Fracture load and stress values according to load, irrigation and volume factors.

Load	Irrigation	Volume (mL)	Fracture Load (N)		Stress (N/mm^2)	
			Mean	SD	Mean	SD
90º ‡	Conventional†	15 ‡	460.88	92.300	465	100
		30 †	785.90	264.589	798	269
	Easy Clean†	15 ‡	429.91	174.237	437	177
		30 †	675.34	223.440	686	227
30º †	Conventional†	15 ‡	612.47	205.415	622	209
		30 †	850.22	161.184	863	164
	Easy Clean†	15 ‡	788.12	213.201	800	217
		30 †	806.00	219.488	819	223

Different symbol indicates significant difference within groups.
Fonte: Autor.

Table 2. Displacement and strain values according to load, irrigation and volume factors.

Load	Irrigation	Volume (mL)	Displacement (mm)		Strain (%)	
			Mean	SD	Mean	SD
90º †	Conventional‡	15 †	2.08	0.805	5.92	2.29
		30 †	2.27	0.759	6.46	2.16
	Easy Clean†	15 †	2.35	0.934	6.70	2.66
		30 †	2.89	1.186	8.24	3.38
30º †	Conventional‡	15 †	2.25	0.575	6.40	1.64
		30 †	2.28	0.592	6.50	1.69
	Easy Clean†	15 †	2.87	1.137	8.18	3.24
		30 †	2.82	0.607	8.03	1.73

A symbol indicates difference at 0.05 significance level from four-way ANOVA.
Fonte: Autor.

5 CONSIDERAÇÕES FINAIS

A partir desta pesquisa, pode-se concluir que ao usar um volume maior e agitação com EasyClean não levaram ao enfraquecimento do dente após o preparo do canal radicular, o que clinicamente não haveria influência significativa na ocorrência a fratura dental.

ANEXO A – COMPROVANTE DE ENVIO DO PROJETO DE PESQUISA

UNIVERSIDADE ESTADUAL DE PONTA GROSSA - UEPG

COMPROVANTE DE ENVIO DO PROJETO

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Resistencia dental após diferentes protocolos de irrigação endodôntica

Pesquisador: Alfonso SánchezAyala

Versão: 2

CAAE: 45555621.2.0000.0105

Instituição Proponente: Universidade Estadual de Ponta Grossa

DADOS DO COMPROVANTE

Número do Comprovante: 036057/2021

Patrocionador Principal: Financiamento Próprio

Informamos que o projeto Resistencia dental após diferentes protocolos de irrigação endodôntica que tem como pesquisador responsável Alfonso SánchezAyala, foi recebido para análise ética no CEP Universidade Estadual de Ponta Grossa - UEPG em 14/04/2021 às 22:04.

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