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FERNANDA CLOTILDE MARIZ SUASSUNA

ANÁLISE TERMOGRÁFICA E VOLUMÉTRICA DE DENTES SUBMETIDOS A DIFERENTES TÉCNICAS DE OBTURAÇÃO ENDODÔNTICA E REMOÇÃO DE GUTA-PERCHA

CAMPINA GRANDE – PB
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Orientadora: Prof.ª Dr.ª Daniela Pita de Melo.

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À memória do meu irmão Thiago

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Em tudo dai graças

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RESUMO

Introdução: As técnicas de obturação endodônticas estão em constante aprimoramento no intuito de promover a vedação tridimensional hermética do conduto radicular. A remoção da guta-percha para retratamento ou reabilitação protética é uma prática rotineira na clínica odontológica. Tanto a obturação endodôntica quanto a desobturação exigem a utilização de instrumentos aquecidos ou geradores de calor, podendo gerar dano aos tecidos periodontais se a temperatura gerada passar de 10°C. **Objetivo:** Avaliar a temperatura da superfície radicular e o volume do material obturador utilizando diferentes técnicas de obturação endodônticas; e avaliar a temperatura da superfície radicular durante a remoção da guta-percha utilizando diferentes métodos de remoção da guta-percha. **Metodologia:** Esse estudo foi dividido em dois eixos correspondentes aos dois artigos derivados da pesquisa. A amostra total da pesquisa constou de 135 pré-molares unirradiculares. Eixo I: 90 dentes foram utilizados neste eixo, 45 para análise térmica e 45 para a análise volumétrica. Para cada grupo, foram realizadas três técnicas de obturação: cone único, condensação lateral e termomecânica, em momentos diferentes de acordo com a análise realizada. Para a análise térmica foi utilizada a câmera térmica FLIR modelo T650sc Infrared. O laboratório de termografia foi mantido em condições controladas de temperatura e humidade. A câmera térmica foi posicionada a 30cm dos dentes, dispostos em um suporte construído para esse fim. As imagens térmicas foram adquiridas em intervalos de 15 segundos, iniciando antes da obturação até normalização da temperatura. A análise volumétrica foi realizada nos demais 45 dentes obturados em ambiente laboratorial controlado, e escaneados 5 dias após obturação endodôntica, utilizando o microtomógrafo NIKON, modelo XTEK XT-H 225 ST com parâmetros que permitiram uma resolução de 11µm. A análise dos volumes microtomográficos foi realizada por dupla segmentação de volumes elaborada no software imageJ®. As imagens térmicas foram analisadas por terços com auxílio da ferramenta reta do software FLIR Tools v. 6.4. nos diferentes tempos de análise. Eixo 2: 45 dentes foram subdivididos igualmente segundo os instrumentos de remoção da guta-percha avaliados: Largo, Protaper retratamento e Reciproc. A variação de temperatura foi analisada simultaneamente por termografia infravermelha (metodologia do eixo 1); e por três termopares tipo K ligados a um termômetro digital (RDXL4SD, Omega) aderidos aos terços cervical, médio e apical dos dentes em estudo. As temperaturas registradas com o termopar seguiram os mesmos tempos de análise da termografia infravermelha. Análise estatística foi realizada de forma descritiva e inferencial pelo pacote estatístico SigmaPlot 12. Foram usados os testes não paramétricos de Mann-Whitney, Kruskal-Wallis e Friedman escolhidos respeitando a natureza de dependência e número de grupos das amostras, com análises bidirecionais de Tukey. **Resultados:** Eixo 1: a maior mediana temperatura foi de 7,5°C (Q_{25} 5,2 - Q_{75} 13,3), observada na técnica termomecânica 15 segundos após a obturação, apenas após 60 segundos a temperatura decaiu de forma estatisticamente significativa em todos os grupos. O terço cervical, apresentou as maiores temperaturas (Md 18,6 - Q_{25} 15,4/ Q_{75} 26,2). A técnica de obturação termomecânica apresentou o maior volume de guta-percha (p=0,011) com média de 67,27±25,61 mm3. A condensação lateral apresentou maior volume de vazios (29,91±15,37 mm3). Eixo 2: A maior temperatura de remoção de guta-percha observada foi 15 segundos após o término da técnica largo com mediana de 20.3°C (Q_{25} 13.5- Q_{75} 27.7). **Conclusões:** O aumento de temperatura gerado por técnicas de obturação está dentro dos limites aceitáveis. Não existiu diferença estatística entre as técnicas de obturação para volume de espaços vazios Maior volume de cimento endodôntico foi observado nas técnicas do cone único e condensação lateral. A variação de temperatura ocasionada pelo instrumento largo gerou aumento de temperatura da superfície radicular acima do considerado seguro.

Descritores: Alterações na temperatura corporal. Obturação do canal radicular. Termografia. Microtomografia por raio-x.

ABSTRACT

Introduction: Endodontic obturation techniques are constantly improving to promote the three-dimensional hermetic sealing of the root canal. Removing gutta-percha for retreatment or prosthetic rehabilitation is a routine practice in the dental clinic. Both endodontic filling and gutta-percha removal require the use of heated instruments or heat generators, which can damage the periodontal tissues at a temperature above 10 ° C. **Objective:** To evaluate the root surface temperature and the volume of the filling material using different endodontic filling techniques; and evaluate the root surface temperature during gutta-percha removal using different methods of gutta-percha removal. **Methodology:** This study was divided into two axes corresponding to the two articles derived from this research. The total sample of the research consisted of 135 single-rooted premolars. Axis I: 90 teeth were used in this axis, 45 for thermal analysis and 45 for volumetric analysis. For each group, three filling techniques were assessed: single cone, lateral condensation and thermomechanical, at different times according to the analysis performed. For thermal analysis, the FLIR Infrared thermal camera model T650sc was used. The thermography laboratory was maintained under controlled conditions of temperature and humidity. The thermal camera was positioned 30cm from the teeth, arranged on a support built for this purpose. Thermal images were acquired at 15-second intervals, starting before the endodontic filling procedure until temperature normalization. Volumetric analysis was performed on the remaining 45 filled teeth in a controlled laboratory environment, and scanned 5 days after obturation, using the NIKON microtomograph, model XTEK XT-H 225 ST with parameters that allowed a resolution of 11 µm. The microtomographic analysis of the volumes was performed by double segmentation of volumes using imageJ® software. The thermal images were analyzed by thirds with the aid of the straight tool from the FLIR Tools v software. 6.4. at different study. Axis 2: 45 teeth were equally divided according to the gutta-percha removal instruments assessed: Largo Peeso, Protaper retreatment and Reciproc. The temperature variation was analyzed simultaneously by infrared thermography (axis 1 methodology); and by three K thermocouples connected to a digital thermometer (RDXL4SD, Omega) adhered to the cervical, middle, and apical thirds of the teeth under study. The temperatures recorded with the thermocouple followed were done in the same study times as the infrared thermography. Statistical analysis was performed in a descriptive and inferential way using the statistical package SigmaPlot 12. Mann-Whitney, Kruskal-Wallis and Friedman non-parametric tests were chosen, respecting the nature of dependence and number of groups of the samples, non-parametric tests were used Mann-Whitney, Kruskal-Wallis and Friedman chosen respecting the nature of dependence and number of groups of the samples, with two-way Tukey analyzes. **Results:** Axis 1: the highest median temperature was 7.5 ° C (Q25 5.2 - Q75 13.3), observed in the thermomechanical technique 15 seconds after endodontic filling, only after 60 seconds did the temperature decline significantly in all groups. The cervical third had the highest temperatures (Md 18.6 - Q25 15.4 / Q75 26.2). The thermomechanical obturation technique showed the largest volume of gutta-percha ($p = 0.011$) with an average of 67.27 ± 25.61 mm3. The lateral condensation technique showed a higher volume of voids (29.91 ± 15.37 mm3). Axis 2: The highest temperature of removal of the gutta-percha observed was 15 seconds after the end of the Largo technique with a median of 20.3 ° C (Q2513.5- Q7527.7). **Conclusions:** The temperature increase generated by filling techniques is within the acceptable limits. There was no statistical difference between endodontic filling techniques for void volume. Higher volume of endodontic cement was observed in the single cone and lateral condensation techniques. The temperature variation caused by the Largo instrument generated an increase in the root surface temperature above that considered safe.

Keywords: Changes in body temperature. Root canal filling. Thermography. X-ray microtomography.

LISTA DE ILUSTRAÇÕES

QUADROS E TABELAS

LISTA DE ABREVIATURAS, SIGLAS E SÍMBOLOS

%	Por cento; percentual de
≤	Menor ou igual que
°C	Graus celsius
NiTi	Níquel Titânio
2D	Bidimensional
TCFC	Tomografia computadorizada de feixe cônico
µCT	Microtomografia computadorizada
3D	Tridimensional
µm	Micrômetro
mm	Milímetro
CAAE	Certificado de Apresentação para Apreciação Ética
UEPB	Universidade Estadual da Paraíba
UFPE	Universidade Federal de Pernambuco
LTC	Laboratório de Tomografia Computadorizada
NENDARX	Núcleo em Ensaios não destrutivos de aplicações de Raios-X
DEN	Departamento de Energia Nuclear
NaCl	Cloreto de sódio
CRT	Comprimento de trabalho
CD	Comprimento do dente
ml	Milímetros
EDTA	Ácido etileno diamino tetracético
E.V.A	Placas de Etil, Vinil e Acetato
cm	Centímetro
ISSO	*International Organization for Standardization*
kV	Quilovolt
bits	Binary digit
µA	Microampére
HU	Escala de Hounsfield

TIFF	*Tagged Image File Format*
rpm	Rotações por minuto
N	Newton
LC	Lateral condensation
SC	Single cone
TMC	Thermomechanical compaction
L	Largo peso
PR	Protaper Retreatment
R	Reciproc

SUMÁRIO

1 CONSIDERAÇÕES INICIAIS

1.1 O CANAL RADICULAR

A morfologia do sistema de canais radiculares é marcada por estreitamentos, irregularidades anatômicas, curvaturas e ramificações. O canal principal geralmente tem forma cônica e possui secção transversal oval, podendo ser dividido didaticamente em três porções ou terços denominados como: cervical, médio e apical. Estes condutos quando necessitam de terapia endodôntica, após modelação e antissepsia, devem ser selados tridimensionalmente, apical, coronal e lateralmente, com materiais inertes ou antissépticos que estimulem ou não interfiram no processo de reparo do periodonto apical (SOARES, GOLDERG, 2002; HARGREAVES, COHEN 2011; WU, BUD, WESSELINK, 2009; JARRETT et al., 2004; LEA et al., 2005).

O processo de selamento do canal radicular é denominado de obturação e é realizado utilizando comumente a guta-percha, por se tratar do material mais popular em virtude de suas características como biocompatibilidade, inércia, plasticidade quando aquecida, facilidade de manuseio e remoção nos casos de retratamento (SHILDER, 1967; LEA et al., 2005; SOBHNAMAYAN, SAHEBI, BORHANHAGHIGHI, 2013).

Entretanto, a guta-percha por não possuir propriedade adesiva, não consegue fornecer a vedação adequada, necessitando assim, da utilização de cimentos endodônticos para preencher as irregularidades visando fornecer uma vedação impermeável (SHILDER, 1967; SHIPPER, TROPE, 2004; KIM et al., 2015). Para conseguir este objetivo, o cimento ideal deve possuir biocompatibilidade, bom tempo de trabalho, capacidade selante, adesividade, radiopacidade, estabilidade dimensional e baixa solubilidade (GROSSMAN, 1976). Entre estas propriedades, a solubilidade, constitui uma característica negativa visto que sua dissolução pode levar à presença de espaços vazios entre a dentina e a guta-percha (OLIVEIRA et al., 2011; SILVA et al., 2015; SILVA et al., 2016). Entre os tipos de cimentos endodônticos, os resinosos apresentam melhor capacidade seladora, adesividade e baixa expansão volumétrica. Destaca-se entre estes, o cimento Ah Plus (TEDESCO et al., 2014; CELIKTEN et al., 2015).

1.2 TÉCNICAS ENDODÔNTICAS DE OBTURAÇÃO E A TEMPERATURA

Em virtude das limitações da técnica a frio, o calor tem sido usado para melhorar sua adaptação dentro da anatomia complexa do canal radicular (WU, BUD, WESSELINK, 2009). Assim, a termoplastificação da guta-percha durante as técnicas de obturação permite um melhor escoamento e imbricamento mecânico às paredes dentinárias do material obturador, que somado ao efeito hidráulico gerado pela compactação com calcadores, permite um maior preenchimento das reentrâncias anatômicas. (SILVER, LOVE, PURTON, 1999; LEA et al., 2005). Entretanto estas técnicas possuem algumas características negativas, como maior probabilidade de extrusão apical do material obturador, dificuldade de execução da maioria das técnicas e utilização de condutores de calor e injetores de guta-percha aquecidos a altas temperaturas que podem gerar aumento da temperatura do cemento em contato com o ligamento periodontal e osso alveolar, principalmente, em dentes com uma fina camada de dentina radicular (KYTRIDOU, GUTMANN, NUNN, 1999; ER, YAMAN, HASAN, 2007; SCHILDER, 1967; LIPSKI, 2006; SHAFER, NELIUS, BURKLEIN, 2012; CELIKTEN et al., 2015).

O calor empregado nas técnicas de obturação é irradiado para a superfície externa, mesmo a dentina possuindo baixa condutividade térmica. O ligamento periodontal e demais tecidos periodontais podem ter sua saúde prejudicada pela elevação da temperatura. Estudos apontam que o aumento pode ser danoso em temperaturas que variam de 6 a 19°C em relação a temperatura corpórea (37°C) (ATRIZADEH, KENNEDY, ZANDER, 1971; ERIKSSON A, ALBREKTSSON T, GRANE, 1982; HUTTULA et al., 2006; MATTHEWS, HIRSCH, 1972; SAUK et al., 1988). Estudos prévios estipularam que um aumento de temperatura da dentina superior a 10°C da temperatura corpórea dá início a alterações na microcirculação regional e gera danos ao tecido conjuntivo adjacente, podendo levar a periodontite crônica e reabsorção dentária. Tais danos podem ser revertidos se tais temperaturas não excedam um aumento superior a 16°C (FORS et al., 1985; GUTMANN et al., 1987; SAUNDERS, 1990).

Outra questão que deve ser levada em consideração em relação ao aquecimento dos tecidos dentários é a aplicação de calor excessivo nos materiais obturadores que podem alterar sua composição química. Segundo Shilder (1967), a temperatura de fusão da guta-percha é de aproximadamente 60°C, podendo variar de acordo com a pureza da fase alfa empregada. Em outro estudo, Venturi, Di Lenarda, Breschi (2006), relataram que a temperatura mínima para plastificação é de 47°C e Zhou et al (2010), utilizando elementos finitos, demostraram que na técnica de ondas contínuas esta temperatura é atingida após 3 segundos de ativação do aparelho. Alterações químicas da guta-percha podem ser percebidas quando ela é submetida a temperaturas acima de 70°C (ATMEH, HADIS, CAMILLERI, 2020). Segundo Goldman et al. (1981), o calor é conduzido através da massa de guta-percha por uma distância de 4,0 a 6,0 milímetros. Este padrão de condutibilidade de calor tem sido utilizado como base para construção de técnicas de termoplastificação da guta-percha, determinando a profundidade de penetração dos condutores de calor (MARROQUIM et al., 2015).

Em relação aos cimentos endodônticos, os resinosos foram submetidos a testes de temperatura a 100°C demonstrando alterações no tempo de presa e resistência a compressão, com resultados ruins para o cimento Ah Plus (VIAPANA et al., 2014; ATMEH, HADIS, CAMILLERI, 2020). O cimento Ah Plus, a base de resina epóxi, é de grande aceitação pelos endodontistas, pois este possui boa capacidade seladora apical, histológica, atividade antimicrobiana, adesiva e excelente escoamento (SALEH et al., 2002; KAPRALOS et al., 2018). Segundo Camilleri (2015), a escolha do cimento endodôntico deve ser considerada de acordo com a técnica de obturação.

Diferentes estudos avaliaram o aumento de temperatura nas técnicas de obturação, visto que a guta-percha é aquecida dentro do conduto radicular, usando condensadores quentes manuais aquecidos a chama, ou um dispositivo eletrônico que gera calor e o transmite através de pontas metálicas de vários tamanhos. Entretanto a literatura mostra que o calor real gerado pelas pontas metálicas não atinge a temperatura marcada no visor do equipamento (SILVER *et al*. 1999, VENTURI *et al*. 2002, VIAPIANA *et al*. 2015; ATMEH, HADIS, CAMILLERI, 2020). Tal achado pode ser positivo, visto que estas temperaturas podem ser prejudiciais. O calor pode ser ainda mais atenuado pela capacidade de dissipação de calor dos dentes e seladores endodônticos, reduzindo ainda mais a temperatura conduzida às superfícies das raízes (VIAPIANA *et al*. 2014).

A pioneira dessas técnicas foi a de Schilder, precursora da técnica da onda contínua de compactação, que utiliza equipamentos específicos, considerada complexa compreendendo manobras no sentido coroa-ápice e complementada no sentido ápice-coroa (GOODMAN, SCHILDER, ALDRICH, 1981). Hand et al (1976) relataram um aumento de 3 a 4°C na superfície externa durante a execução da técnica de Schilder, enquanto Weller e Koch (1995) observaram variações de temperatura externa de até 5°C na técnica de injeção de guta-percha plastificada.

A injeção de guta-percha termoplastificada é realizada por meio de aparelhos especiais e compactada posteriormente a frio. Este sistema é constituído por uma unidade de controle, uma arma de mão que contém uma câmara rodeada por um elemento de aquecimento em que uma porção de guta-percha é carregada, e aquecida a uma temperatura de, no mínimo, 160 ° C. Quando plastificada, a guta-percha é injetada através das agulhas de prata no canal radicular (LIPSKI, 2006).

Outra técnica é a de onda contínua de compactação que é realizada por equipamentos que permitem uma homogeneidade de temperatura do compactador que gira em torno de 200°C. Quando realizada com o System B, esta técnica mostrou aumento de temperatura considerado danoso ou limítrofe (ER, YAMAN, HASAN, 2007; CHENG et al., 2007; SILVER et al 1999).

Algumas técnicas de obturação inserem instrumentos em altas temperaturas no interior do conduto, bem como não inserem a guta-percha plastificada (ou seja, com temperatura mínima de 47°C). Estas utilizam o calor de forma pontual, seja no corte e na plastificação da guta-percha na porção cervical com instrumentos aquecidos ou plastificam a guta-percha por meio do atrito. Tais técnicas precisam ser estudadas quanto as suas variações térmicas durante sua execução.

Também chamada de condensação a frio, a técnica de condensação lateral é considerada como principal técnica obturadora, utilizando instrumentos aquecidos apenas para cortar e remover o excesso de guta-percha. Mesmo com tamanha relevância, esta possui algumas desvantagens, tais como a falta de homogeneidade da massa de guta-percha, uma elevada percentagem de cimento endodôntico na porção apical do canal, má adaptação às paredes do canal radicular e indução a fratura vertical (SCHILDER, 1967; WU et al., 2009; SCHÄFER, NELIUS, BURKLEIN, 2013; CELIKTEN et al., 2015).

Com a popularidade dos instrumentos em Níquel-Titânio (NiTi) com conicidades maiores que os confeccionados em aço inox, surgiu uma nova técnica de obturação, que permite a utilização de um cone de guta-percha com calibre e conicidade correspondente ao último instrumento em NiTi utilizado para instrumentação. O uso destes cones em conjunto com o cimento obturador pode fornecer vedação do canal radicular, sem a exigência de cones acessórios, sendo denominada técnica do cone único. Além disso, esta técnica é considerada simples, rápida, com melhor adaptação com a parede dentinária do canal radicular e gera menos estresse para o paciente e profissional (TASDEMIR et al., 2015; BERUTTI et al., 2011; CAVENAGO, 2012).

McSpaden (1980) introduziu o uso de instrumentos termocompactadores visando a plastificação da guta-percha. Estes instrumentos promovem a compactação lateral e apical do material obturador através da geração de calor por atrito sem extrusão apical do material e reduzem o tempo de trabalho e o número de espaços vazios no material de obturação. Tais instrumentos foram modificados podendo ser fabricados utilizando liga de níquel-titânio (NiTi) que fornecem uma maior flexibilidade. (MALAGNINO et al., 2011; VERSIANI, 2013).

1.3 TÉCNICAS DE REMOÇÃO DA GUTA-PERCHA E TEMPERATURA

A remoção total da guta-percha dos canais radiculares obturados endodonticamente, seguida de uma nova instrumentação e obturação é o primeiro tratamento de escolha para os casos de insucesso da terapia endodôntica. Tal remoção pode ser realizada com auxílio de instrumentos manuais e rotários em aço inox, ou instrumentos de NiTi rotatórios ou reciprocantes, utilizando ou não solventes (BRAMANTE et al., 2010; CAMPELLO et al., 2019; FAUS-MATOSES et al., 2020). Alguns estudos relatam que a utilização de instrumentos em NiTi é mais segura quando comparada a instrumentos em aço inox. Não havendo diferença de efetividade da remoção da guta-percha entre os rotatórios e reciprocantes de NiTi (ROSSI-FEDELE, MAHAMED, 2017).

Foram desenvolvidos sistemas de instrumentação em NiTi específicos para remoção da obturação endodôntica, como o Mtwo Retratamento, a ProTaper Universal Retratamento e o R-Endo R3. No entanto, instrumentos de NiTi para tratamento vêm sendo usados com resultado satisfatório (MARTINS et al 2017; ZUOLO et al 2013).

Em casos que grande parte da coroa dentária é perdida, a dentina remanescente não fornece ancoragem suficiente para manter uma restauração definitiva, assim, se faz necessária a utilização de retentores intrarradiculares. Para inserção destes, grande parte do material obturador deve ser removido, tais procedimentos geralmente são realizados por alargadores acionados por motores de baixa rotação. Este gera calor que pode ser danoso aos tecidos periodontais (MENEZES et al, 2008; GARCIA-CUERVA et al, 2017).

Em ambas as situações, remoção da guta-percha para retratamento ou ancoragem protética, a estrutura dentária já se encontra fragilizada devido à perda tecidual realizada mecanicamente e biologicamente. Por vezes, é realizada uma remoção adicional da dentina intrarradicular para ampliar a ancoragem de retentores intrarradiculares tal procedimento além de aumentar a fragilidade do dente também aumenta a capacidade de irradiação de calor para a superfície radicular (LERTCHIRAKARN, TIMYAM, MESSER, 2002; FUKUI et al., 2009). Segundo García-Cuerva et al (2017), o aumento externo da temperatura pode ser significante e capaz de gerar danos ao periodonto quando instrumentos rotários de aço inox em baixa rotação são utilizados.

1.4 METODOS DE ANÁLISE TÉRMICA

As câmeras térmicas possuem a capacidade de detecção da radiação infravermelha emitida por objetos, transformando em imagens, denominadas termogramas, geradas em tempo real. Assim a termografia é um método de análise por imagem não ionizante e não invasiva, que capta e registra a distribuição térmica possibilitando a medição de temperaturas e a observação de padrões de distribuição de calor em diversos sistemas. Existe uma vasta gama de aplicações da termografia nas áreas militares, medicina humana, medicina veterinária, industrial e engenharia civil. Este método é capaz de produzir imagens precisas, em virtude da alta resolução das imagens geradas pelos aparelhos atuais, permitindo assim medições realistas de estruturas, quando os reflexos são evitados e a temperatura ambiente é mantida constante (SWEATMAN, BAUMGARTNER, SAKAGUCHI, 2001; ALTOÉ, OLIVEIRA FILHO, 2012; PERRY et al., 2013; MOON, 2014).

Nas ciências da saúde, este método proporciona informações sobre a microcirculação na pele, permitindo estudar a extensão das alterações funcionais, nervosas e vasculares geradas por processos inflamatórios, distúrbios endócrinos ou oncológicos (GRATT, 1998; BRIOSCHI et al., 2003; BRIOSCHI et al., 2007; HADDAD et al., 2012; DIBAI-FILHO et al., 2014; MELO et al., 2019).

Sua utilização permite estabelecer a temperatura de qualquer pixel de uma área de interesse. Estudos prévios avaliaram variações de temperatura no cemento/dentina radicular durante a execução de técnicas de obturação e remoção da guta-percha (MC CULLAGH et al., 2000; SWEATMAN et al., 2001; MC CULLAGH et al., 2003; LIPSKI 2004; LIPSKI 2006; KILIC et al., 2013; MARROQUIN et al 2015; DIEGRITZ et al., 2019), porém, a maioria dos estudos utilizou modelos de câmera térmica com menor resolução e não foram encontrados na literatura trabalhos com técnicas de obturação consideradas frias.

A termografia como método de análise térmica pode garantir uma reprodutibilidade mais fidedigna em comparação com métodos que utilizam termopar e termômetros, que restringem a aferição de temperatura a um ou poucos pontos (LIPSKI M, MROZEK J, DRO´ZDZIK, 2010; MARROQUIN et al., 2015). Outra opção, é a utilização de análise por elementos finitos, entretanto esta opção é realizada nas amostras de forma individual, demandando recursos tecnológicos e tempo de análise (AGRAWAL , PARDASANI, 2016).

Um termopar é um sensor utilizado para a medição da temperatura. Seu funcionamento se deve ao "Efeito Seebeck", que ocorre quando dois fios de metais diferentes são unidos em ambas extremidades e uma das extremidades é aquecida, gerando um fluxo de corrente contínua no circuito termoeléctrico. Este sensor deve ser ligado a um termômetro termopar ou outro dispositivo com capacidade registrar de dados. Os termopares são conhecidos por sua versatilidade, utilizados em uma ampla gama de aplicações - desde um termopar de uso industrial ao encontrado em utilitários e aparelhos elétricos. As diferentes combinações de metais resultam em diferentes sensores com intervalos de temperatura específicos, os mais comuns são J, K, T e E (NICHOLAS, WHITE, 1994; SCERVINI, 2009).

1.5 ANÁLISE VOLUMÉTRICA

A presença de infiltrações na obturação pode ser detectada por uma variedade de métodos experimentais. Estes métodos incluem a utilização de corante de penetração, espectrometria de radioisótopos, métodos eletrométricos, penetração bacteriana e modelo de transporte de fluido (YUCEL, CIFTCI, 2006; KIM et al., 2015; SADR et al., 2015). A utilização destes métodos não permite a preservação da amostra, podendo deslocar o material de obturação antes da análise, além de limitar a avaliação a apenas duas regiões do ápice.

A análise da qualidade obturadora e o diagnóstico inicial de fraturas radiculares são realizados na clínica odontológica, por meio de radiografias periapicais (MORTMAN, 2011; KARYGIANNI et al., 2014). A radiografia dentária possui limitações devido a sua característica bidimensional (MORTMAN, 2011). A Tomografia computadorizada de feixe cônico (TCFC) marca a mudança da análise bidimensional (2D) para a volumétrica no campo da odontologia, produzindo imagens precisas e de qualidade para um diagnóstico (WHITE; PHAROAH, 2014).

Entretanto, a TCFC possui limitações para diagnóstico clínico. A utilização de materiais na cavidade oral com alta densidade e alto número atômico resulta na geração de artefatos. Estes podem comprometer o diagnóstico em áreas onde os artefatos sobrepõem regiões de interesse (SCHULZE et al., 2011). Em dentes obturados, há a formação de artefatos gerados pela guta-percha e cimento obturador nas imagens de TCFC, representando um fator prejudicial para o diagnóstico (MOELLER et al., 2013; GUPTA, DHINGRA, PANWAR, 2015).

Oriunda do tomógrafo convencional, a microtomografia computadorizada (μCT) representa um método não destrutivo de análise in vitro, gerando imagens de obturações radiculares, com correlação histológica, por apresentar uma alta resolução espacial 3D em um nível micrométrico, fornecendo dados objetivos, devido à diminuição de artefatos (KIERKLO et al., 2014; KIERKLO et al., 2015).

O funcionamento da μCT baseia-se na aquisição das imagens radiográficas a partir de diversas projeções angulares da amostra ao longo de uma rotação de 180° ou 360°. As imagens são capturadas por um sensor e convertidas em imagens digitais, com alta resolução, para tanto é necessário maior tempo de exposição aos raios-X. Esta característica gera sua principal limitação: a impossibilidade da sua utilização em estudos *in vivo* devido à grande exposição à radiação. Apesar e por isso, é considerada padrão-ouro em estudos *ex-vivo* (PETERS et al., 2010; MORTMAN, 2011; MACIANO et al., 2012).

O voxel fornecido pode variar em média de 5-50 μm no μCT e quanto menor o tamanho do voxel, maior será a resolução da imagem gerada. A distância entre a fonte de radiação e o objeto de análise determina a resolução da imagem obtida e o tempo de exposição necessário. A maior resolução exige maior tempo de exposição aos raios-X e a depender da densidade do objeto, um tempo mais longo de digitalização e de arquivamento das imagens pelo software são necessários. (VERSIANI et al., 2011; MACIANO et al., 2012).

As amostras analisadas no μCT podem ser quantificadas e categorizadas de forma precisa e não-invasiva, observando os tipos de anatomia, qualidade do preparo e da obturação do sistema de canal radicular. A possibilidade de repetir o procedimento, manipular as imagens e executar outros testes na mesma amostra são vantagens que têm levado ao crescente uso do μCT em pesquisas, principalmente em tecido duro. Considerada assim, como a forma mais confiável e menos invasiva de distinguir os materiais obturadores e os espaços vazios no interior do canal radicular (JUNG, LOMMEL, KLIMEK, 2005; FREIRE et al., 2011; VERSIANI et al., 2011; ZASLANSKY et al., 2011; MACIANO et al., 2012; MOLLER et al., 2013; VERSIANI et al., 2013; CELIKTEN et al., 2015; FREIRE et al., 2015).

2 OBJETIVOS

2.1 OBJETIVO GERAL

Avaliar o comportamento térmico da superfície externa de raízes dentárias submetidas a diferentes técnicas de obturação endodônticas e de remoção da guta-percha, observando o comportamento volumétrico nas obturações realizadas.

2.2 OBJETIVOS ESPECÍFICOS

- Determinar e comparar a variação de temperatura do remanescente radicular nos terços cervical, médio e apical nos diferentes tempos do estudo em cada técnica de obturação e remoção da guta-percha;
- Analisar a variação de temperatura das técnicas de obturação e remoção da guta-percha no longo eixo do dente nos diferentes tempos;
- Observar a variação de temperatura imediatamente após execução das técnicas de obturação e remoção da guta-percha no remanescente radicular radiculares em teste e seu declínio até a normatização da temperatura;
- Elucidar qual das técnicas de obturação e remoção da guta-percha possui maior temperatura durante a instrumentação e menor declínio de temperatura em relação ao tempo;
- Avaliar quantitativamente o volume dos materiais obturadores e dos vazios presentes após a obturação do canal radicular por três diferentes técnicas de obturação.

3 METODOLOGIA

3.1 ASPECTOS ÉTICOS

Seguindo os preceitos estabelecidos pela Resolução 466/12 do Conselho Nacional de Saúde (Ministério da Saúde), este estudo foi registrado na Plataforma Brasil e submetido ao Comitê de Ética em Pesquisa da Universidade Estadual da Paraíba, obtendo parecer favorável à sua execução, registrado sob o protocolo CAAE - 14464819.2.0000.518 (ANEXO A).

3.2 TIPO E LOCAL DO ESTUDO

Este estudo experimental *in vitro,* foi desenvolvido em duas instituições:

1). Universidade Estadual da Paraíba – UEPB - Departamento de Odontologia onde foi realizada a seleção das amostras e preparo nos Laboratórios de Prótese e Dentística. No Laboratório de Termografia foram realizadas a aquisição dos termogramas e mensurações da temperatura por meio do termopar durante a execução das técnicas de obturação endodôntica e remoção da guta-percha;

2). Universidade Federal de Pernambuco – Laboratório de Tomografia Computadorizada (LTC) do Núcleo em Ensaios não destrutivos de aplicações de Raios-X (NENDARX) do Departamento de Energia Nuclear (DEN) da Universidade Federal de Pernambuco – UFPE, onde foram realizadas as microtomografias.

3.3 AMOSTRA

Está pesquisa foi dividida em dois eixos. O primeiro, correspondendo a análise volumétrica e térmica das técnicas de obturação endodônticas e o segundo, dedicado a análise das técnicas de remoção da guta-percha.

Todos os dentes da amostra tiveram suas superfícies radiculares limpas com auxílio de cureta periodontal, foram esterilizados em autoclave e armazenados em solução salina NaCl

0,9%. A observação dos critérios de inclusão e exclusão foi realizada utilizando radiografias periapicais.

Foram selecionados 135 pré-molares inferiores com rizogênese completa, canais radiculares únicos e com ≤5°de angulação, segundo o método de Schneider (1971). Adotou-se como critérios de exclusão a presença de nódulos pulpares, reabsorção interna, tratamento endodôntico prévio ou fratura radicular. Estes foram divididos em dois grupos de estudo: Eixo 1: Submetidos as técnicas de obturação - 90 pré-molares, 45 destes foram obturados em ambiente controlado nas diferentes técnicas em teste, garantindo a qualidade da obturação endodôntica realizada. Os demais foram obturados durante a aquisição dos termogramas; Eixo 2: Submetidos a técnicas de remoção da guta-percha - 45 pré-molares, desobturados por diferentes técnicas e analisados termicamente de forma simultânea.

3.4 PREPARO DA AMOSTRA

Os espécimes selecionados tiveram sua porção coronária removida por meio de um corte perpendicular ao longo eixo da raiz, na altura da junção amelocementária (FIGURA 1A) com auxílio de um disco diamantado (KG Sorensen, Zenith Dental ApS, Agerskov, Dinamarca) e micro motor elétrico (LB 100, Beltec, Araraquara, SP, Brasil). Em seguida, os dentes foram inseridos separadamente em tubos de polipropileno tipo Eppendorf (Micro Test Tubes 3810X standard - Eppendorf do Brasil Ltda, São Paulo, SP, Brasil) com solução salina de NaCl 0,9% trocada semanalmente, onde ficaram armazenados nos intervalos das etapas da pesquisa. Os dentes e tubos foram identificados numericamente (FIGURA 1B), quanto ao comprimento de trabalho (CRT), instrumento memória e técnica de obturação utilizados na amostra.

O comprimento de trabalho foi estabelecido como igual ao comprimento real do dente, ou seja, o limite apical de instrumentação e obturação foi estabelecido em 0,0mm. Tal medida visou fornecer condições de análise semelhante entre os métodos de imagem utilizados.

Visando fixar as extremidades sensíveis dos termopares, desgastes esféricos foram realizados nas faces linguais com broca diamantada n°1012 (KG Sorensen, Zenith Dental ApS, Agerskov, Dinamarca). Os pontos foram mensurados e demarcados de modo equidistante nos três terços dos dentes com profundidade aproximada de 1mm (FIGURA 2).

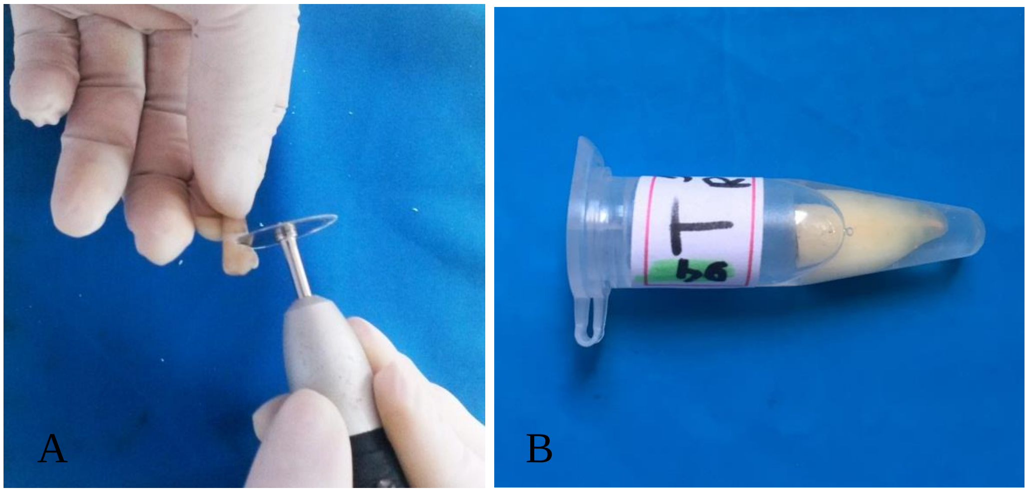

Figura 1. a. Corte da porção coronária na junção amelocementária facilitando padronização da intrumentação e execução das técnicas de obturação. **b.** Raiz armazenada em solução salina 0,9%, contida tubo Eppendorf etiquetado (Fonte: acervo da pesquisa).

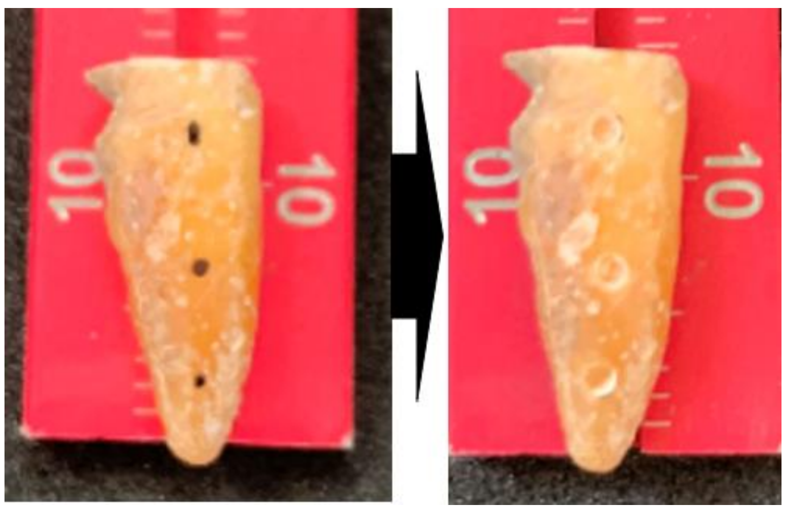

Figura 2. Desgastes esféricos nos terços cervical, médio e apical na face lingual das amostras (Fonte: acervo da pesquisa).

3.5 INSTRUMENTAÇÃO DO CANAL RADICULAR

O canal radicular foi irrigado com 2ml de hipoclorito de sódio a 2,5% (Ciclo farma, Serrana, SP, Brasil) com auxílio de uma seringa para irrigação (Ultradent Products Inc., South Jordan, UT, EUA) e agulha Endo-Enze (Ultradent Products Inc., South Jordan, UT, EUA). Limas manuais número 10, tipo K (Dentsply Maillefer, Ballaigues, Suiça) foram introduzidas até o forame apical e a medida encontrada, referente ao comprimento do dente (CD) foi estabelecida como comprimento de trabalho (CT=CD - 0,0) e etiquetada no tubo Eppendorf.

Para preparo do canal radicular foi utilizado a lima de NiTi Reciproc (VDW, Munique, Alemanha), de uso único e com preparo realizado com um instrumento em movimento oscilatório, realizando uma rotação de 150° no sentido anti-horário (direção de corte) e 30 ° no sentido horário (KIM et al., 2012; PEDULLÁ et al., 2013).

Com o canal devidamente irrigado, a escolha do instrumento Reciproc a ser utilizado seguiu as recomendações do fabricante. Este orienta a inserção de lima tipo K para seleção. Assim, um instrumento manual número 30# foi inserido passivamente até a região apical, com a lima alcançando o comprimento do dente, o canal radicular foi considerado amplo e um instrumento R50 (50.05) selecionado. Caso essa lima não tenha alcançado de forma passiva a região apical, uma lima manual número 20# foi inserida. Se esta alcançar a região apical, o canal foi considerado médio e um instrumento R40 (40.06) selecionado (FIGURA 3). Devido à seleção da amostra conter apenas dentes com conduto único não foram encontrados raízes com condutos estreitos, onde se indicaria um instrumento R25 (25.08).

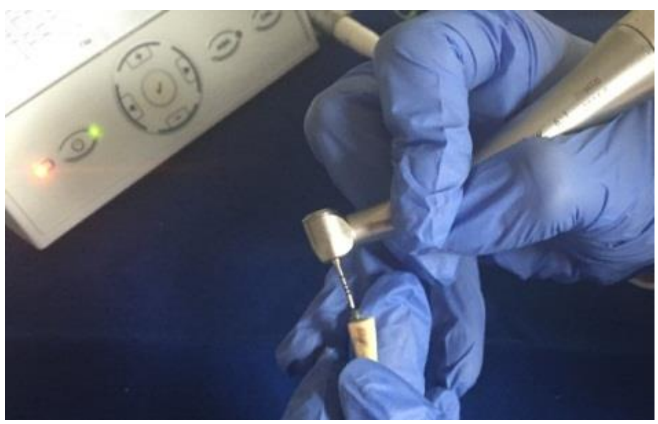

Figura 3. Instrumentação com lima Reciproc R40 e motor elétrico VDW Silver (Fonte: acervo da pesquisa).

O acionamento do sistema reciproc foi realizado nesta pesquisa por meio da utilização do contra-ângulo sirona (SN 25185, VDW GmbH, Munique, Alemanha) acoplado ao micromotor SMR 114058 (VDW GmbH, Munique, Alemanha), que foi conectado ao motor elétrico VDW Silver (VDW GmbH, Munique, Alemanha). Este motor elétrico possui velocidade e torque calibrados automaticamente para os sistemas reciproc.

Quanto à cinemática de movimento, seguiu-se a indicação do fabricante de utilização passiva, em movimentos de bicada, com avanços lentos até atingir o CRT. Após alcançar o comprimento desejado foram feitos movimentos de pincelamento, em todas as paredes do canal radicular. Nesta etapa a irrigação foi constante, sendo realizada a cada cinco movimentos de bicada e/ou pincelamento.

Finalizada a instrumentação, os condutos radiculares passaram por uma irrigação final com 2ml de ácido etileno diamino tetracético (EDTA) a 17% (Biodinâmica Química e Farmacêutica Ltda, Ibiporã, PR, Brasil), por 3 minutos, sendo agitado com o auxílio de uma lima manual tipo k 15, seguido por nova irrigação com 2ml de hiploclorito de sódio a 2,5%.

Após a instrumentação, as amostras foram divididas em três grupos testes de acordo com cada protocolo de obturação. Cada grupo composto por 15 dentes, com as dimensões específicas de instrumentação e obturação descritos em instrumento de pesquisa (APÊNDICE A).

3.6 ANÁLISE POR TERMOGRAFIA INFRAVERMELHA

A aquisição dos termogramas foi realizada por uma câmera portátil de sensor infravermelho FLIR modelo T650sc *Infrared* (Flir, Wilsonville, Oregon, USA), com lente de 25 mm e resolução espacial de 640 x 480 pixels. Esta foi fixada em tripé (Manfrotto 055 – Cabeça de tripé manfrotto MH804-3W), para realização das imagens.

As aquisições foram realizadas no Laboratório de Termografia Infravermelha (Departamento de Odontologia - UEPB) com temperatura do ambiente padronizada. Para isso, foi utilizado um termohigrômetro digital (MT-242, Minipa, São Paulo, Brasil), monitorando a temperatura ambiente e a umidade relativa do ar, que foram mantidas, respectivamente, entre 20 a 21°C e 40 a 60%.

O laboratório possui ar-condicionado com capacidade térmica suficiente para o tamanho deste, a direção do ar frio não ficou direcionada diretamente para as amostras, evitando resfriamento maior que a temperatura ambiente. Além disso, o ambiente não possui janelas e utiliza lâmpadas fluorescentes para iluminação. No máximo três pessoas permaneciam na sala no momento da aquisição para evitar o risco de aumento da temperatura ambiente.

3.6. 1 Barreiras isolantes e fixação da amostra

Visando eliminar interferências térmicas externas nas amostras, foi elaborado um dispositivo que permitisse a proximidade do operador durante a realização dos experimentos sem interferir na temperatura obtida. Este dispositivo consistiu em uma caixa térmica de placas de poliestireno expandido (isopor), com um dos seus lados removidos e suas paredes internas revestidas como uma camada de papel alumínio recoberto por E.V.A preto (FIGURA 4a). Assim, foi formada uma barreira térmica isolante contra possíveis fontes externas de calor e fazendo com que nenhuma imagem fantasma fosse formada ou refletida no momento do exame.

Para delimitar o campo de visão apenas para a amostra, na porção lateral, outrora removida, foi feita uma abertura retangular e em seguida realizado o mesmo revestimento descrito anteriormente (FIGURA 4b).

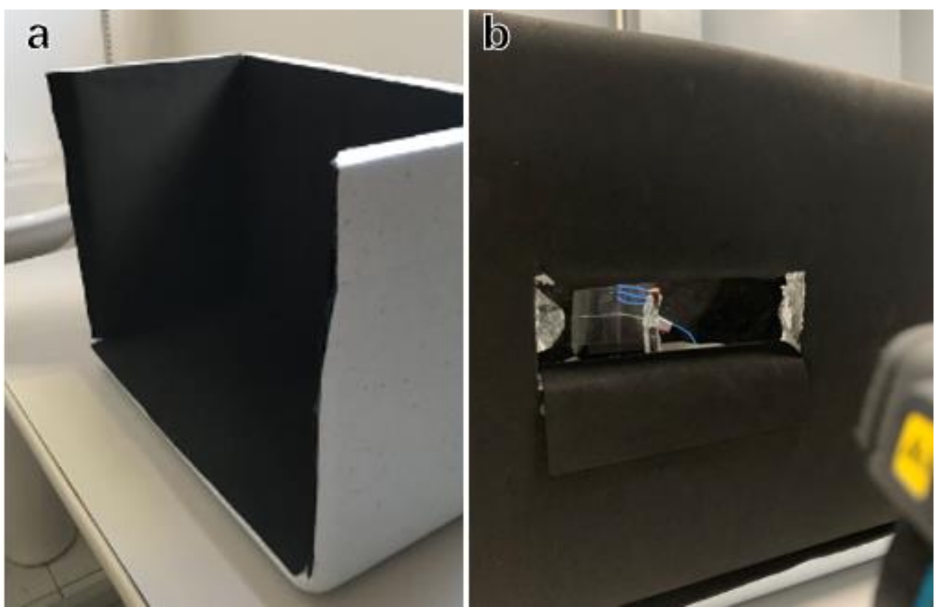

Figura 4.a. Caixa térmica adaptada para realização de imagens térmicas. **b**. Janela de visualização Silver (Fonte: acervo da pesquisa).

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Para fixação da amostra na posição ortorradial em relação a câmera térmica, foi utilizado um alicate de marceneiro plástico. Este possui sua porção de fixação reta com estrias antiderrapantes. O alicate foi inserido em uma base de gesso tipo 1 contido pela porção inferior de uma garrafa pet. O conjunto foi inserido em um cilindro de isopor com sua porção externa revestida por papel alumínio e E.V.A., como descrito anteriormente (FIGURA 5).

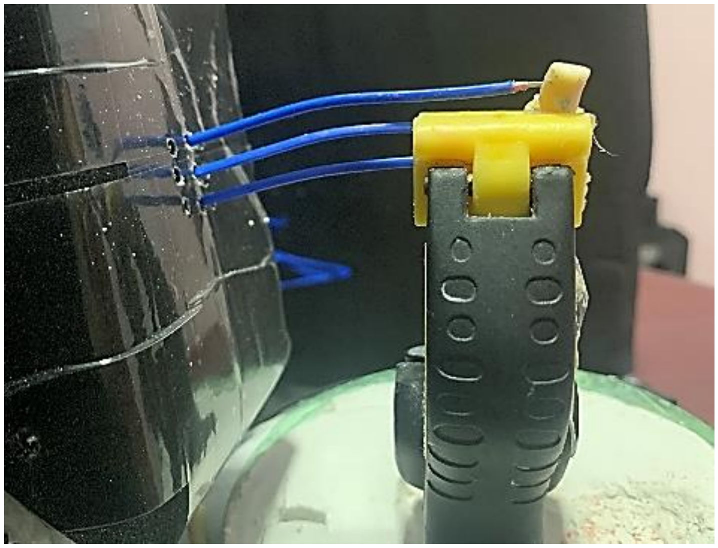


Figura 5. Amostra fixada (Fonte: acervo da pesquisa).

3.6.2 Aquisição dos termogramas

A câmera térmica foi posicionada a 30cm das amostras. Tal distância foi estipulada por ser a mínima descrita pelo fabricante capaz de manter alta resolução e precisão para a lente selecionada (FIGURA 6).

Visando permitir uma análise térmica dependente do tempo, a câmera foi programada para adquirir imagens a cada 15 segundos, iniciando imediatamente antes do início das intervenções até a normatização da temperatura. Foram fixados como parâmetros na câmera térmica: A distância 0 cm, correspondente a menor distância possível permitida pela lente; emissividade de 0,98 estipulada para tecidos humanos e a humidade relativa em 44%.

Figura 6. Distância da lente à amostra (Fonte: acervo da pesquisa).

3.6.3 Aquisição das temperaturas

As imagens térmicas foram adquiridas durante a execução das técnicas de obturação e remoção da guta-percha a cada 15 segundos. As maiores temperaturas nesta fase foram anotadas e utilizadas como "temperatura durante tempo de trabalho". Após a conclusão da etapa anterior, os termogramas foram adquiridos e posteriormente analisados a cada 15 segundos durante o primeiro minuto. O tempo até a normalização da temperatura foi observado simultaneamente pela câmera térmica e pelo uso de termopares, sendo registrado como tempo de resfriamento da amostra.

Em todas as amostras as temperaturas registradas no instrumento de pesquisa são resultantes da subtração entre a temperatura máxima no tempo de estudo e a temperatura inicial registrada antes da execução dos métodos sob análise (QUADRO 1).

Quadro 1. Dinâmica de aquisição dos intervalos de temperatura sob estudo.

Tempos estudados	**T0**	**T1 Temperatura no tempo de trabalho**	**T2 15s após**	**T3 30s após**	**T4 45s após**	**T5 60s após**
Legenda	Temperatura inicial	Aumento máximo	Aumento da temperatura 15s após o término	Aumento da temperatura 30s	Aumento da temperatura 45s	Aumento da temperatura 60s
Aquisição	T0	T1=Tmáx– T0	T2=T15s–T0	T2=T30s–T0	T2=T45s-T0	T2 =T60s–T0

Após a aquisição dos termogramas, estes foram analisados pelo Software *FLIR Tools* v. 6.4. (Flir, Wilsonville, Oregon, USA). Inicialmente a escala de temperatura foi reduzida eliminando as temperaturas inferiores do *background.* Em seguida quatro retas foram traçadas: no longo eixo do dente, contemplando o comprimento de trabalho, na porção cervical, média e apical da distal a mesial (FIGURA 7).

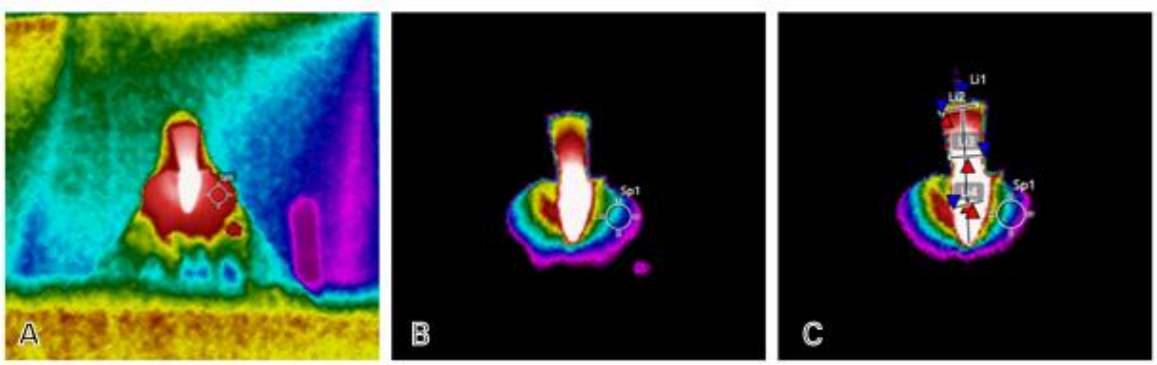


Figura 7.a. Termogramas no *FLIR Tools* **b**. Remoção do *background* **c.** Uso da ferramenta reta para mensurações (Fonte: acervo da pesquisa).

3.7 ANÁLISE TÉRMICA COM USO DE TERMOPARES

Na análise termográfica utilizando termopares, foi utilizado um termômetro digital de quatro canais (RDXL4SD, Omega Engineering, USA) onde foram conectados três termopares tipo K. Os termopares possuem uma resolução de 0,1°C no intervalo de temperatura entre -50,0 a 999,9°C.

3.7.1 Aquisição das temperaturas

Visando manter os termopares em posição para que não interferissem nas imagens térmicas, foi elaborado um retângulo de isopor isolado termicamente com três orifícios feitos em linha reta na vertical e equidistantes entre si, capazes de deixar os sensores estendidos e sua porção sensível aprisionada no orifício circular confeccionado nas amostras (FIGURA 8). Um termopar foi inserido em cada terço dos dentes.

O termômetro foi posicionado externamente à caixa de análise e filmado (FIGURA 8b). O início da filmagem e o fim foi idêntico ao da aquisição das imagens térmicas (FIGURA 8d), os vídeos gerados foram assistidos e as temperaturas de interesse forma anotadas em instrumento de pesquisa (APÊNDICE B).

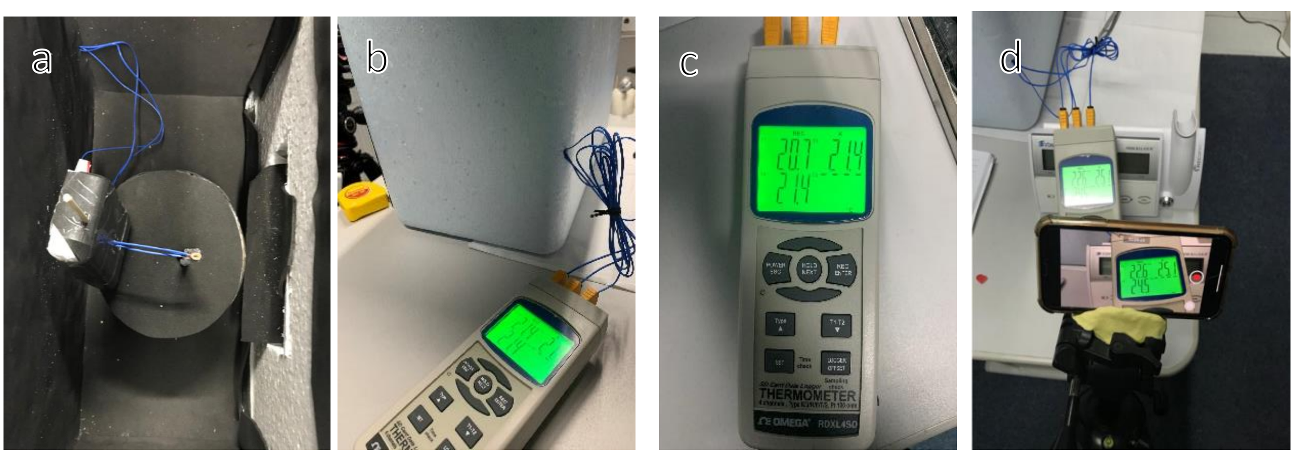


Figura 8a. Posicionamento dos termopares na amostra. **b.** termopares transpondo a caixa de análise e ligados ao termômetro. **c.** Termômetro exibindo a temperatura local dos três terços do dente. **d.** Gravação em vídeo do termômetro (Fonte: acervo da pesquisa)

3.8 OBTURAÇÃO DOS CANAIS RADICULARES

3.8.1 Divisão dos grupos de análise

Ressalta-se que as amostras foram divididas em dois grupos de estudo. No primeiro, as técnicas de obturação endodônticas foram analisadas por métodos térmicos (termografia infravermelha e termopares) e volumétricos.

De acordo com o método de análise, os 90 dentes foram subdivididos em: 1. Submetidos exclusivamente a análise volumétrica: 45 pré-molares, obturados em ambiente controlado nas diferentes técnicas em teste, garantindo a qualidade da obturação endodôntica realizada; 2. Submetidos a análise térmica: 45 pré-molares, obturados e analisados termicamente de forma simultânea. Ambos os grupos, foram subdivididos em três grupos, cada um com 15 amostras, correspondendo às técnicas de obturação em teste.

3.8.2 Técnicas de obturação dos canais radiculares

Após a instrumentação do canal radicular, os dentes divididos em três grupos foram submetidos aos protocolos de obturação. Todos os protocolos utilizaram cones de papel absorvente do sistema reciproc que possuem mesma conicidade dos instrumentos utilizados, seja R40 ou R50 (VDW GmbH, Munique, Alemanha) e cimento resinoso Ah Plus (Dentsply, Rio de Janeiro, Brasil), com sua manipulação seguindo as recomendações do fabricante.

3.8.2.1 Técnica de Condensação Lateral

Na condensação lateral é preconizada a utilização de cones de guta-percha que utilizam conicidade ISO (.02). Desta forma, o cone principal foi selecionado de acordo com o instrumento memória. Assim, cones de conicidade 40.02 ou 50.02 foram selecionados de acordo com a instrumentação e medidos seguindo o comprimento de trabalho do dente, comprovando se estavam adequados pela realização da prova do cone. Os cones acessórios (Dentsply Maillefer, Ballaigues, Suíça) foram selecionados de acordo com espaçador e o espaço a ser preenchido.

Com o canal seco, o cimento foi aplicado com o próprio cone nas paredes do canal e espalhado em seguida nos cones que foram utilizados. O espaçador de NiTi (Dentsply Maillefer, Ballaigues, Suíça) penetrou o mais próximo possível do comprimento total de trabalho, conferindo espaço adequado aos cones acessórios que foram inseridos em seguida. O processo repetiu-se até o preenchimento da porção cervical. O excesso de guta-percha na região cervical foi removido com calor e a porção coronária compactada com calcador apropriado (Odous de Deus, Belo Horizonte, Brasil) (FIGURA 9).

Figura 9.a. Materiais utilizados na condensação lateral; **b**. Amostra durante a obturação (Fonte: acervo da pesquisa).

3.8.2.2 Compactação Termomecânica

A execução da técnica se deu pela adaptação de um cone de tamanho e conicidade idênticos ao instrumento utilizado no preparo mecânico (40.06 ou 50.05). Com o conduto seco, se realizou pincelamento do cimento nas paredes do conduto com o próprio cone e, posteriormente o cimento foi uniformemente espalhado no cone, e em seguida este foi inserido no CRT.

O termocompactador PacMac 45.04 de 21 mm (SybronEndo Dental Specialties, Glendora, CA, EUA) montado em contra-ângulo com rotação em sentido horário, foi inserido ao lado do cone, sendo acionado em movimentos de bicada. O instrumento gerou fricção, termoplastificando a guta-percha e a impulsionando apicalmente. A massa plástica foi compactada verticalmente com calcador frio (FIGURA 10).

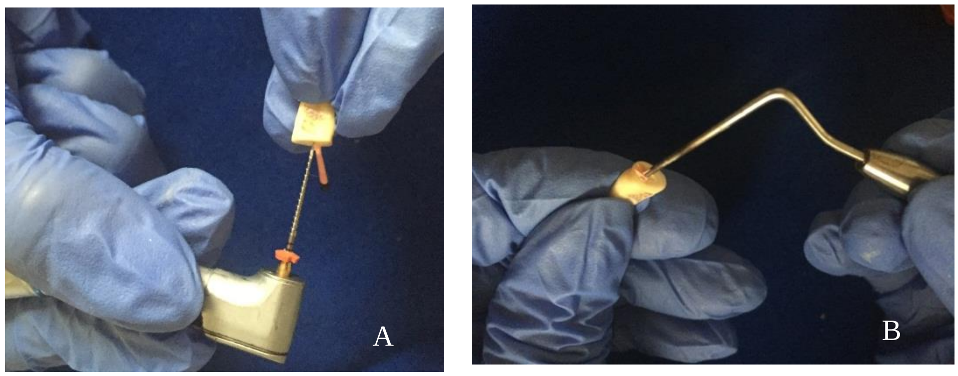


Figura 10. a. Plastificação da guta-percha com termoplastificador; **b.** Compactação vertical a frio (Fonte: acervo da pesquisa).

3.8.2.3 Cone único

Os dentes obturados com a técnica de cone único foram preenchidos com cones de guta-percha com conicidade e tamanho idêntico ao instrumento de preparo radicular (40.06 ou 50.05), com uso do cimento pincelado no interior do conduto com o próprio cone e posteriormente, envolvido no cone. Este foi adaptado ao canal radicular em seu comprimento de trabalho e o seu excesso removido com calcador aquecido e, em seguida, compactado verticalmente a frio (FIGURA 11).

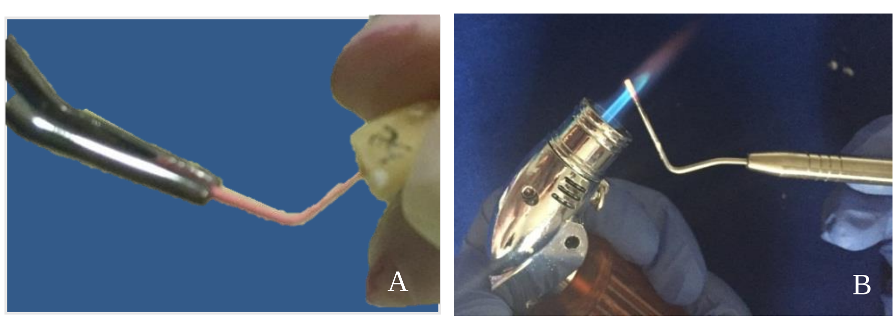


Figura 11. a. Inserção do cone no CT; **b.** Calcador em rubro (Fonte: acervo da pesquisa).

Após a instrumentação, as amostras foram armazenadas separadamente nos tubos de polipropileno tipo Eppendorf previamente identificados contendo solução salina NaCl 0,9% por 5 dias até as avaliações microtomográficas.

3.9 AVALIAÇÃO MICROTOMOGRÁFICA

As amostras foram escanceadas utilizando o microtomógrafo NIKON, modelo XTEK XT-H 225 ST *microfocos*, com fonte de 225 kV, foco de 3µm, alvo rotativo e volume de medição CT de até 250 mm de diâmetro e 600 mm de altura. Detector modelo Varian 2520 *Flat panel* de 250 x 200 mm, resolução de alta faixa dinâmica produzindo imagens de 1920 x 1536 digitalizadas para 16 bits. Para aquisição das imagens, os parâmetros utilizados foram 80 kV de tensão, 222 µA de corrente e magnificação de 120.0981, sem filtro. O protocolo adotou um tamanho do pixel de 11µm, de acordo com os limites volumétricos da amostra e tempo de aquisição de aproximadamente 25 minutos, sendo geradas 3017 imagens. Para a aquisição da referida resolução, os dentes escaneados foram inseridos 2 a 2 em blocos de isopor, visto a densidade radiográfica similar ao ar, medindo 14cmx14cmx15cm. Os blocos foram fixados no suporte com auxílio de fita dupla-face deixando-os bem presos para que não se movessem durante o escaneamento (FIGURA 12).

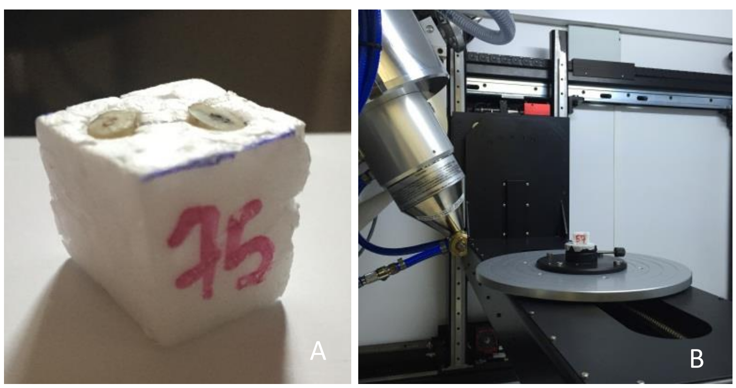


Figura 12. a. Bloco de isopor para fixar as amostras; **b.** Cubo fixado no suporte giratório do microtomógrafo rubro (Fonte: acervo da pesquisa).

As imagens obtidas foram reconstruídas nos planos axial, sagital e coronal, utilizando o software XTEK-CT PRO 3D, desenvolvidas pela própria NIKON (Reino Unido). A partir da imagem reconstruída foi selecionado o volume de interesse a ser estudado, correspondendo ao volume da região apical.

Em seguida, as imagens da amostra selecionada foram importadas pelo software VG Studio Max 2.2 (Volume Graphics Gmbh, Heidelberg, Alemanha) e a elas atribuídos valores relativos à escala de Hounsfield (HU) (HOUNSFIELD, 1973) para a área de geociências (Ar= 0 e água= 1000), pré-estabelecido para os parâmetros utilizados. Em seguida, foi aplicado o filtro Gaussiano (3x3x3), objetivando suavizar a presença de artefatos e ruídos comuns nas imagens digitais. O uso de filtros visa aumentar a conformidade das imagens e facilitar o posterior processo de segmentação. Após a aplicação do filtro, as imagens foram exportadas no formato TIFF e arquivadas para posterior análise.

3.9.1 Análise das imagens

As imagens TIFF foram analisadas no programa ImageJ versão 1.41 (desenvolvido pelo *National Institute sof Health* (NIH), Bethesda, MD, EUA, http: // rsb.info.nih.gov/ ij /).

Inicialmente as imagens axiais foram importadas para o software ImageJ, sendo a região correspondente ao conduto radicular recortada utilizando a ferramenta de seleção quadrada. Um novo recorte foi realizado visando manter uma proporção semelhante de cimento, dentina e vazio, para visualização dos valores de *voxel* referentes a cada material nos picos do histograma (FIGURA 13).

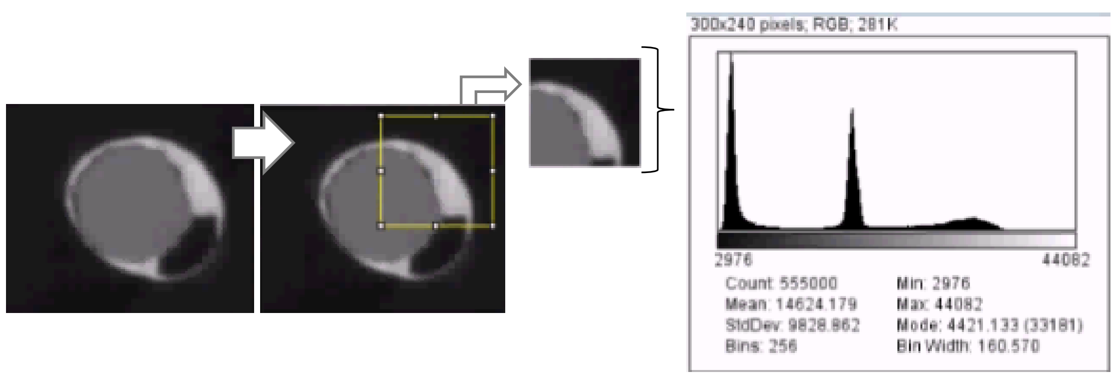


Figura 13. Histograma inicial (Fonte: acervo da pesquisa).

Tomado os valores dos intervalos de pixel de cada material, os volumes foram submetidos a duas segmentações por meio da ferramenta *CT segmentation*. A primeira entre cimento e demais estruturas, e a segunda entre dentina com os espaços vazios e os demais materiais. Os volumes resultantes das duas segmentações foram somados pela ferramenta *image calculator* operação adição, resultando em uma segmentação trifásica com valores definidos entre os três materiais de interesse que preenchem o conduto (FIGURA 14).

Para remoção do background, o volume segmentado de forma trifásica foi duplicado e sua cópia convertida em volume binário através da ferramenta *large bitwidth threshoiding*. No volume binário, foi aplicada a ferramenta *erode,* umas das ferramentas binárias disponíveis no programa, que tem por objetivo acrescentar camadas morfométricas a forma em questão (FIGURA 15).

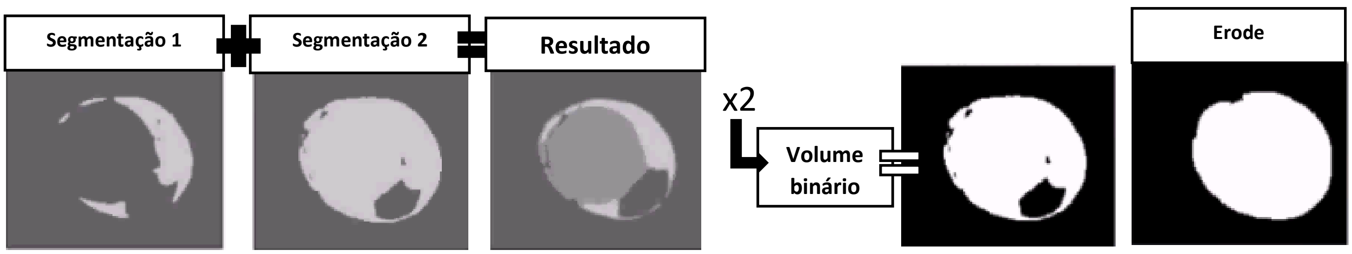


Figura 14. Adição entre a segmentação 1 (cimento e outros materiais) e a segmentação 2 (dentina e outros materiais). Alterando o resultado para volume binário e usando a ferramenta erode (Fonte: acervo da pesquisa).

Do volume binário foi subtraído o valor 254 com auxílio da ferramenta *image calculator* operação subtração, com objetivo de zerar o valor do background e fornecer o valor de "um" a região correspondente ao canal radicular. Ao volume binário com os valores de "zero" e "um" foi dado o nome de máscara (FIGURA 15).

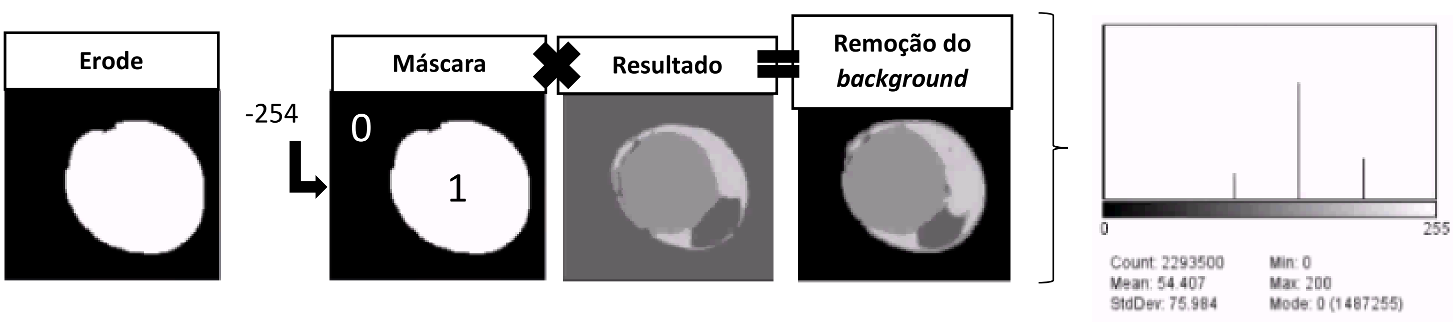


Figura 15. Subtração do volume binário por 254. Multiplicando a máscara pelo resultado, eliminando o *background*. Histograma final gerado após a exclusão do plano de fundo (Fonte: acervo da pesquisa).

Por fim, a multiplicação por meio da ferramenta *image calculator* operação multiplicação, entre o resultado da soma das segmentações e a máscara, resultou em um volume sem background e com valores de voxel definidos para cada material. Deste modo, ao gerar um histograma deste último volume é possível definir o número de voxels de cada material na amostra e por conseguinte o volume de cada material presente (FIGURA 15).

3.10 INSTRUMENTOS DE REMOÇÃO DA GUTA-PERCHA

3.10.1 Largo

Os alargadores do tipo largo foram montados em contra ângulo com movimento para a direita (sentido horário) e acoplado em motor elétrico em baixa rotação. Estes instrumentos são fabricados em três diâmetros. A escolha do instrumento foi realizada de acordo com o diâmetro do conduto quando comparada as radiografias prévias.

Estes instrumentos foram levados aos canais, girando como forma de evitar o atrito estático. Os fragmentos de guta-percha foram removidos gradualmente com o instrumento sendo introduzido e retirado sucessivamente do canal radicular para evitar super aquecimento.

Foi estipulado como limite apical de desobturação endodôntica três milímetros do fim do comprimento de trabalho.

3.10.2 Protater universal retratamento

Entre os sistemas rotatórios em NiTi desenvolvidos para retratamento, um dos mais populares é o ProTaper Retratamento Universal (ProTaper UR; Dentsply / Maillefer, Ballaigues, Suíça). Este sistema possui três instrumentos D1 (30.09 - 16mm), D2 (25.08 - 18mm) e D3 (20.07 - 22mm) usado até 500rpm. As limas foram ativadas utilizando o motor elétrico VDW Silver (VDW GmbH, Munique, Alemanha) ajustado para 2N de torque e 250rpm de velocidade. O instrumento D1 foi utilizada para remoção no terço cervical, D2 para o terço médio e D3 até o comprimento de trabalho. A remoção foi considerada completa quando não foi possível observar guta-percha no interior do conduto.

3.10.3 Reciproc

Mais conhecido representante das limas oscilatórias, a Reciproc (RB, VDW, Munique, Alemanha) consiste em uma lima de uso único que utiliza o movimento oscilatório para reduzir a fadiga. Estas foram introduzidas no conduto obturado em acionamento e com movimentos de "vai e vem", para evitar aquecimentos desnecessários. Três tipos de instrumentos reciproc's estão disponíveis comercialmente R25 (25.08), R40 (40.06) e R50 (50.05), a escolha destes dependeu do diâmetro radiográfico do conduto. A remoção foi considerada completa quando não foi possível observar guta-percha no interior do conduto.

3.11 ANÁLISE ESTATÍSTICA

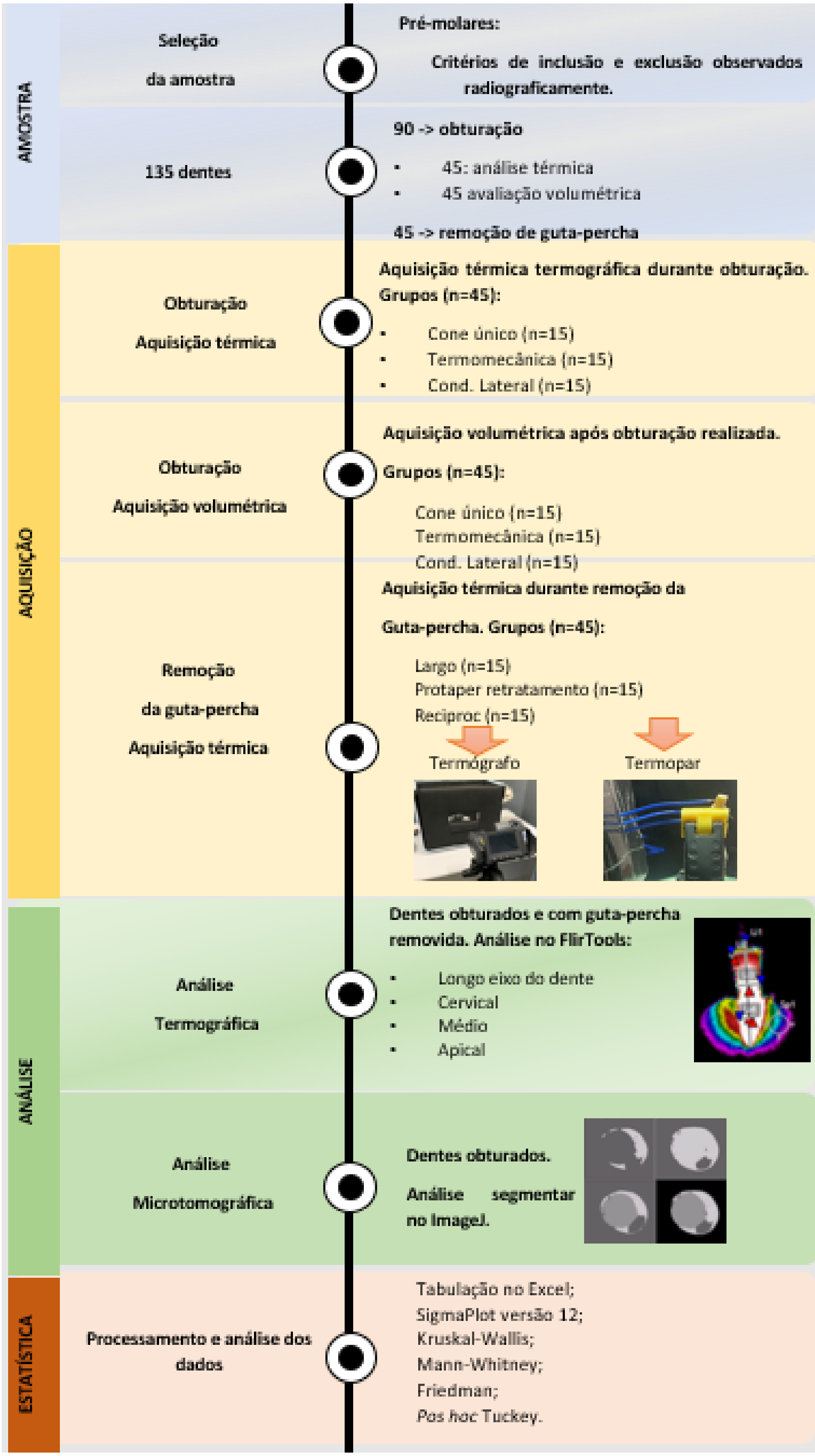
Os dados foram registrados e tabulados com auxílio do software Excel Office 2016 e, posteriormente, importados para o pacote estatístico SigmaPlot versão 12.

Inicialmente, foi empregada a análise estatística descritiva, em seguida a análise inferencial com comparações múltiplas entre as técnicas de obturação e remoção da guta-percha nos diferentes terços do dente, tempos de trabalho e resfriamento.

Após análise de normalidade pelo teste de Shapiro-Wilk foi constada a distribuição a anormal da amostra, assim os testes de comparação foram delimitados. Para amostras independentes, envolvendo apenas dois grupos, foi utilizado o teste não paramétrico de Mann-Whitney. Para amostras independentes, com três ou mais grupos, foi utilizado o teste de Kruskal-Wallis. Para as diferenças entre grupos pareadamente observadas com o teste *post hoc* de Tuckey.

Para amostras dependentes, que possuíam três grupos ou mais, foi utilizado o teste de Friedman com análise variância bidirecional de Tuckey. O nível de significância foi fixado em 5%, considerando-se $p < 0,05$.

3.12 FLUXOGRAMA



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Thermal and volumetric assessment of endodontic filling techniques

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ABSTRACT

Aim: To assess root temperature variation during different filling technique and to quantify the volume and voids of endodontic filling materials. using infrared thermography and µCT. **Methods:** The sample consisted of 90 premolars equally divided into 3 groups according to the filling techniques assessed: 1) Lateral condensation (LC), single cone (SC) and thermomechanical compaction (TMC) techniques. Half of the sample was submitted to the three studied filling techniques while monitored by a FLIR T650sc thermal camera and the other half was scanned on a NIKON µCT scanner. Thermal analysis was conducted on the teeth's three thirds and its long axis. The volumetric analysis was conducted to assess gutta-percha, cement and the void volumes. Descriptive and inferential statistical analysis were done (non-parametric Mann-Whitney, Kruskal-Wallis, and Friedman tests with Tukey's bidirectional analysis of variance). **Results:** The highest median temperature increase was of 7.5 ° C for TM at 15 seconds after endodontic filling was done 60 seconds after obturation, the temperature decrease was statistically significant in the three studied groups. The cervical third showed the highest temperature increase compared to the other thirds (18.6 ° C). In the volumetric assessment, TMC presented the largest volume of gutta-percha ($p < 0.05$) with an average of 67.27 ± 25.61 mm3. Among the three techniques, LC presented a higher void volume (29.91 ± 15.37 mm3). **Conclusion**: The temperature increase generated by the studied gutta-percha endodontic filling techniques is within the acceptable limits. A greater volume of endodontic cement was observed in the single cone and lateral condensation filling techniques.

Keywords: Thermography; Root Canal Obturation; X-Ray Microtomography

INTRODUCTION

The success of endodontic treatment depends on the correct shaping of the root canal and the hermetic sealing of its fluids. Endodontic filling aims to prevent further contamination by sealing the root, what may be impaired by (Vertucci 2005, Muliyar *et al*. 2014). Since a previous study indicated that 58% of endodontic treatment failures were due to incomplete obturation (Ingle *et al*. 1994), great emphasis has been placed on developing materials and techniques aiming to improve the endodontic filling and sealing of the root canal.

Gutta-percha is the most popular endodontic filling material due to its biocompatibility, inertia, plasticity when heated, easy handling and removal in cases of retreatment (Shilder, 1967, Lea *et al*. 2005, Sobhnamayan *et al*. 2013). However, gutta-percha does not have adhesive properties, and is unable to provide proper sealing of the root canal. Therefore, the use of endodontic cements to provide impermeable sealing is needed as it fills irregularities and small discrepancies between gutta-percha and the root canal walls (Shilder 1967, Shipper &Trope 2004, Kim *et al*. 2015).

Micro Computed Tomography (µCT) is an accurate and non-destructive in vitro image method that allows the study of the root canal system and the quality of root canal filling techniques. This image method presents high-resolution image acquisition, image enhancement, artifact reduction filters and allows repeated analysis of the same sample, which are advantages that have led to the increasing use of µCT in research. µCT is considered the most reliable method to assess filling materials and voids induced by endodontic treatment (Suassuna *et al*. 2017, Castagnola *et al*. 2018, Heran *et al*. 2019; Roizenblit et al., 2019, Zhong et al., 2019).

To improve gutta-percha flow rate, heat has been used on endodontic filling techniques. The endodontic filling techniques known as "hot techniques" thermoplasticize gutta-percha or use compactors heated to an average of 200 ° C to plasticize gutta-percha (Silver *et al.* 1999, Venturi *et al.* 2006, Viapiana *et al.* 2015, Atmeh *et al.* 2020). Venturi et al (2006) found that the minimum temperature for gutta-percha plasticization is 47°C, what means that “cold techniques” such as lateral condensation, single cone and thermomechanical techniques may increase the tooth temperature as well. When using heat to properly fill the root canal, the temperature irradiation to the external surface must be considered. Studies show that periodontal tissues can be damaged if the temperature increases 10°C above the normal body temperature (Fors *et al*. 1985, Gutmann *et al*. 1987, Saunders, 1990).

Thermography is a method of image analysis that records the thermal distribution of a surface by capturing the infrared waves emitted by the object under analysis. Its high resolution allows to establish the temperature of any pixel in the region of interest (Marroquin *et al.* 2015, Melo *et al.* 2018, Diegritz *et al*. 2019). Previous studies used thermal cameras or thermocouples to analyze the temperature variation generated by filling techniques; however, there is a lack of studies assessing techniques considered cold (Mc Cullagh *et al* 1997, Mc Cullagh *et al.* 2000, Sweatman *et al.* 2001, Lipski 2004, Lipski 2006, Kilic *et al* 2013, Marroquín *et al*. 2015, Donnermeyer *et al.* 2018, Diegritz *et al.* 2019). Additionally, previous studies used thermocouples which can only measure the temperature of specific points of the sample (Sweatman *et al.* 2001; Donnermeyer *et al.* 2018), and when infrared thermography was used the environmental conditions of the study room was not reported (Mc Cullagh *et al* 1997, Mc Cullagh *et al.* 2000, Lipski 2004).

Therefore, this study aims to assess the temperature increase and quantify the intracanal filling material of lateral condensation, single cone and thermomechanical endodontic filling techniques using infrared thermography and µCT.

MATERIAL AND METHODS

This *ex-vivo* experimental study was approved by the University Ethics Committee (protocol number: 14464819.2.0000.518) and is in accordance with the Helsinki Declaration.

Sample Preparation

The sample consisted of 90 single-rooted premolars, with unique root canals, maximum root curvature of ≤5° and similar dimensions verified by digital radiographs. After cleaning and disinfection protocols, all crowns were removed at the cementoenamel junction with the aid of a diamond disc (KG Sorensen, Zenith Dental ApS, Agerskov, The Netherlands). The sample was stored in NaOCl 0.9% saline solution.

The root canal was irrigated with 2 ml of sodium hypochlorite 2.5% (Ciclo farma, Serrana, SP, Brazil). K-type hand files #10 (DentsplyMaillefer, Ballaigues, Switzerland) were introduced up to the apical foramen and the tooth’s length (TL) was measured, which was considered the working length (WL). The apical limit of instrumentation and obturation was defined as 0.0 mm (WL = TL).

The root canal preparation was carried out by a specialist with a NiTi Reciproc file (VDW, Munich, Germany) with an R50 instrument (50.05) for wide canals or R40 (40.06) for medium canals. The reciprocal system was operated with the electrical motor VDW Silver (VDW GmbH, Munich, Germany) with speed and torque automatically calibrated.

Following the instrumentation, the root canals were irrigated with 2 ml of ethylenediaminetetraacetic acid (EDTA) 17% (Biodinâmica Química e Farmacêutica Ltda, Ibipora, PR, Brazil) for 3 min under stirring with a type k-15 hand file, followed by a second irrigation with 2 ml of sodium hypochloride 2.5% and dried using paper cones.

For further assessment, the sample was divided into two groups in order to guarantee the endodontic filling quality for the volumetric analysis: 1) 45 premolars treated endodontically in standardized conditions; 2) 45 premolars treated endodontically during infrared thermography image acquisition.

Obturation protocols

The sample was equally divided into three groups (n =30), according to the endodontic filling technique used: Lateral condensation (LC), single cone (SC) and thermomechanical compaction (TMC). Ah Plus (DentsplyMaillefer, Ballaigues, Switzerland) cement was used for all techniques.

Group LC: Insertion of the main gutta-percha cone with 40.02 or 50.02 conicity smeared cement on the WL, and accessory cones (DentsplyMaillefer, Ballaigues, Switzerland) embedded in cement. NiTi spacer (DentsplyMaillefer, Ballaigues, Switzerland) was used to provide adequate space for the accessory cones. The process was repeated until the complete filling of the canal. The excessive gutta-percha was removed with heat and the crown was compacted with an appropriate presser (Odous de Deus, Belo Horizonte, Brazil).

Group SC: Adaptation of the gutta-percha cone with identical size and conicity of the instrument used in the mechanical preparation (40.06 or 50.05), followed by the smearing of cement on the WL, removing the cervical excess with a heated presser and subsequent cold vertical compaction.

Group TMC: Adaptation of the cone with identical size and conicity to those of the instrument used in the mechanical preparation (40.06 or 50.05), smeared on the cement on the WL. The thermocompactor PacMac 45.04 of 21 mm (SybronEndo Dental Specialties, Glendora, CA) mounted at the counter-angle with rotation to the right was inserted beside the cone, operating in back and forth movements to obtain gutta-percha apical filling.

Infrared Thermography Image Acquisition

A FLIR T650sc (Flir, Wilsonville, Oregon, USA) handheld camera with infrared sensor, 25 mm lens and spatial resolution of 640×480 pixels, was used to capture the thermographic images. During thermographic image acquisition, the room temperature was maintained at 23 ± 1°C, and the relative humidity of the air between 40 and 60%, verified by means of a Digital Hygro Thermometer (MT-242, minipa, São Paulo, Brazil) placed close to the sample.

In order to eliminate any thermal interference from the operator, an apparatus to hold and isolate the sample was built, consisting of a thermal box of expanded polystyrene plates, with its internal walls coated with a layer of aluminum foil covered by black Ethylene Vinyl Acetate (EVA), avoiding image artifacts at the time of the examination. Aiming to delimit the field of view size uniquely to the sample, a rectangular opening was made at the point where the images of the sample should be captured. To fix the sample in the orthoradial position, plastic pliers were used. The tooth-plastic pliers set was inserted in a Styrofoam cylinder with its outer portion covered by aluminum foil and EVA (Figure 1).

Figure 3. Apparatus to hold and isolate the sample.

The thermal camera was positioned 30 cm from the sample (Figure 2). The camera was programmed to continually acquire images with a 15s interval from each other immediately before the start of the endodontic treatment until the temperature was normalized. The following parameters were set in the thermal camera: 0.98 emissivity and 44% relative humidity.

The measured temperature values were considered as an increase from the initial temperature, so the highest temperature in the established worktime minus the initial temperature of the sample (before the endodontic filling technique was initiated). The temperature assessment was divided in root temperatures during the endodontic filling procedures, root temperatures 60 seconds after the end of the filling techniques procedures. The time taken to normalize the root temperature was also measured.

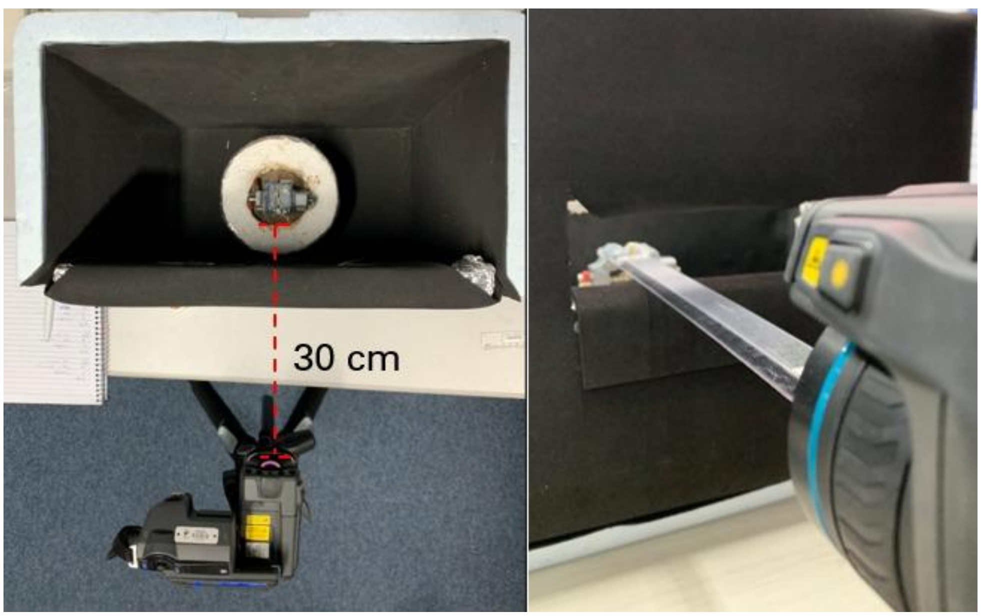


Figure 2. Infrared thermal camera distance from the sample (30 cm).

μCT Image Acquisition

The sample was scanned on NIKON (model XTEK XT-H 225 ST, 225 kV microfocus source, Brighton, MI, EUA) μCT scanner. The exposure parameters were set at 80 kV, 222 µA and 11 µm resolution adjusted to the volumetric limits of the sample. The sample was inserted into Styrofoam blocks of 14×14×15 cm and then fixed to the support for scanning.

The images obtained were reconstructed along the axial, sagittal and coronal planes using XTEK-CT PRO 3D software (Brighton, MI, EUA), and imported to VG Studio Max 2.2 software (Volume Graphics Gmbh, Heidelberg, Germany). In the sequence, a Gaussian filter (3×3×3 mm) was applied to smooth artifacts and noise. The images were finally exported in TIFF format.

Infrared Thermography Image Assessment

Four temperature measurements were performed using the FLIR Tools v. 6.4 software (Flir, Wilsonville, Oregon, USA), with the straight tool: 1- along the long axis of the tooth-working length (cervical-apical); 2- horizontal measurements on three points of the working length (cervical, mesial, and apical portions) (Figure 3).

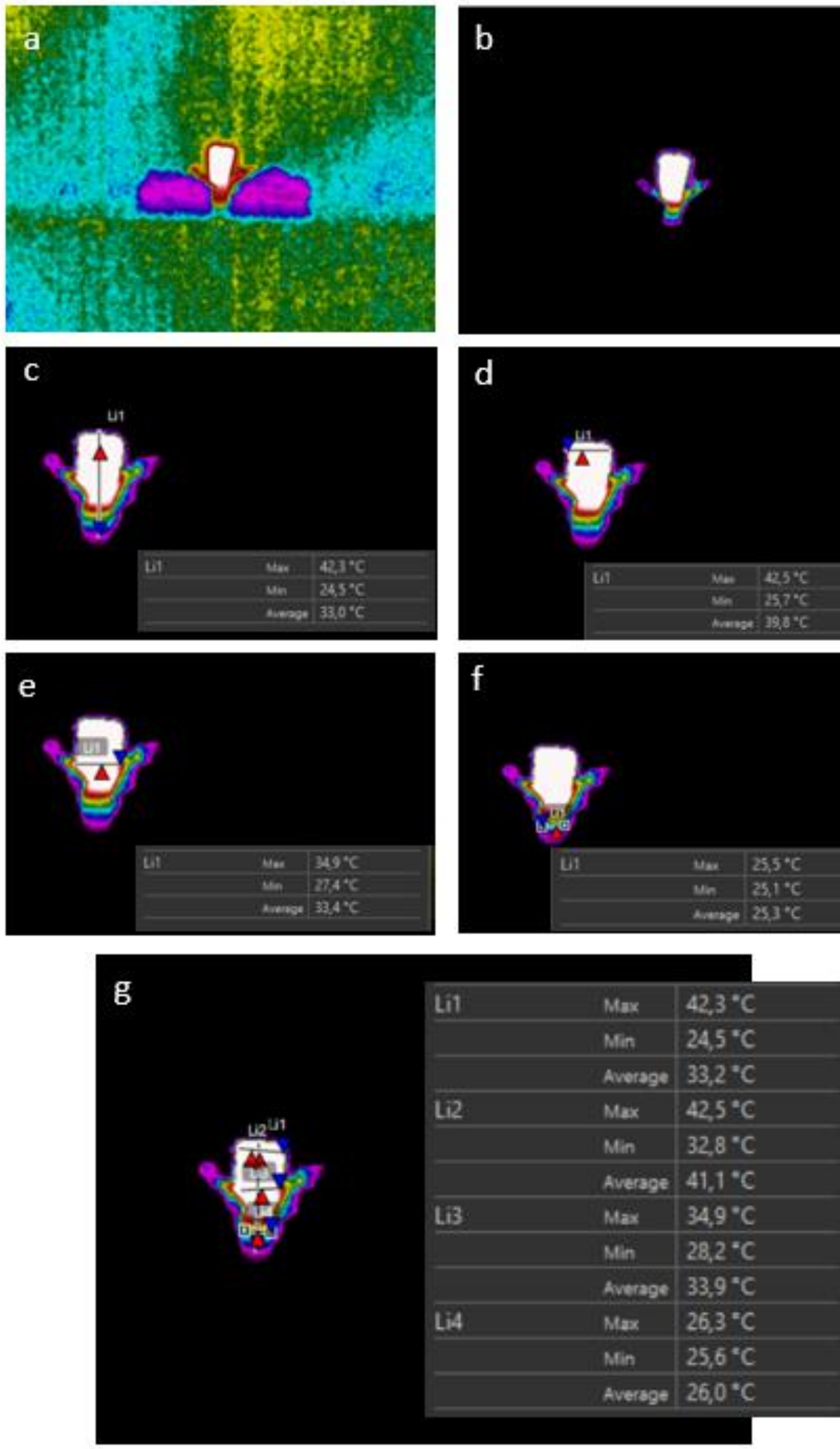


Figure 3. Temperature measurement in thermograms using FLIR Tools v. 6.4. **(a)** Initial thermogram. **(b)** Thermogram with background removed. **(c)** Line 1: traced along the long axis of the tooth. **(d)** Line 2: drawn perpendicular to the long axis in the cervical portion. **(e)** Line 3: drawn perpendicular

to the long axis in the middle portion. **(f)** Line 4: drawn perpendicular to the long axis in the apical portion of the tooth.

μCT Assessment

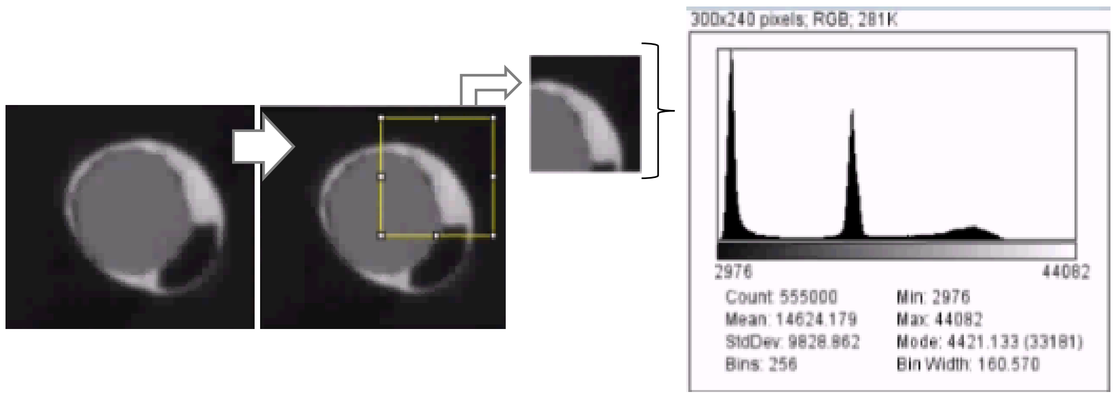
All images were analyzed and measured using an ImageJ software (64-bit Java 1.8.0_172, National Institutes of Health, Bethesda, MD, http:// rsb.info.nih.gov/ij/). Initially, the axial images were imported into the ImageJ software, with the region corresponding to the root canal cut out using the square selection tool. A new selection was made in order to maintain a similar proportion of cement, dentin and void, to view the voxel values for each material in the peaks of the histogram.

Based on the pixel interval values of each material, the volumes were subjected to two segmentations using the CT segmentation tool. The first segmentation was between cement and other structures, and the second between dentin with empty spaces and other materials. The volumes resulting from the two segments were added by the image calculator operation addition tool, resulting in a three-phase segmentation with values defined between the three materials of interest that fill the root canal.

To remove the background, the three-phase segmented volume was doubled, and its copy converted into a binary volume using the tool *large bit width thresholding*. In the binary volume, the erode tool was applied aiming to add morphometric layers to the shape.

The value 254 was subtracted from the binary volume with the aid of the image calculator operation subtraction tool, with the objective of zeroing the background value and providing the value of "one" for the region corresponding to the root canal. The binary volume with the values of "zero" and "one" was given the name of mask (Figure 4). The multiplication using the image calculator multiplication operation tool, between the result of the sum of the segmentations and the mask, resulted in a volume with no background and with voxel values defined for each material. Thus, when generating a histogram of this last

volume, it is possible to define the number of voxels of each material in the sample and, therefore, the volume of each studied material (Figure 4).



a. First histogram.

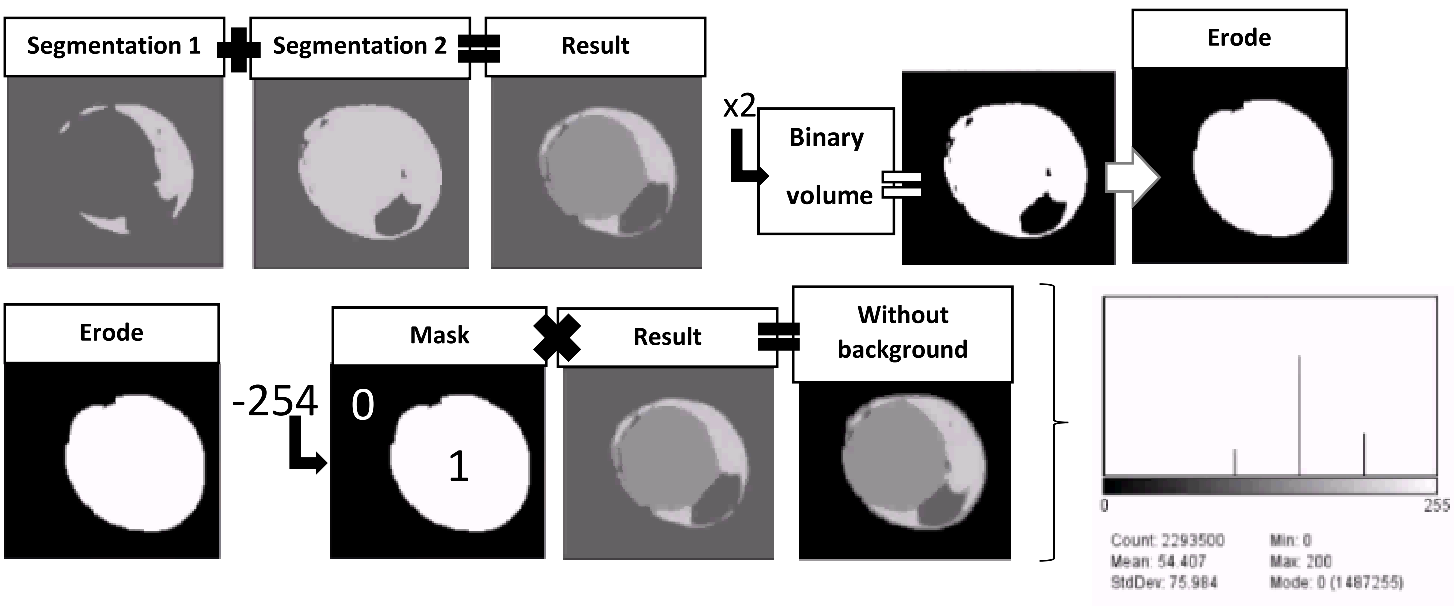


Image 4. Addition between segmentation 1 (Sealer and other materials) and segmentation 2 (Dentine and other materials). Changing the result in binary volume and use of the erode tool. Subtraction of the binary volume by 254. Multiplying the mask by the result, elimination the background. Final histogram generated after background deletetion.

Data analysis

Data were imported into the statistical package Sigma Plot version 12 (Systat Software, Inc., San Jose, California, USA). Descriptive and inferential statistical analysis were used.

After applying the Shapiro-Wilk test, the sample was considered abnormally distributed. For dependent variables with 3 groups, the Friedman test was used, followed by the Tukey pos hoc test. For independent variables with 3 groups, the Kruskal-Wallis non-parametric test was used, and the Tukey test and the Mann-Whitney test for the volumetric analyzes.

The level of significance was set at 5%, considering $p < 0.05$.

RESULTS

In the long axis of the tooth, the highest temperatures were found during the endodontic filling and 15 seconds after the beginning of the endodontic filling technique for all studied techniques ($p < 0.05$). The TMC technique presented a statistically significant decrease in temperature 45 seconds after the completion of the technique. For the other studies techniques (LC and SC), temperature decrease was only observed 30s after the filling ($p < 0.05$) (Table 1).

TMC presented the highest temperature increase 7.5 ° C throughout the long axis of the tooth, differing statistically from SC ($p = 0.004$). Cervical, middle, and apical thirds temperatures differed from each other for all studied times ($p < 0.05$). The cervical third presented the highest temperature values for the LC technique. For the middle and apical thirds during the endodontic filling, the highest temperatures were observed for the TMD technique which differed from SC for all the studied times ($p<0.05$) (Table 2).

Regarding the endodontic filling techniques temperature normalization time, there was no statistical difference between the studied endodontic filling techniques (Table 3).

As for the volume of voids, the LC technique presented a higher average void volume (29.91 mm3), however it did not differ from the other studied techniques. Gutta-percha volume was greater in the TMC technique, followed by lateral condensation ($p=0.011$) (Table 4).

When analyzing the volume of gutta-percha by thirds, the cervical third concentrates the largest volume of gutta-percha and the middle and apical thirds the largest volume of cement. The single cone technique presented the lowest gutta-percha volume when compared to the other studied techniques ($p=0.011$) (Table 5).

Table 1. Comparison between the temperature rise generated at different times measured in different endodontic filling techniques in tooth length.

Filling techniques	Work time	15s	30s	45s	60s	p*
Tooth log axis						
SL	4.4^{a} (3.6-5.5)	4.7^{a} (3.3-5.8)	$4^{a,b}$ (2.8-6.3)	$3.4^{a,b}$ (2.6-5.5)	3.2^{b} (2.1-5)	<0.001
LC	6.5^{a} (5-8.7)	6.6^{a} (5-8.4)	$5.9^{a,b}$ (4.3-7.8)	$5^{b,c}$ (4-6.9)	4.3^{c} (3.6-5.7)	<0.001
TMC	6.6^{a} (5.1-9.3)	7.5^{a} (5.2-13.3)	6.9^{a} (4.3-11.6)	$6.9^{a,b}$ (3.6-11.4)	$5{,}8^{b}$ (3.3-11.1)	0.003
Cervical						
SL	15.7^{a} (10.2-20.7)	12.9^{a} (9.4-17.7)	9.5^{a} (6.7-13.8)	$7.2^{a,b}$ (5.3-10.7)	6.6^{b} (3.8-9.4)	<0.001
LC	18.6^{a} (15.4-26.2)	14.8^{a} (10.9-20)	10.3^{b} (8.3-13.8)	$8.4^{b,c}$ (7.1-12.2)	7.2^{c} (5.5-9.5)	<0.001
TMC	10.3^{a} (5.1-16.2)	13.5^{a} (6.4-19.2)	13.6^{a} (8-25.8)	$14.7^{a,b}$ (9.2-24.4)	13.1^{b} (10.4-24.1)	<0.001
Middle						
SL	2.9^{a} (1.2-4.7)	$4.4^{a,b}$ (2.5-6.2)	4.2^{a} (3-6)	$4.5^{a,b}$ (2.7-6.7)	$3.7^{a,b}$ (2.2-5)	0.027
LC	$6.2^{a,b}$ (4.1-9.7)	7.1^{a} (5,1-8,)	$6.6^{a,b}$ (4,4-8,3)	$6.2^{a,b}$ (4.7-8.4)	5.2^{b} (4.3-7.5)	0.026
TMC	$10.6^{a,b}$ (7.6-15.4)	9.8^{a} (7.2-23.6)	$8.6^{a,b}$ (6.4-13.6)	$9.1^{a,b}$ (5.5-16)	9^{b} (4.8-15.1)	0.001
Apical						
SL	0.3^{a},b (0.2-0.5)	0.3a (0.2-0,6)	$0.5^{b,c}$ (0.4-1)	0.8^{c} (0.4-1,3)	1^{c} (0.4-1.3)	<0.001
LC	1.6a (1.3-1.8)	1.6^{a},b (1.1-2.2)	$1.2^{b,c}$ (1-1.8)	$1.3^{b,c}$ (0.7-1.8)	0.9^{c} (0.5-1.5)	<0.001
TMC	2.9 (1.3-4.2)	2.8 (1.8-5.1)	2.5 (1.8-4.4)	2 (1.6-3.2)	2.1 (1.9-3.7)	0.168

*Friedman Test

^{a,b} Tukey Test

Table 2. Comparison between filling techniques in different thirds of the tooth and working times according to thermal analysis.

		SC		CL		TMC		
Endodontic filling techniques	**n**	**Median**	**Q_{25}-Q_{75}**	**Median**	**Q_{25}-Q_{75}**	**Median**	**Q_{25}-Q_{75}**	***p****
				Work time (°C)				
Tooth log axis	*15*	4.4^{a}	*3.6-5.5*	$6.5^{a.b}$	*5-8.7*	6.6^{b}	*5.1-9.3*	*0.016*
Cervical	15	15.7(A)	10.2-20.7	18.6(A)	15.4-26.2	13.1(A)	10.4-24.1	0.475
Middle	15	2.9^{a}(B)	1.2-4.7	6.2^{b}(B)	4.1-9.7	10.6^{c}(A)	7.6-15.4	*<0.001*
Apical	15	0.3^{a}(C)	0.2-0.5	0.9^{b}(C)	0.5-1.5	2.9^{b}(B)	1.3-4.2	*<0.001*
		<0.001		*<0.001*		*<0.001*		
				***15 seconds after Endodontic filling* (°C)**				
Tooth log axis	*15*	4.7^{a}	*3.3-5.8*	$6.6^{a.b}$	*5-8.4*	7.5^{b}	*5.2-13.3*	0.004
Cervical	15	12.9(A)	9.4-17.7	14.8(A)	10.9-20	13.5(A)	7.3-20.8	0.561
Middle	15	4.4^{a}(B)	2.5-6.2	7.1^{b}(B)	5.1-8.6	9.8^{b}(A)	7.2-23.6	*<0.001*
Apical	15	0.3^{a}(C)	0.2-0.6	1.3^{b}(C)	0.7-1.8	2.8^{c}(B)	1.8-5.1	*<0.001*
p		*<0.001*		*<0.001*		*<0.001*		
				30 seconds after Endodontic filling (°C)				
Tooth log axis	*15*	4^{a}	*2.8-6.3*	$5.9^{a.b}$	*4.3-7.8*	6.9^{b}	*4.3-11.6*	0.008
Cervical	15	9.5(A)	6.7-13.8	10.3(A)	8.3-13.8	13.6(A)	8-25.8	0.176
Middle	15	4.2^{a}(B)	3-6	$6.6^{a.b}$(A)	4.4-8.3	8.6^{b}(A)	6.4-13.6	*<0.001*
Apical	15	0.5^{a}(C)	0.4-1	$1.2^{a.b}$(B)	1-1.8	2.5^{b}(B)	1.8-4.4	*<0.001*
p		*<0.001*		*<0.001*		*<0.001*		
				45 seconds after Endodontic filling (°C)				
Tooth log axis	*15*	3.4^{a}	2.6-5.5	$5^{a.b}$	4-6.9	6.9^{b}	3.6-11.4	0.012
Cervical	15	7.2(A)	5.3-10.7	8.4(A)	7.1-12.2	13.5(A)	6.4-19.2	0.076
Middle	15	4.5^{a}(A)	2.7-6.7	$6.2^{a.b}$(A)	4.7-8.4	9.1^{b}(A)	5.5-16	*0.002*
Apical	15	0.8^{a}(B)	0.4-1.3	$1.6^{a.b}$(B)	1.1-2.2	2^{b}(B)	1.6-3.2	*<0.001*
p		*<0.001*		*<0.001*		*<0.001*		
				60 seconds after Endodontic filling (°C)				
Tooth log axis	*15*	3.2^{a}	2.1-5	$4.3^{a.b}$	3.6-5.7	5.8^{b}	3.3-11.1	0.034
Cervical	15	6.6(A)	3.8-9.4	7.2(A)	5.5-9.5	10.3(A)	5.1-16.2	0.274
Médio	15	3.7^{a}(A)	2.2-5	$5.2^{a.b}$(A)	4.3-7.5	9^{b}(A)	4.8-15.1	*<0.001*
Apical	15	1^{a}(B)	0.4-1.3	$1.6^{a.b}$(B)	1.3-1.8	20.1^{b}(B)	1.9-3.7	*<0.001*
p		*<0.001*		*<0.001*		*<0.001*		

*Kruskal-Wallis test

$^{a.b}$ Tukey's bidirectional analysis of variance - lowercase letters in horizontal and uppercase letters in vertical.

Table 3. Comparison between cooling time to room temperature in different filling techniques

Endodontic filling techniques	**n**	***Time to temperature normalization seconds (minutes)***		
		Mediana	**Q_{25}-Q_{75}**	***p****
Single cone	15	211 (3:31)	167-252 (2:46-4:12)	*0.410*
Lateral Condensation	15	224 (3:43)	151-266 (2:31 – 4:25)	
Thermomechanical	15	227 (3:46)	168-299 (2:48-4:58)	

*Kruskal-Wallis test

Table 4. Comparison of the averages of the volume of materials present in the root canal filled by filling techniques.

Volume	**Single cone**		**Thermomechanical Compaction**		**Lateral Condensation**		***p****
	Average (mm^3)	**Average (%)**	**Average (mm^3)**	**Average (%)**	**Average (mm^3)**	**Average (%)**	
Gutta-percha	48.4^{a}	50	67.3^{b}	64.6	$66.9^{a.b}$	57.2	**0.011**
Cement	28.3^{a}	31	12.1^{b}	12.7	20.3^{a}	17.3	**<0.001**
Empty space	17.5	19	23.8	22.7	29.9	25.5	0.072
Total	**94.2**	**100**	**103.2**	**100**	**117.1**	**100**	

* Teste Kruskal-Wallis.
$^{a.b}$: Peer comparison using the Mann-Whitney test. with Bonferroni penalties (*p*=0.01).

Table 5. Comparison of the average volume of filling materials per third in relation to the filling techniques used.

Volume	Single cone		Thermomechanical Compaction		Lateral Condensation		*p**
	Average (mm^3)	Average (%)	Average (mm^3)	Average (%)	Average (mm^3)	Average (%)	
Gutta-percha	**48.4[a]**	**100**	**67.3[b]**	**100**	**66.9[a.b]**	**100**	**0.011**
Cervical	30[a]	63.8	41.2[b]	61.4	48.1[a.b]	69.5	**0.041**
Middle	15.4[a]	28.8	17.7[b]	28	14.1[a]	22.3	**0.011**
Apical	3[a]	7.4	8.4[b]	10.6	4.7[b]	8.2	**0.001**
Cement	**28.3[a]**	**100**	**12.1[b]**	**100**	**20.3[a]**	**100**	**<0.001**
Cervical	8.3[a]	29.3	0.8[b]	6.3	5.4[a]	24.6	**<0.001**
Middle	11[a]	38.9	4.4[b]	34	7.5[a]	37.8	**<0.001**
Apical	9[a]	31.8	6.9[a]	59.7	7.4[a]	37.6	0.092

* Teste Kruskal-Wallis.
[a.b]: Peer comparison using the Mann-Whitney test. with Bonferroni penalties (*p*=0.01).

DISCUSSION

Previous studies have assessed vertical and hot wave condensation root temperature increase using thermocouples and found that their temperature increase does not reach over the 10°C critical temperature limit (Barkordar *et al.* 1990, Wellwe & Koch 1995; Sweatman *et al.* 2001, Venturi *et al.* 2002). However, previous studies using thermal cameras demonstrate contradictory results with alarming temperature increases, probably due to different methodologies, lack of standardized thermal protocols and low-resolution infrared thermography cameras (Mc Cullagh *et al.* 1997, Mc Cullagh *et al.* 2000, Lipski 2004, Lipski 2006, Kilic *et al* 2013, Donnermeyer *et al* 2018). Thus, there is no consensus in the literature on gutta-percha removal techniques root temperature increase. Studies using thermal cameras to assess the temperature throughout the whole sample are needed to confirm these findings.

Periodontal anatomy must also be considered when assessing the root temperature. According to Cen *et al.* (2018) the blood flow present in the periodontal ligament leads to a decrease in temperature that is transferred from the cementum to the bone. The endodontic filling technique execution time must be taken in consideration when assessing root temperature increase. In this study, the longest normalization time found was of 3:46 minutes. According to Zhang *et al* (2011), tooth temperature increases of 2 to 6 ° C for 5 minutes can induce bone formation, and can lead to ankylosis, while temperature rises over 10°C can induce bone resorption. In this study, the root temperature increase reached over 10°C during root filling but decreased and normalized in an inferior time than what is considered harmful; therefore, the studied cold techniques do not injure the periodontium.

In the cervical portion of the root, temperature increase reaches values above 10°C during endodontic filling procedures and 15 seconds after the technique is finished for all studied endodontic filling techniques. LC technique presents the highest temperature values probably due to the direct use of heated instruments in the cervical portion of the tooth. After the removal of the heated instruments in the LC technique, the temperature decreases approximately 10°C in one minute. Diegritz *et al.* (2019) also observed a temperature decrease of 14.5°C one minute after the execution of the warm vertical compaction.

In the cervical third of the root, the thermomechanical technique has a different heating pattern than the other studied techniques, presenting its peak temperature 45 seconds after completion of the root filling, probably because the instrument is inserted cold in the canal and then the heating is triggered by friction to plasticize gutta-percha (Mc Spadden 1980). Frictional heating allows a larger area of gutta-percha to be heated and thus plasticized, this may justify the high volume of gutta-percha in the cervical portion of the canal.

The apical third showed the lowest temperatures when compared to the other studied thirds, in accordance with Venturi *et al* (2002) study which found a temperature increase of 4.1°C and 0.9 ° C in the cervical and apical areas, respectively. According to Marroquin *et al* (2015) gutta-percha is a poor thermal conductor, transports heat irregularly, and should be heated 1–2 mm from the target area, what justifies lower temperatures in the apical third of the root. The difficulty in plasticizing gutta-percha in the apical region must be linked to the low volume of gutta-percha in this region, which corroborates with most studies that report that the apical region is more likely to present voids (Kierklo *et al.* 2014; Kierklo *et al*. 2015; Castagnola *et al* . 2018).

A systematic review compared hot and cold condensation techniques and concluded that they did not show statistical differences regarding the quality of gutta-percha filling (Peng 2007). This study tested two cold techniques and one" warm" technique (TMC), finding no statistical difference between the three and with a lower volume of voids in the single cone technique. LC due to the juxtaposition of several cones does not allow the formation of a cohesive gutta-percha mass, leading to a greater number of voids when compared to hot techniques and single cone technique (Clinton & Himel 2001, Lea *et al*. 2005; Ho *et al.* 2016).

There was no statistical difference in the total volume of gutta-percha between the LC and TMC technique. However, the middle third in the TMC technique presented higher volume of gutta-percha and higher temperature increase during the endodontic procedure than the other studied techniques. This indicates that the gutta-percha may have achieved the ideal plasticization temperature, what leads to a lower volume of voids in this technique.

Cement fills irregularities and slight discrepancies between the root canal walls and gutta-percha (Shilder 1967, Shipper & Trope 2004, Kim *et al.* 2015). But among its property's, solubility constitutes a negative characteristic since its dissolution can lead to the presence of voids between the dentin and gutta-percha (Oliveira *et al*. 2011, SILVA *et al.* 2015, SILVA *et al.* 2016). Therefore, techniques that lead to a greater volume of cement, like single cone technique and lateral condensation, are not ideal techniques. To minimize those effects, resinous cements are indicated, as their sealing capacity and adhesiveness is higher, and they also present lower volume expansion. (Tedesco *et al.* 2014, Celikten *et al.* 2015).

Lipki (2006) reported a safe increase in temperature in the continuous wave technique in the upper central incisors, but the increase in temperature exceeded the critical level in the lower central incisors that have less dentin volume. Studies by Cen *et al.* (2018) and Zhou *et al.* (2010) using finite elements show that the molar furcation area has great heating potential. Therefore, studies using different teeth, with one or more roots, are necessary to evaluate the thermal increase of the endodontic filling technique.

CONCLUSION

Temperature increase generated by the studied endodontic filling techniques are considered in the acceptable range, however, the cervical third needs extra attention to avoid a temperature increase over 10°C. Lateral condensation and single cone techniques present higher cement volume than the thermomechanical compaction technique. The thermomechanical technique presents acceptable temperature increase and good endodontic material volumetric filling.

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ARTIGO 2
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Variation of root surface temperature during root canal filling removal material

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ABSTRACT

Aim: to assess the temperature variation of gutta-percha removal with a stainless steel and two NiTi instruments using infrared thermography and thermocouples. **Material and Methods:** 45 single-rooted teeth were divided into three groups according to the following gutta-percha removal instruments: Largo Peeso (L), Protaper Retreatment (PR) and Reciproc (R). Thermal analysis was conducted using FLIR T650sc infrared thermography camera and three thermocouples. For infrared thermography assessment, the infrared camera was programed to acquire thermograms every 15 seconds, before the gutta-percha removal started until temperature normalization. Root temperature was assessed in the thermograms using FLIR tools software v6.4 with the straight-line tool along the long axis of the tooth; and in the cervical, middle, and apical thirds of each tooth. The temperature from the thermocouples were recorded and registered for each root third. For data analysis, inferential statistical analysis Kruskal-Wallis and post hoc Tuckey tests were used. **Results:** For the infrared thermography camera, the highest median temperature value was found 15 seconds after gutta-percha removal for the L technique (20.3°C), which presented the highest temperatures at all studied times. For thermocouples, the highest temperature was found in the middle third during gutta-percha removal with L (20.7°C). For both methods PR and R presented similar patterns of root temperature. **Conclusion:** Protaper Universal Retreatment and Reciproc NiTi instruments present lower temperature increase values. Stainless-steel Largo Peeso temperature reaches values above 10°C; however, for insufficient time to cause injuries to the periodontium. Infrared thermography and thermocouples can be used to assess root temperature variation.

Key words: Root canal preparation; transition temperature; endodontic.

INTRODUTION

Gutta-percha removal is needed when dealing with unsuccessful endodontic therapy or when intracanal anchoring is needed. When gutta-percha removal is indicated, the tooth structure is already weakened due to previous mechanical and biological tissue loss. Gutta-percha removal can be performed with the aid of stainless-steel rotary instruments or NiTi rotary or oscillatory instruments, with or without the aid of solvents (BRAMANTE et al., 2010; CAMPELO et al., 2019; FAUS-MATOSES et al., 2020).

Temperature increase leads to changes in the microcirculation of the adjacent tissues which can harm the adjacent connective tissue, leading to chronic periodontitis and tooth resorption. External root temperature increase can be harmful to the periodontium when higher than 10°C than the body temperature; however, the damage is still reversible (FORS et al. 1985; GUTMANN et al. 1987; SAUNDERS. 1990). When the temperature increases over 16°C, the periodontium alterations may be irreversible and even injure the adjacent bone tissue (FORS et al. 1985; GUTMANN et al. 1987; SAUNDERS. 1990; GARCÍA-CUERVA et al. 2017).

Thermal measurements can be performed using thermocouples or infrared thermal cameras. The thermocouple is a temperature sensor made of two metallic wires connected to a thermometer/data logger which informs the temperatures of a surface where its wires are connected to (SCERVINI. 2009). Thermocouples have been used to measure root temperature caused by gutta-percha removal techniques (BRAMANTE et al. 2010; GARCÍA-CUERCA et al. 2017); however, restricting heat measurement to a limited contact point or points may constitute a limitation of this method. Infrared thermography cameras can detect infrared radiation emitted by objects creating real time thermographic images (thermograms). Infrared thermography captures and records the thermal distribution allowing the measurement of temperatures and the observation of heat distribution patterns of the whole study subject (SWEATMAN. BAUMGARTNER. SAKAGUCHI. 2001; ALTOÉ. OLIVEIRA FILHO. 2012; PERRY et al. 2013; MOON. 2014).

During gutta-percha removal, dentin removal may be needed, which may increase the amount of heat irradiated to the root surface generated by stainless-steel or NiTi instruments (LERTCHIRAKARN. TIMYAM. MESSER. 2002; FUKUI et al., 2009). Previous studies report that the use of NiTi instruments is safer when compared to stainless steel instruments and there is no difference in the effectiveness between NiTi rotary and oscillatory (reciprocating) instruments (ROSSI-FEDELE. MAHAMED. 2017). However, the few studies on temperature increase during gutta-percha removal used thermocouples as a method of temperature analysis, which limits the thermal analysis to the point of contact of the sensor with the root (BRAMANTE et al. 2010; GARCÍA-CUERCA et al. 2017).

Therefore, this study aims to analyze root temperature variation during gutta-percha removal with a stainless-steel and two NiTi (rotary and oscillatory) instruments using infrared thermography and thermocouples.

MATERIAL AND METHODS

This ex-vivo experimental study was approved by the University Ethics Committee (protocol number: 14464819.2.0000.518) and follows the Helsinki Declaration.

Sample Preparation

The sample consisted of 45 single-rooted premolars. Inclusion criteria determined that all teeth should have a maximum root curvature of ≤5°, similar dimensions and a unique canal. After cleaning and disinfection protocols, all crowns were removed at the cementoenamel junction and the sample was stored in 0.9% saline solution.

The root canals were irrigated with 2 ml of 2.5% sodium hypochlorite (Ciclo farma, Serrana, SP, Brazil). K-type hand files #10 (DentsplyMaillefer, Ballaigues, Switzerland) were introduced up to the apical foramen to determine the tooth's length (TL), which was considered the working length (WL). Then, the apical limit of instrumentation and obturation was defined as 0.0 mm (WL = TL).

The root canal preparation was done with a NiTi Reciproc file (VDW, Munich, Germany) with an R50 instrument (50.05) for wide canals or R40 (40.06) for medium canals. The root canals were irrigated with 2 ml of ethylenediaminetetraacetic acid (EDTA) 17% (Biodinâmica Química e Farmacêutica Ltda, Ibipora, PR, Brazil) for 3 min under stirring using k-15 hand file, followed by a second irrigation with 2 ml of 2.5% sodium hypochlorite and dried using paper cones.

The root canal was then filled with gutta-percha using the thermomechanical compaction technique. A cone with identical size and conicity to the instrument used in the mechanical preparation (40.06 or 50.05) was adapt to the canal, and then smeared on the Ah

Plus cement (Dentsply Maillefer, Ballaigues, Suíça) on the WL. The thermocompactor PacMac 45.04 of 21 mm (SybronEndo Dental Specialties, Glendora, CA) mounted on the counter-angle with rotation to the right was inserted beside the cone, operating using back and forth movements to obtain the apical sealing.

Thirty days after obturation, the sample was divided into three groups (n=15) to assess the following gutta-percha removal instruments: 1) Largo Peeso Reamer (Stainless-steel instrument), 2) Protaper Universal Retreatment (Rotary NiTi instrument) and 3) Reciproc (oscillatory/reciprocating NiTi instrument).

1). Largo Peeso Reamer: The instrument size was chosen according to the diameter of the canal. The gutta-percha fragments were gradually removed by repeatedly introducing and removing the reamer to avoid overheating of the root. The apical endodontic clearance limit was set at 3 millimeters from the end of the WL.

2) Protaper Universal Retreatment: ProTaper NiTi rotary instruments were used in a crown-down technique with an electric motor VDW Silver (VDW GmbH. Munique. Germany) at 2N torque and 250rpm. D1 (30.09 - 16mm) was used to remove gutta-percha from the cervical third, D2 (25.08 - 18mm) for the middle third and D3 (20.07 - 22mm) until WL. Removal was considered complete when it was not possible to observe gutta-percha inside the conduit.

3) Reciproc: Reciproc NiTi reciprocating instruments were used in crown-down technique, with an electric motor VDW Silver (VDW GmbH. Munique. Germany) in the reciproc function. R25 (25.08), R40 (40.06) and R50 (50.05) according to the radiographic diameter of the canal. Removal was considered complete when it was not possible to observe gutta-percha inside the canal.

Root temperature assessment

The external root temperature was assessed using two different temperature assessment modalities simultaneously: thermocouples and infrared thermography.

Thermocouples root temperature assessment

Type k thermocouples with 0.1°C resolution and temperature range of -50 °C to 999.9C ° were used to assess temperature values during gutta-percha removal. The thermocouples sensitive wire ends were fixed at the root external surface by creating three spherical small wears on the lingual surfaces of the roots using a n°1012 spherical diamond drill (KG Sorensen. Zenith Dental ApS, Agerskov, Denmark). The spherical wears positions were determined by dividing the root in three thirds and were equidistant from each other with an approximate depth of 1mm (Figure 1).

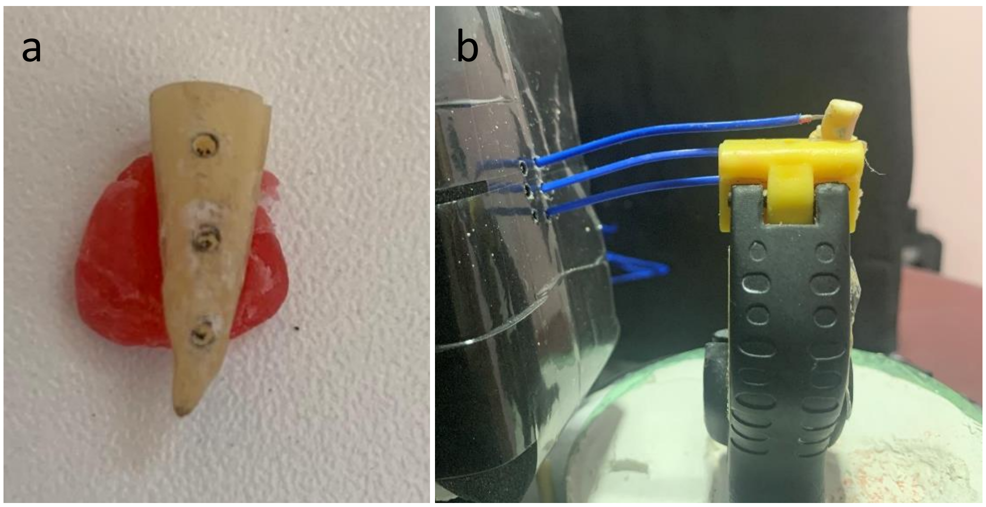

Figure 1 (a) Spherical wears on the lingual surfaces of the roots to adapt the thermocouples wires. (**b)** Root attached to the thermocouples sensitive wire ends and fixed on the plastic pliers.

To register the temperatures obtained from the thermocouple, the thermometer was positioned outside the thermal box and filmed using a cellphone (iPhone XR, California, USA). The videos were analyzed, and the temperatures of the thermocouples wire ends were recorded at same time the infrared thermography thermograms were acquired (Figure 2).

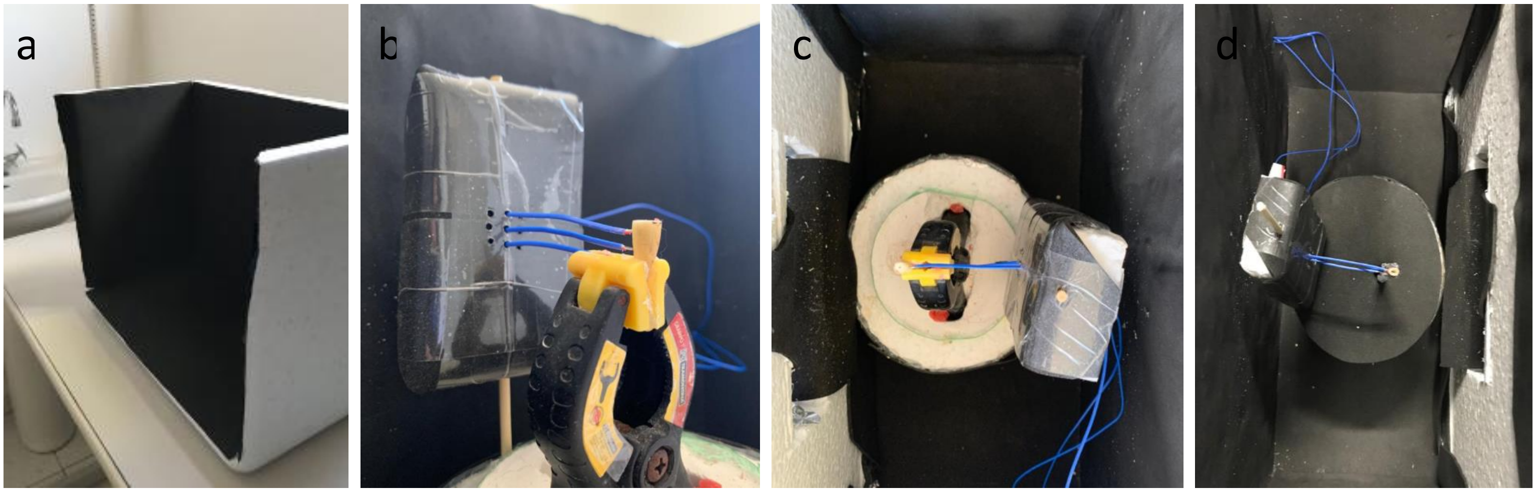

Figure 2. (a) Box of expanded polystyrene plates coated with aluminum foil covered by black Ethylene Vinyl Acetate (EVA). **(b)** Sample fixed with plastic pliers and thermocouple plugs - front view. **(c)** Sample fixed with plastic pliers and thermocouple plugs – upper view **(d)** Record of the temperature acquired by thermocouples by filming.

Infrared thermography root temperature assessment

A FLIR T650sc (Flir Systems, Oregon, USA) handheld camera with an infrared sensor, 25 mm lens and spatial resolution of 640×480 pixels, was used to capture the thermographic images of the root during gutta-percha removal. During the thermograms acquisition, room temperature and relative humidity were maintained in constant at 20 to 21°C and 40 to 60%, respectively.

To eliminate any thermal interference from the operator, a thermal box of expanded polystyrene plates coated with aluminum foil covered by black Ethylene Vinyl Acetate (EVA) was built to hold and isolate the sample. A rectangular opening was made where the images of the sample should be captured to establish the image area. Plastic pliers were used to fix the sample in the orthoradial position and inserted in a Styrofoam cylinder (Figure 3).

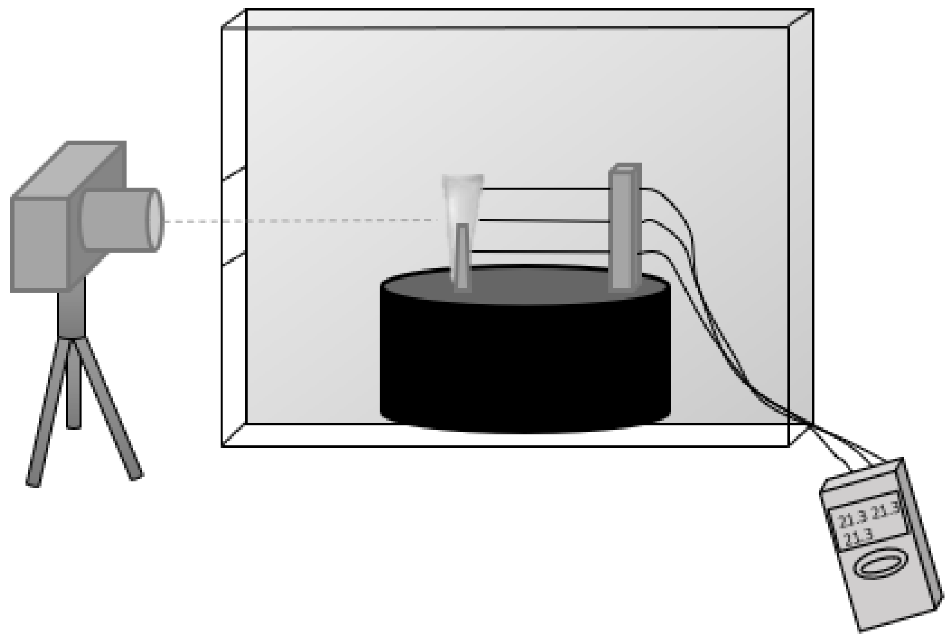

Figure 3. Representative image of thermocouples and thermography temperature acquisition.

The thermal camera was positioned 30 cm from the samples according to the manufacturer's instructions. The infrared camera exposure parameters were set at 98% emissivity and 44% of relative humidity, and the camera was programed to acquire thermograms every 15 seconds, before the gutta-percha removal started until the temperature was normalized.

The thermograms temperatures were assessed using the FLIR Tools v. 6.4 (Flir Systems, Oregon, USA) software. Initially, the temperature scale was reduced by eliminating the background temperatures (Figure 4). Four lines were traced: One at the long axis of the tooth and other three perpendicular to the long axis on the cervical, middle, and apical portions of the tooth (Figure 5).

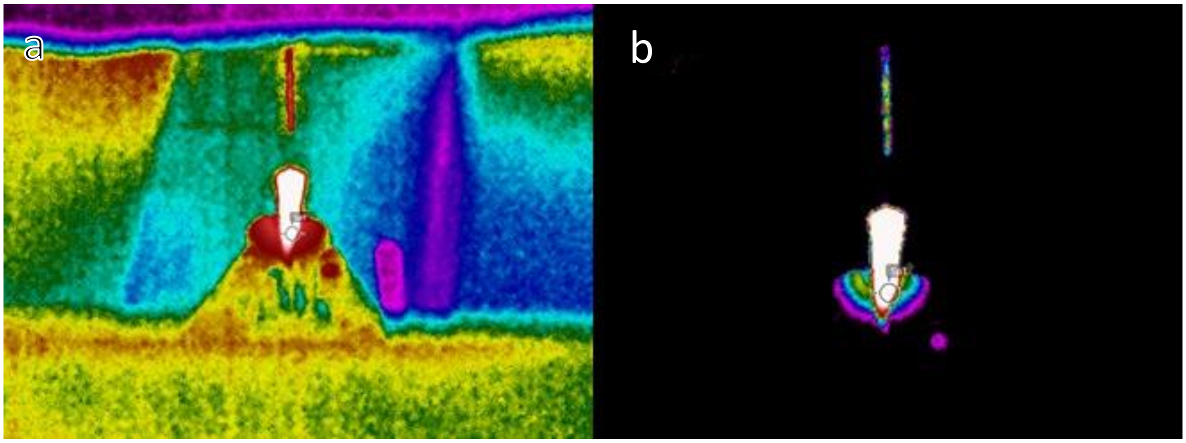

Figure 4. (a) Background removal using FLIR Tools v. 6.4 software; (b) temperature measurement using straight tool along the long axis of the tooth and at the cervical, middle, and apical thirds.

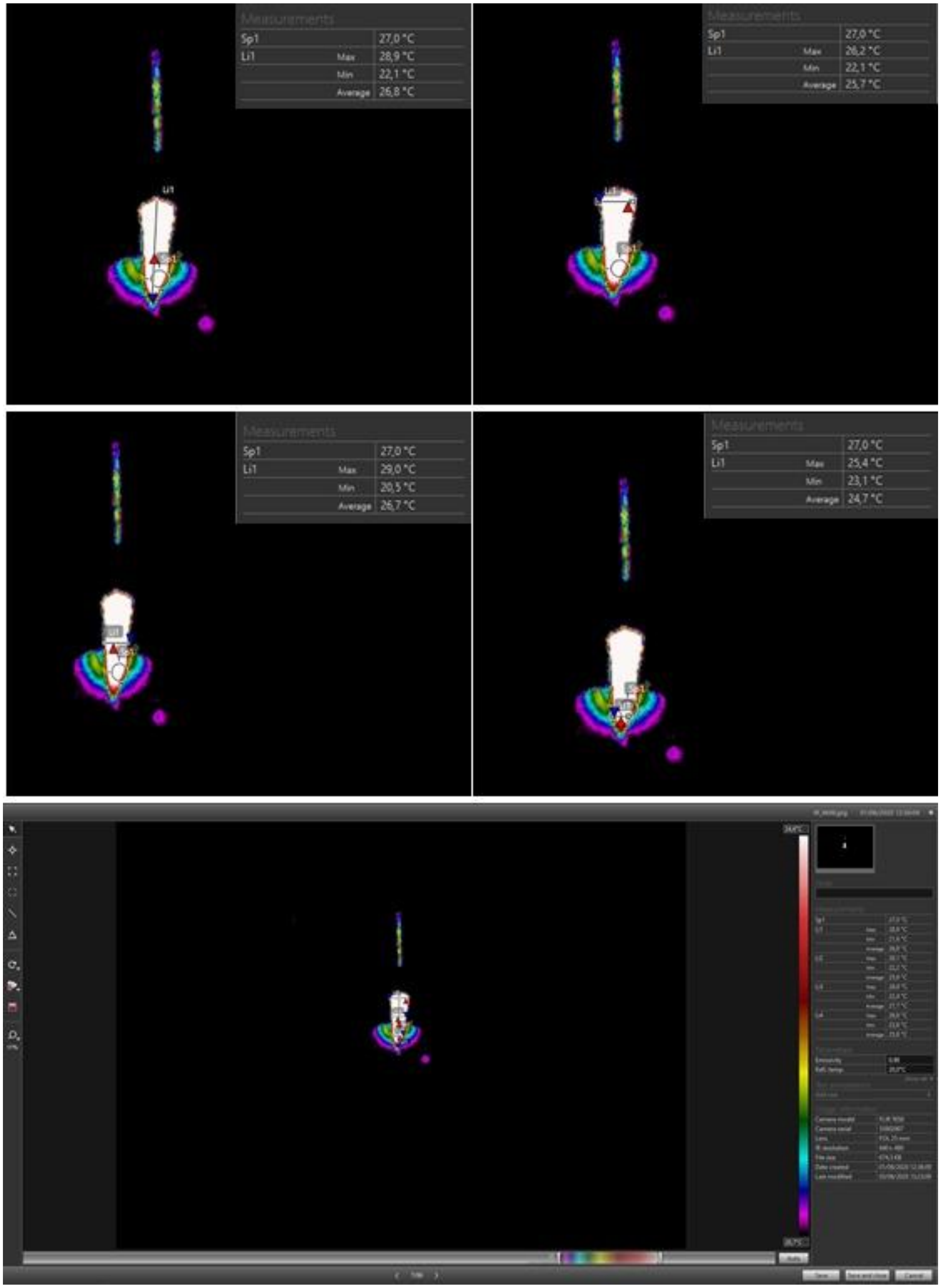

Figure 5. Temperature measurement in thermograms using FLIR Tools v. 6.4. Four lines were traced: One at the long axis of the tooth and other three perpendicular to the long axis on the cervical, middle, and apical portions of the tooth.

Thermal images were acquired during gutta-percha removal with an interval of 15 seconds starting before the initiation o the technique and until the temperature was normalized. The measured temperature values were considered as an increase from the initial temperature, so the highest temperature in the established worktime minus the initial temperature of the sample. After analyzing the root temperature during the gutta-percha removal technique, the temperatures were assessed during 60 seconds after the completion of the technique. Then the time that was needed for temperature normalization was also registered.

Data Analyzes

Data were imported into the statistical package Sigma Plot version 12 (Systat Software, Inc., San Jose, California, USA). Descriptive and inferential statistical analysis were done. Shapiro-Wilk test verified the abnormal distribution of the sample. Kruskal-Wallis and post hoc Tukey test were used to assess data. The level of significance was set at 5% ($p < 0.05$).

RESULTS

For infrared thermography analysis, the highest median temperature increase throughout the teeth long axis was of 20.3°C ($p<0.001$) for the Largo Peeso reamer, at 15 seconds after the gutta-percha removal. Largo Peeso reamer showed the highest temperature values throughout the teeth long axis for all studied times ($p<0.001$). Largo Pesso reamers and Reciproc presented similar temperature values at the teeth's apical third (Table 1).

For thermocouple analysis, the highest temperature increase median values were found in the middle third of the teeth when Largo Peeso reamers were used (20.7°) ($p<0.05$) (Table 2).

When infrared thermography and thermocouples were compared, infraered thermography registered higher temperature values than thermocouples. (Table 3).

When assessing the techniques worktime and temperature variation of each technique throughout the teeth long axis, temperature decrease differed from the initial temperature value at 45 seconds after temperature measurement started for Largo Pesso and Protaper Universal Retreatment ($p<0.001$), and at 30 seconds for Reciproc instruments ($p<0.001$).

When assessing worktime and temperature variation of each technique at the studied teeth's thirds, at the cervical third Protaper Universal Retreatment and Reciproc temperature decrease differed from the initial temperature value at 60 seconds and 45 seconds after temperature measurement started, respectively ($p<0.001$). At the apical third, Reciproc temperature decrease differed from the initial temperature value at 60 seconds ($p<0.001$) (Table 3).

Largo Peeso reamer temperature increases surpassed 10°C at all studied thirds, persisting for 60 seconds after gutta-percha removal (Table 4).

Temperature normalization was achieved for Largo Peeso reamers at approximately 5:54 minutes after the gutta-percha removal was finished, differing statistically from the other studied instruments ($p=0.002$) (Table 5).

Table 1. Comparison between the temperature increase (°C) generated by gutta-percha removal techniques in the different thirds of the tooth and working times for infrared thermography thermal analysis

		Gutta-percha removal instruments						
		Largo		**Protaper**		**Reciproc**		
Thirds	**n**	**Median**	**Q_{25}-Q_{75}**	**Median**	**Q_{25}-Q_{75}**	**Median**	**Q_{25}-Q_{75}**	***p****
				During Work time (°C)				
Tooth log axis	*15*	*18.9[a]*	*10.5-20.9*	*2.9[b]*	*2.2-3.6*	*4.8[b]*	*4.2-6.7*	*<0.001*
Cervical	15	22.7[a(A)]	18.7-35.5	3.6[b]	2-4.4	5.1[b]	2.8-7	*<0.001*
Middle	15	25.6[a(A)]	13.2-27.3	3.6[b]	2.5-4.4	7.4[b]	3.3-8.3	*<0.001*
Apical	15	15.6[a(B)]	2.3-20.3	2.4[b]	0.6-3.6	5.1[a]	4.4-8.2	*<0.001*
*p**		*0.002*		0.066		0.456		
				15 seconds after* gutta-percha removal *(°C)				
Tooth log axis	*15*	20.3[a]	13.5-27.7	2.4[b]	2.1-3.5	5.3[b]	3-6	*<0.001*
Cervical	15	23[a]	19.4-24.3	2.7[b]	1.7-3.8	3.7[b]	3.3-5.8	*<0.001*
Middle	15	26.5[a]	7-34.7	2.8[b]	1.8-4.4	5.9[c]	3.2-7.5	*<0.001*
Apical	15	17.3[a]	1.5-33	2.3[b]	0.8-3.1	5.1[a]	2.9-6.6	*<0.001*
*p**		0.163		0.122		0.322		
				30 seconds after* gutta-percha removal *(°C)				
Tooth log axis	*15*	16.2[a]	10.2-22.3	2.2[b]	1.6-3.2	4.1[b]	2.1-4.9	*<0.001*
Cervical	15	16.6[a]	15.1-17.4	2.5[b]	1.4-4.1	3.0[b]	2.6-4.9	*<0.001*
Middle	15	20.1[a]	6.6-27.4	2.7[b]	1.4-4	4.8[b]	2.5-5.9	*<0.001*
Apical	15	14.7[a]	1.8-23.5	2[b]	0.6-2.5	3.9[a.b]	2.2-5.2	*<0.001*
*p**		0.375		0.184		0.454		
				45 seconds after* gutta-percha removal *(°C)				
Tooth log axis	*15*	13[a]	9.2-15.9	1.8[b]	0.9-2.6	2.6[b]	1.8-3.9	*<0.001*
Cervical	15	14[a]	11.1-14.8	2.3[b]	1.2-3.2	3.7[b]	2.4-4.3	*<0.001*
Middle	15	15.5[a]	5.3-18.7	1.8[b]	1.1-3.4	4.2[b]	2.8-5b	*<0.001*
Apical	15	11.9[a]	2.4-18.2	1.3[b]	0.5-2.3	2.8[b]	1.9-4.3	*<0.001*
*p**		0.394		0.295		0.450		
				60 seconds after* gutta-percha removal *(°C)				
Tooth log axis	*15*	9.2[a]	6.9-13.7	1.3[b]	0.7-3	2.7[b]	2.2-3.4	*<0.001*
Cervical	15	11[a]	8.9-13.1	2.3[b]	1.3-3	2.6[b]	2.4-3.5	*<0.001*
Middle	15	10.4[a]	8.1-14.9	1.4[b]	1-3.3	3[b]	2.2-3.7	*<0.001*
Apical	15	8.3[a]	2.5-14.3	1.2[b]	0.4-3.3	3.2[a.b]	2-3.9	*<0.001*
*p**		0.179		0.596		0651		

*Kruskal-Wallis test

[a.b] Tukey's bidirectional analysis of variance - lowercase letters in horizontal and uppercase letters in vertical .

Table 2. Comparison between the temperature increase (°C) generated by gutta-percha removal techniques in the different studied teeth thirds and working times for thermocouples.

		Gutta-percha removal instruments						
		Largo		**Protaper**		**Reciproc**		
Thirds	**n**	**Median**	**Q_{25}-Q_{75}**	**Median**	**Q_{25}-Q_{75}**	**Median**	**Q_{25}-Q_{75}**	***p****
				During Work time (°C)				
Cervical	15	$17.4^{a(A)}$	13.5-22.4	$3.7^{b(A)}$	2.3-5.4	$6.3^{c(A)}$	5.3-7.8	*<0.001*
Middle	15	$20.7^{a(A)}$	14.3-27.1	$3.8^{b(A)}$	2-4.6	$3.8^{b(A)}$	2.9-6.4	*<0.001*
Apical	15	$11.9^{a(B)}$	11.1-16.2	$2^{b(B)}$	0.7-2.9	$1.3^{b(B)}$	0.9-1.6	*<0.001*
*p**		*<0.001*		*0.005*		*<0.001*		
				15 seconds after* gutta-percha removal *(°C)				
Cervical	15	$12.1^{a(A)}$	8.2-15.7	$2.1^{b(A)}$	1.6-2.9	$3.8^{b(A)}$	2.8-4.9	*<0.001*
Middle	15	$11.9^{a(A)}$	108-14.5	$1.8^{b(A)}$	1.3-3.1	$2.8^{b(A)}$	2.4-3.7	*<0.001*
Apical	15	$6.1^{a(B)}$	5.3-10.2	$1.3^{b(B)}$	0.6-1.4	$1.3^{b(B)}$	0.9-1.6	*<0.001*
*p**		*<0.001*		0.003		*<0.001*		
				30 seconds after* gutta-percha removal *(°C)				
Cervical	15	$8.9^{a(A)}$	6.8-14.8	$1.9^{b(A)}$	1.3-2.4	$3.4^{c(A)}$	2.5-4.4	*<0.001*
Middle	15	$10.8^{a(A)}$	8.7-11.1	$1.4^{b(A.B)}$	1.1-2.6	$2.5^{b(A)}$	2.1-3.5	*<0.001*
Apical	15	$5.8^{a(B)}$	3.1-8.5	$1.1^{b(B)}$	0.5-1.2	$1.2^{b(B)}$	0.9-1.3	*<0.001*
*p**		*<0.001*		0.002		*<0.001*		
				45 seconds after* gutta-percha removal *(°C)				
Cervical	15	$7.7^{a(A)}$	5.8-11.3	$1.6^{b(A)}$	1.1-2.1	$3.1^{c(A)}$	2.3-3.7	*<0.001*
Middle	15	$8.3^{a(A)}$	7.4-9.3	$1.4^{b(A.B)}$	0.9-2.1	$2.4^{c(A)}$	1.9-3	*<0.001*
Apical	15	$5.6^{a(B)}$	2.6-6.5	$1^{b(B)}$	0.5-1.1	$1.1^{b(B)}$	0.7-1.2	*<0.001*
*p**		*<0.001*		0.002		*<0.001*		
				60 seconds after* gutta-percha removal *(°C)				
Cervical	15	$6.5^{a(A)}$	4.4-8.9	$1.4^{b(A)}$	0.9-1.9	$2.6^{c(A)}$	2.1-3.4	*<0.001*
Middle	15	$6.8^{a(B)}$	6.3-7.8	$0.9^{b(A.B)}$	0.8-1.9	$1.7^{b(B)}$	1.3-2.6	*<0.001*
Apical	15	$4.9^{a(A)}$	2.5-5.3	$0.8^{b(B)}$	0.4-1	$1.1^{b(C)}$	0.6-1.2	*<0.001*
*p**		*<0.001*		0.005		*<0.001*		

*Teste de Kruskal-Wallis

a.b Tukey's bidirectional analysis of variance - lowercase letters in horizontal and uppercase letters in vertical ..

Table 3. Comparison between the studied thermal analysis methods (°C) temperature increase generated by the studied gutta-percha removal instruments for the teeth thirds.

Thirds	Largo Median ($Q_{25} – Q_{75}$) Termography	Largo Termocouples	Largo p*	Protaper Median ($Q_{25} – Q_{75}$) Termography	Protaper Termocouples	Protaper p*	Reciproc Median ($Q_{25} – Q_{75}$) Termography	Reciproc Termocouples	Reciproc p*
Work time (°C)									
Cervical	22.7 (18.7-35.5)	17.4 (13.5-22.4)	*0.034*	3.6 (2-4.4)	3.7 (2.3-5.4)	0.299	6.3 (5.3-7.8)	5.1 (2.8-7)	0.105
Middle	25.6 (13.2-27.3)	20.7 (14.3-27.1)	0.506	3.6 (2.5-4.4)	3.8 (2-4.6)	0.787	3.8 (2.9-6.4)	7.4 (3.3-8.3)	0.124
Apical	15.6 (2.3-20.3)	11.9 (11.1-16.2)	0.868	2.4 (0.6-3.6)	2 (0.7-2.9)	0.520	1.3 (0.9-1.6)	5.1 (4.4-8.2)	*<0.001*
15 seg (°C)									
Cervical	20.7 (19.4-24.3)	12.1 (8.2-15.7)	*0.002*	2.1 (1.6-2.9)	2.7 (1.7-3.8)	0.171	3.7 (3.3-5.8)	3.8 (2.8-4.9)	0.361
Middle	11.9 (10.8-14.5)	26.5 (7-34.7)	*0.031*	2.8 (1.8-4.4)	1.8 (1.3-3.1)	*0.032*	2.8 (2.4-3.7)	5.9 (3.2-7.5)	*0.006*
Apical	17.3 (1.5-33)	6.1 (5.3-10.2)	0.243	1.3 (0.6-1.4)	2.3 (0.8-3.1)	0.078	5.1 (2.9-6.6)	1.3 (0.9-1.6)	*<0.001*
***30 seg* (°C)**									
Cervical	16.6 (15.1-17.4)	8.9 (6.8-14.8)	*<0.001*	1.9 (1.3-2.4)	2.5 (1.4-4.1)	0.124	3 (2.6-4.9)	3.4 (2.5-4.4)	0.371
Middle	20.1 (6.6-27.4)	10.8 (8.7-11.1)	*0.038*	2.7 (1.4-4)	1.4 (1.1-2.6)	*0.029*	2.5 (2.1-3.5)	4.8 (2.5-5.9)	*0.034*
Apical	14.7	5.8	0.096	1.1	2	*0.031*	3.9	1.2	*<0.001*

	(1.8-23.5)	(3.1-5.5)		(0.5-1.2)	(0.6-2.5)		(2.2-5.2)	(0.9-1.3)	
***45 seg* (°C)**									
Cervical	7.7	14	*<0.001*	2.3	1.6	0.124	3.1	3.7	0.299
	(5.8-11.3)	(11.1-14.8)		(1.2-3.3)	(1.1-2.1)		(2.3-3.7)	(2.4-4.3)	
Middle	15.5	8.3	*0.038*	1.4	1.8	0.077	4.2	2.4	*0.010*
	(5.3-18.7)	(7.4-9.3)		(0.9-2.1)	(1.1-3.4)		(2.8-5)	(1.9-3)	
Apical	5.6	11.9	*0.046*	1.3	1	0.176	1.1	2.8	*<0.001*
	(2.6-6.5)	(2.4-18.2)		(0.5-2.3)	(0.5-1.1)		(0.7-1.2)	(1.9-4.3)	
***60 seg* (°C)**									
Cervical	11	6.5	*0.002*	2.3	1.4	0.053	2.6	2.6	0.647
	(8.9-13.1)	(4.4-8.9)		(1.3-3)	(0.9-1.9)		(2.1-3.4)	(2.4-3.5)	
Middle	10.4	6.8	*0.002*	0.9	1.4	0.105	3	1.7	*<0.001*
	(8.1-14.9)	(6.3-7.8)		(0.8-1.9)	(1-3.3)		(2.2-3.7)	(1.3-2.6)	
Apical	4.9	8.3	0.157	1.2	0.8	0.114	1.1	3.2	*<0.001*
	(2.5-5.3)	(2.5-14.3)		(0.4-3.3)	(0.4-1)		(0.6-1.2)	(2-3.9)	

*Mann-Whitney test

[a,b] Tukey's bidirectional analysis of variance

Table 4. Comparison between the temperature increase generated at the studied worktimes for the studied gutta-percha removal techniques analyzed by thermography.

Thirds	*Work time*	15s	30s	45s	60s	p*
			Tooth log axis			
Largo	18.9^{a} (10.5-20.9)	20.3^{a} (13.5-27.7)	$16.2^{a.b}$ (10.2-22.3)	$13^{b.c}$ (9.2-15.9)	9.2^{c} (6.9-13.7)	<0.001
Protaper	2.9^{a} (2.2-3.6)	2.4^{a} (2.1-3.5)	$2.2^{a.b}$ (1.6-3.2)	1.8^{b} (0.9-2.6)	1.3^{b} (0.7-3)	<0.001
Reciproc	4.8^{a} (4.2-6.7)	5.3^{a} (3-6)	4.1^{b} (2.1-4.9)	2.6^{b} (1.8-3.9)	2.7^{b} (2.2-3.4)	<0.001
			Cervical			
Largo	22.7^{a} (18.7-35.5)	20.7^{a} (19.4-24.3)	$16.6^{a.b}$ (15.1-17.4)	$14^{b.c}$ (11.1-14.8)	11^{c} (8.9-13.1)	<0.001
Protaper	3.6^{a} (2-4.4)	$2.7^{a.b}$ (1.7-3.8)	$2.5^{a.b.c}$ (1.4-4.1)	$2.3^{b.c}$ (1.2-3.3)	3.7^{c} (2.4-4.3)	<0.001
Reciproc	5.1^{a} (2.8-7)	3.7^{a} (3.3-5.8)	$3^{a.b}$ (2.6-4.9)	$3.7^{b.c}$ (2.4-4.3)	2.6^{c} (2.4-3.5)	<0.001
			Middle			
Largo	25.6^{a} (13.2-27.3)	26.5^{a} (7-34.7)	$20.1^{a.b}$ (6.6-27.4)	15.5^{b} (5.3-18.7)	10.4^{b} (8.1-14.9)	<0.001
Protaper	3.6^{a} (2.5-4.4)	2.8^{a} (1.8-4.4)	$2.7^{a.b}$ (1.4-4)	1.8^{b} (1.1-3.4)	1.4^{b} (1-3.3)	<0.001
Reciproc	7.4^{a} (3.3-8.3)	$3.7^{a.b}$ (3.3-5.8)	$4.8^{a.b}$ (2.5-5.9)	$4.2^{b.c}$ (2.8-5)	3^{c} (2.2-3.7)	<0.001
			Apical			
Largo	$15.6^{a.b}$ (2.3-20.3)	17.3^{a} (1.5-33)	14.7^{a} (1.8-23.5)	$11.9^{a.b}$ (2.4-18.2)	8.3^{b} (2.5-14.3)	0.002
Protaper	2.4^{a} (0.6-3.6)	2.3^{a} (0.8-3.1)	$2^{a.b}$ (0.6-2.5)	$1.3^{a.b}$ (0.5-2.3)	1.2^{b} (0.4-3.3)	0.002
Reciproc	5.1^{a} (4.4-8.2)	$5.1^{a.b}$ (2.9-6.6)	$3.9^{a.b}$ (2.2-5.2)	$2.8^{b.c}$ (1.9-4.3)	3.2^{c} (2-3.9)	<0.001

*Friedman test

[a.b] Tukey’s bidirectional analysis of variance - lowercase letters in horizontal and uppercase letters in vertical .

Table 5. Comparison between temperature decrease time for the studied gutta-percha removal instruments.

Thirds	n	Time until temperature standardization *seconds (minutes)*		
		Median	**Q_{25}-Q_{75}**	***p****
Largo	15	354[a] (5:54)	286-481 (4:45-8:06)	*0.002*
Protaper	15	210[a.b] (3:30)	180-285 (3-4:45)	
Reciproc	15	180[b] (3)	180-225 (3-3:45)	

*Teste de Kruskal-Wallis

DISCUSSION

The use of thermocouples limits the temperature increase study to a limited point of the sample (1,7). To increase the surface thermically analyzed in this study, infrared thermography was added to the thermocouple's temperature analysis. When comparing the temperature analyzes methods, infrared thermography tends to present higher temperature values than thermocouples; however, with no statistical difference.

Currently infrared thermography is an image method capable of producing accurate temperature data due to its high resolution, allowing precise temperature measurements, when heat reflections are avoided, and the ambient temperature is kept constant (9, 10, 11, 12). It is important to acknowledge the advantages and limitations of this method when establishing the methodology, to create an environment for the acquisition of thermal images with a minimum of external interference (16,17, 18).

According to García-Cuerva et al (7), the generation of heat when removing gutta-percha from the root canal system can be affected by the type of instrument used, condition of the instrument's cutting edges, rotation type and speed, the cutting pressure applied and time of contact with the tooth structure. The external root temperature increase caused by rotary stainless-steel instruments at low speed may damage the periodontium (7). In this study stainless steel and NiTi instruments with different kinematics were assessed to verify if the instruments' metal alloy and kinematics may interfere on temperature variation during gutta-percha removal.

In this study, the highest temperatures were observed when using the Largo Peeso rotating stainless steel instrument in all studied tooth thirds and working times; probably because this instrument is used with a contra-angle on low speed rotation micromotor (5.000 a 20.000 rpm), while NiTi instruments are used with a 250 to 300 rpm rotation speed micromotors. Stainless steel rotary instruments used with low rotation speed can generate a significant external temperature increase and can be harmful to the periodontium (7).

A systematic review states that the application of the different protocols can be effectively, and that NiTi retreatment files have no advantages when compared with conventional techniques (15). However, in this study, NiTi oscillatory and rotatory instruments generated minimum temperature increase during gutta-percha removal, what can be considered an advantage.

The apical third showed lower temperatures with a statistically significant difference from the cervical and middle thirds for thermocouple thermal analysis. This result may be due to the low thermal conduction of the gutta-percha that starts plasticizing 2 mm from where heat is applied. (19, 20, 21).

Largo Peeso reamers presented a temperature increase above 10°C in all tooth thirds and above 16°C after 30 seconds worktime. An increase of 10°C can lead to changes in the adjacent connective tissue, chronic periodontitis, and tooth resorption, which can be reverted until the temperature increase surpasses 16°C (4, 5, 6). According to Zhang et al (22), temperature increases above 10°C for 5 minutes can lead to bone resorption. In this study, Largo Peeso reamers showed temperature normalization after gutta-percha removal of 5:54 minutes and after 60 seconds the warmest region of interest showed median temperature value of 11°C; therefore, the damage caused by this technique to the periodontium is considered reversible.

Larger preparation sizes and hybrid techniques are associated with less remaining filling material (15). Dentin has a lower thermal conductivity; however, additional removal of dentin is usually needed to anchor intracanal posts what can lead to an increase on gutta-percha thermal irradiation through the root (13, 14). In this study, premolars were assessed, however, teeth with thinner dentin thickness like lower incisors may present a higher temperature increase in the external surface of the root what may lead to irreversible injuries to the periodontium (23); and molars with furcation areas have great heating potential what can also affect the periodontium (20, 24). Studies assessing different teeth and different gutta-percha removal techniques are needed to verify any possible potential periodontium harm.

CONCLUSION

Protaper Universal Retreatment and Reciproc NiTi instruments present lower temperature increase values and should be chosen for gutta-percha removal. Stainless-steel Largo Peeso temperature reaches values above 10°C; however, for insufficient time to cause injuries to the periodontium. Infrared thermography and thermocouples can be used to assess root temperature variation.

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APÊNDICES

APÊNDICE A: INSTRUMENTO DE PESQUISA - INFORMAÇÕES DAS AMOSTRAS PARA OBTURAÇÃO

GRUPO 1:								
AMOSTRA	CRD	INSTRUMENTO MEMÓRIA	CONE PRINCIPAL	TEMPERATURA AMBIENTE INICIAL	HUMIDADE RELATIVA	TEMPO OBTURAÇÃO	TEMPO TOTAL	TERMOGRAMAS
GRUPO 2:								
AMOSTRA	CRD	INSTRUMENTO MEMÓRIA	CONE PRINCIPAL	TEMPERATURA AMBIENTE INICIAL	HUMIDADE RELATIVA	TEMPO OBTURAÇÃO	TEMPO TOTAL	TERMOGRAMAS

APÊNDICE B: INSTRUMENTO DE PESQUISA: TEMPERATURAS DADAS POR TERMOPAR

GRUPO					
AMOSTRA	**CRD**	**TEMPERATURA AMBIENTE INICIAL**	**HUMIDADE RELATIVA**	**TEMPO DESOBTURAÇÃO**	**TEMPO TOTAL**
MÁXIMA DESOB.	T1 – TERMOPAR CERVICAL		T2 – TERMOPAR MÉDIO	T3 – TERMOPAR APICAL	
15S					
30S					
45S					
60S					

GRUPO					
AMOSTRA	**CRD**	**TEMPERATURA AMBIENTE INICIAL**	**HUMIDADE RELATIVA**	**TEMPO DESOBTURAÇÃO**	**TEMPO TOTAL**
MÁXIMA DESOB.	T1 – TERMOPAR CERVICAL		T2 – TERMOPAR MÉDIO	T3 – TERMOPAR APICAL	
15S					
30S					
45S					
60S					

GRUPO					
AMOSTRA	**CRD**	**TEMPERATURA AMBIENTE INICIAL**	**HUMIDADE RELATIVA**	**TEMPO DESOBTURAÇÃO**	**TEMPO TOTAL**
MÁXIMA DESOB.	T1 – TERMOPAR CERVICAL		T2 – TERMOPAR MÉDIO	T3 – TERMOPAR APICAL	
15S					
30S					
45S					
60S					

ANEXOS

ANEXO A: PARECER DO COMITÊ DE ÉTICA

UNIVERSIDADE ESTADUAL DA PARAÍBA - PRÓ-REITORIA DE PÓS-GRADUAÇÃO E

Continuação do Parecer: 3.442.932

Considerações sobre os Termos de apresentação obrigatória:

O projeto apresenta todos os termos de apresentação obrigatória.

Recomendações:

O projeto apresenta uma metodologia bem estruturada, condizendo com a proposta do estudo.

Conclusões ou Pendências e Lista de Inadequações:

O projeto não apresenta pendências relacionadas aos termos de apresentação obrigatórios. Está aprovado salvo melhor entendimento

Considerações Finais a critério do CEP:

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_1340000.pdf	02/07/2019 11:41:52		Aceito
Projeto Detalhado / Brochura Investigador	projeto_Fernanda_Mariz.pdf	02/07/2019 11:41:20	Fernanda Clotilde Mariz da Costa	Aceito
Folha de Rosto	folha_de_rosto.pdf	23/05/2019 10:56:04	Fernanda Clotilde Mariz da Costa	Aceito

Situação do Parecer:

Aprovado

Necessita Apreciação da CONEP:

Não

CAMPINA GRANDE, 08 de Julho de 2019

Assinado por:
Dóris Nóbrega de Andrade Laurentino
(Coordenador(a))

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ANEXO B: NORMAS PARA SUBMISSÃO: INTERNATION ENDODONTIC JOURNAL

Author Guidelines

Content of Author Guidelines:

Useful Websites: **Submission Site**, **Articles published in *International Endodontic Journal***, **Author Services**, **Wiley's Ethical Guidelines**, **Guidelines for Figures**

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International Endodontic Journal publishes original scientific articles, reviews, clinical articles and case reports in the field of Endodontology; the branch of dental sciences dealing with health, injuries to and diseases of the pulp and periradicular region, and their relationship with systemic well-being and health. Original scientific articles are published in the areas of biomedical science, applied materials science, bioengineering, epidemiology and social science relevant to endodontic disease and its management, and to the restoration of root-treated teeth. In addition, review articles, reports of clinical cases, book reviews, summaries and abstracts of scientific meetings and news items are accepted.

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Authors submitting a paper do so on the understanding that the manuscript has been read and approved by all authors and that all authors agree to the submission of the manuscript to the Journal.

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Acknowledgements: Under acknowledgements please specify contributors to the article other than the authors accredited. Please also include specifications of the source of funding for the study and any potential conflict of interests if appropriate. Please find more information on the conflict of interest form in section 2.6.

2.2 Ethical Approvals

Experimentation involving human subjects will only be published if such research has been conducted in full accordance with ethical principles, including the World Medical Association **Declaration of Helsinki** (version 2008) and the additional requirements, if any, of the country where the research has been carried out. Manuscripts must be accompanied by a statement that the experiments were undertaken with the understanding and written consent of each subject and according to the above mentioned principles. A statement regarding the fact that the study has been independently reviewed and approved by an ethical board should also be included. Editors reserve the right to reject papers if there are doubts as to whether appropriate procedures have been used.

When experimental animals are used the methods section must clearly indicate that adequate measures were taken to minimize pain or discomfort. Experiments should be carried out in accordance with the Guidelines laid down by the National Institute of Health (NIH) in the USA regarding the care and use of animals for experimental procedures or with the European Communities Council Directive of 24 November 1986 (86/609/EEC) and in accordance with local laws and regulations.

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The International Endodontic Journal asks that authors submitting manuscripts reporting from a clinical trial to register the trial *a priori* in any of the following public clinical trials registries: **www.clinicaltrials.gov**, **https://www.clinicaltrialsregister.eu/**, **http://isrctn.org/**. Other primary registries if named in the WHO network will also be considered acceptable. The clinical trial registration number and name of the trial register should be included in the Acknowledgements at the submission stage.

2.3.1 Randomised control clinical trials
Randomised 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/prirate/**

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**)

2.3.2 Epidemiological observational trials
Submitting authors of epidemiological human observations studies are required to review and submit a 'strengthening the reporting of observational studies in Epidemiology' (STROBE) checklist and statement. Compliance with this should be detailed in the materials and methods section. (**www.strobe-statement.org**)

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1. Nagendrababu V, Duncan HF, Tsesis I, Sathorn C, Pulikkotil SJ, Dharmarajan L, Dummer PMH. PRISMA for abstracts: best practice for reporting abstracts of systematic reviews in Endodontology. Int Endod J. 2019 Mar 19:1096-07. doi: 10.1111/iej.13118.
2. Nagendrababu V, Dilokthornsakul P, Jinatongthai P, Veettil SK, Pulikkotil SJ, Duncan HF, Dummer PMH. Glossary for systematic reviews and meta-analyses. Int Endod J. 2020 Feb;53(2):232-249. doi: 10.1111/iej.13217. Epub 2019 Nov 25.

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Papers reporting protein or DNA sequences and crystallographic structure determinations will not be accepted without a Genbank or Brookhaven accession number, respectively. Other supporting data sets must be made available on the publication date from the authors directly.

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3.1. Getting Started

• Launch your web browser (supported browsers include Internet Explorer 5.5 or higher, Safari 1.2.4, or Firefox 1.0.4 or higher) and go to the journal's online Submission Site: http://mc.manuscriptcentral.com/iej
• Log-in, or if you are a new user, click on 'register here'.
• If you are registering as a new user.
- After clicking on 'register here', enter your name and e-mail information and click 'Next'. Your e-mail information is very important.
- Enter your institution and address information as appropriate, and then click 'Next.'
- Enter a user ID and password of your choice (we recommend using your e-mail address as your user ID), and then select your areas of expertise. Click 'Finish'.
• If you are registered, but have forgotten your log in details, please enter your e-mail address under 'Password Help'. The system will send you an automatic user ID and a new temporary

password.
• Log-in and select 'Author Centre '

3.2. Submitting Your Manuscript
• After you have logged into your 'Author Centre', submit your manuscript by clicking on the submission link under 'Author Resources'.
• Enter data and answer questions as appropriate. You may copy and paste directly from your manuscript and you may upload your pre-prepared covering letter.
• Click the 'Next' button on each screen to save your work and advance to the next screen.
• You are required to upload your files.
- Click on the 'Browse' button and locate the file on your computer.
- Select the designation of each file in the drop down next to the Browse button.
- When you have selected all files you wish to upload, click the 'Upload Files' button.
• Review your submission (in HTML and PDF format) before completing your submission by sending it to the Journal. Click the 'Submit' button when you are finished reviewing.

ORCID
As part of the journal's commitment to supporting authors at every step of the publishing process, *International Endodontic Journal* requires the submitting author (only) to provide an ORCID iD when submitting a manuscript. This takes around 2 minutes to complete. Please see Wiley's resources on ORCID **here**.

3.3. Manuscript Files Accepted
Manuscripts should be uploaded as Word (.doc) or Rich Text Format (.rft) files (not write-protected) plus separate figure files. GIF, JPEG, PICT or Bitmap files are acceptable for submission, but only high-resolution TIF or EPS files are suitable for printing. The files will be automatically converted to HTML and PDF on upload and will be used for the review process. The text file must contain the abstract, main text, references, tables, and figure legends, but no embedded figures or Title page. The Title page should be uploaded as a separate file. In the main text, please reference figures as for instance 'Figure 1', 'Figure 2' etc to match the tag name you choose for the individual figure files uploaded. Manuscripts should be formatted as described in the Author Guidelines below.

3.4. Blinded Review
Manuscript that do not conform to the general aims and scope of the journal will be returned immediately without review. All other manuscripts will be reviewed by experts in the field (generally two referees). International Endodontic Journal aims to forward referees´ comments and to inform the corresponding author of the result of the review process. Manuscripts will be considered for fast-track publication under special circumstances after consultation with the Editor.
International Endodontic Journal uses double blinded review. The names of the reviewers will thus not be disclosed to the author submitting a paper and the name(s) of the author(s) will not be disclosed to the reviewers.
To allow double blinded review, please submit (upload) your main manuscript and title page as separate files.
Please upload:
• Your manuscript without title page under the file designation 'main document'
• Figure files under the file designation 'figures'
• The title page and Acknowledgements where applicable, should be uploaded under the file designation 'title page'

All documents uploaded under the file designation 'title page' will not be viewable in the html and pdf format you are asked to review in the end of the submission process. The files viewable in the html and pdf format are the files available to the reviewer in the review process.

3.5. Suspension of Submission Mid-way in the Submission Process
You may suspend a submission at any phase before clicking the 'Submit' button and save it to submit later. The manuscript can then be located under 'Unsubmitted Manuscripts' and you can click on 'Continue Submission' to continue your submission when you choose to.

3.6. E-mail Confirmation of Submission
After submission you will receive an e-mail to confirm receipt of your manuscript. If you do not receive the confirmation e-mail after 24 hours, please check your e-mail address carefully in the system. If the e-mail address is correct please contact your IT department. The error may be caused by some sort of spam filtering on your e-mail server. Also, the e-mails should be received if the IT department adds our e-mail server (uranus.scholarone.com) to their whitelist.

3.7. Manuscript Status
You can access ScholarOne Manuscripts any time to check your 'Author Centre' for the status of your manuscript. The Journal will inform you by e-mail once a decision has been made.

3.8. Submission of Revised Manuscripts
To submit a revised manuscript, locate your manuscript under 'Manuscripts with Decisions' and click on 'Submit a Revision'. Please remember to delete any old files uploaded when you upload your revised manuscript.

4. MANUSCRIPT TYPES ACCEPTED

Original Scientific Articles: must describe significant and original experimental observations and provide sufficient detail so that the observations can be critically evaluated and, if necessary, repeated. Original Scientific Articles must conform to the highest international standards in the field.

Review Articles: are accepted for their broad general interest; all are refereed by experts in the field who are asked to comment on issues such as timeliness, general interest and balanced treatment of controversies, as well as on scientific accuracy. Reviews should generally include a clearly defined search strategy and take a broad view of the field rather than merely summarizing the authors´ own previous work. Extensive or unbalanced citation of the authors´ own publications is discouraged.

Clinical Articles: are suited to describe significant improvements in clinical practice such as the report of a novel technique, a breakthrough in technology or practical approaches to recognised clinical challenges. They should conform to the highest scientific and clinical practice standards.

Case Reports: illustrating unusual and clinically relevant observations are acceptable but they must be of sufficiently high quality to be considered worthy of publication in the Journal. On rare occasions, completed cases displaying non-obvious solutions to significant clinical challenges will be considered. Illustrative material must be of the highest quality and healing outcomes, if appropriate, should be demonstrated.

Supporting Information: *International Endodontic Journal* encourages submission of adjuncts to printed papers via the supporting information website (see submission of supporting information below). It is encouraged that authors wishing to describe novel procedures or illustrate cases more fully with figures and/or video may wish to utilise this facility.

Letters to the Editor: are also acceptable.

Meeting Reports: are also acceptable.

5. MANUSCRIPT FORMAT AND STRUCTURE

5.1. Format

Language: The language of publication is English. It is preferred that manuscript is professionally edited.

Presentation: Authors should pay special attention to the presentation of their research findings or clinical reports so that they may be communicated clearly. Technical jargon should be avoided as much as possible and clearly explained where its use is unavoidable. Abbreviations should also be kept to a minimum, particularly those that are not standard. The background and hypotheses underlying the study, as well as its main conclusions, should be clearly explained. Titles and abstracts especially should be written in language that will be readily intelligible to any scientist.

Article Preparation Support: **Wiley Editing Services** offers expert help with English Language Editing, as well as translation, manuscript formatting, figure illustration, figure formatting, and graphical abstract design – so you can submit your manuscript with confidence. Also, check out our resources for **Preparing Your Article** for general guidance about writing and preparing your manuscript.

Abbreviations: International Endodontic Journal adheres to the conventions outlined in Units, Symbols and Abbreviations: A Guide for Medical and Scientific Editors and Authors. When non-standard terms appearing 3 or more times in the manuscript are to be abbreviated, they should be written out completely in the text when first used with the abbreviation in parenthesis.

5.2. Structure

All manuscripts submitted to *International Endodontic Journal* should include Title Page, Abstract, Main Text, References and Acknowledgements, Tables, Figures and Figure Legends as appropriate

Title Page: The title page should bear: (i) Title, which should be concise as well as descriptive; (ii) Initial(s) and last (family) name of each author; (iii) Name and address of department, hospital or institution to which work should be attributed; (iv) Running title (no more than 30 letters and spaces); (v) No more than six keywords (in alphabetical order); (vi) Name, full postal address, telephone, fax number and e-mail address of author responsible for correspondence.

Abstract for Original Scientific Articles should be no more than 350 words giving details of what was done using the following structure:

• **Aim**: Give a clear statement of the main aim of the study and the main hypothesis tested, if any.
• **Methodology**: Describe the methods adopted including, as appropriate, the design of the study, the setting, entry requirements for subjects, use of materials, outcome measures and statistical tests.
• **Results**: Give the main results of the study, including the outcome of any statistical analysis.
• **Conclusions**: State the primary conclusions of the study and their implications. Suggest areas for further research, if appropriate.

Abstract for Systematic Review Articles should be no more than 350 words using the following structure where applicable:

• **Title:** Identify the report as a systematic review, meta-analysis, or both.
• **Background:** Provide a brief introduction of the subject and why it is important.
• **Objectives:** The research question including components such as participants, interventions, comparators, and outcomes. Use PICO format.
• **Methods:** Briefly describe i) the inclusion criteria, ii) provide databases searched and dates, iii) mention the method used to assess study quality (risk of bias) iv) meta-analysis methodology (if appropriate).
• **Results:** i) Number and type of included studies and participants ii) results for main outcomes (benefits and harms). If a meta-analysis was undertaken, include summary measures and confidence intervals. iii) direction of the effect in terms that are meaningful to clinicians and patients.
• **Discussion:** i) Strengths and ii) limitations of evidence.
• **Conclusions**: General interpretation of the results and important implications.
• **Funding:** Primary source of funding for the review (if no funding: say 'none').
• **Registration**: Registration number and name.

Abstract for Review Articles (narrative)
The Abstract should be unstructured and no more than 350 words.

Abstract for Case Reports should be no more than 350 words using the following structure:

• **Aim**: Give a clear statement of the main aim of the report and the clinical problem which is addressed.
• **Summary**: Describe the methods adopted including, as appropriate, the design of the study, the setting, entry requirements for subjects, use of materials, outcome measures and analysis if any.
• **Key learning points**: Provide up to 5 short, bullet-pointed statements to highlight the key messages of the report. All points must be fully justified by material presented in the report.

Abstract for Clinical Articles should be no more than 350 words using the following structure:

• **Aim:** Give a clear statement of the main aim of the report and the clinical problem which is addressed.
• **Methodology:** Describe the methods adopted.
• **Results:** Give the main results of the study.
• **Conclusions:** State the primary conclusions of the study.

Main Text of Original Scientific Article should include Introduction, Materials and Methods, Results, Discussion and Conclusion:

• **Introduction**: should be focused, outlining the historical or logical origins of the study and gaps in knowledge. Exhaustive literature reviews are not appropriate. It should close with the explicit statement of the specific aims of the investigation, or hypothesis to be tested.
• **Material and Methods**: must contain sufficient detail such that, in combination with the references cited, all clinical trials and experiments reported can be fully reproduced.

(i) Clinical Trials should be reported using the PRIRATE 2020 guidelines. A PRIRATE 2020 checklist must be completed and included along with a flow diagram (as a Figure) in the submission material. These are available at **http://pride-endodonticguidelines.org/prirate/**.

(ii) Experimental Subjects: experimentation involving human subjects will only be published if such research has been conducted in full accordance with ethical principles, including the World Medical Association **Declaration of Helsinki** (version 2008) and the additional requirements, if any, of the country where the research has been carried out. Manuscripts must be accompanied by a statement that the experiments were undertaken with the understanding and written consent of each subject and according to the above mentioned principles. A statement regarding the fact that the study has been independently reviewed and approved by an ethical board should also be included. Editors reserve the right to reject papers if there are doubts as to whether appropriate procedures have been used.

When experimental animals are used the methods section must clearly indicate that adequate measures were taken to minimize pain or discomfort. Experiments should be carried out in accordance with the Guidelines laid down by the National Institute of Health (NIH) in the USA regarding the care and use of animals for experimental procedures or with the European Communities Council Directive of 24 November 1986 (86/609/EEC) and in accordance with local laws and regulations.

All studies using human or animal subjects should include an explicit statement in the Material and Methods section identifying the review and ethics committee approval for each study, if applicable. Editors reserve the right to reject papers if there is doubt as to whether appropriate procedures have been used.

(iii) Suppliers: Suppliers of materials should be named and their location (Company, town/city, state, country) included.

• **Results**: should present the observations with minimal reference to earlier literature or to possible interpretations. Data should not be duplicated in Tables and Figures.
• **Discussion**: may usefully start with a brief summary of the major findings, but repetition of parts of the abstract or of the results section should be avoided. The Discussion section should progress with a review of the methodology before discussing the results in light of previous work in the field. The Discussion should end with a brief conclusion and a comment on the potential clinical relevance of the findings. Statements and interpretation of the data should be appropriately supported by original references.
• **Conclusion**: should contain a summary of the findings.

Main Text of systematic review articles should be divided into Introduction, Methods, Results and Conclusions:

• **Introduction:** Should be focused to place the subject matter in context and to justify the need for the review.
• **Method:** Divide into logical sub-sections in order to improve readability and enhance

understanding (e.g. details of protocol registration, literature search process, inclusion/exclusion criteria, data extraction, quality assessment, outcome(s) of interest, data synthesis and statistical analysis, quality of evidence).

• **Results:** Present in structured fashion (e.g. results of the search process, characteristics of the included studies, results of primary meta-analysis, additional analysis, publication bias, quality of evidence).

• **Discussion:** Should summarize the results, highlighting completeness and applicability of evidence, quality of evidence, agreements and disagreements with other studies or reviews, strength and limitations, implications for practice and research.

• **Conclusion(s):** Section should reach clear conclusions and/or recommendations on the basis of the evidence presented.

Main Text of Review Articles should be divided into Introduction, Review and Conclusions. The Introduction section should be focused to place the subject matter in context and to justify the need for the review. The Review section should be divided into logical sub-sections in order to improve readability and enhance understanding. Search strategies must be described and the use of state-of-the-art evidence-based systematic approaches is expected. The use of tabulated and illustrative material is encouraged. The Conclusion section should reach clear conclusions and/or recommendations on the basis of the evidence presented.

Main Text of Case Reports should be divided into Introduction, Report, Discussion and Conclusion,. They should be well illustrated with clinical images, radiographs, diagrams and, where appropriate, supporting tables and graphs. However, all illustrations must be of the highest quality.

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**)

Acknowledgements: *International Endodontic Journal* requires that all sources of institutional, private and corporate financial support for the work within the manuscript must be fully acknowledged, and any potential conflicts of interest noted. Grant or contribution numbers may be acknowledged, and principal grant holders should be listed. Acknowledgments should be brief and should not include thanks to anonymous referees and editors. See also above under Ethical Guidelines.

5.3. References

It is the policy of the Journal to encourage reference to the original papers rather than to literature reviews. Authors should therefore keep citations of reviews to the absolute minimum.

We recommend the use of a tool such as **EndNote** or **Reference Manager** for reference management and formatting. The EndNote reference style can be obtained upon request to the editorial office (**iejeditor@cardiff.ac.uk**). Reference Manager reference styles can be searched for here: **www.refman.com/support/rmstyles.asp**

In the text: single or double authors should be acknowledged together with the year of publication, e.g. (Pitt Ford & Roberts 1990). If more than two authors the first author followed by *et al*. is sufficient, e.g. (Tobias *et al.* 1991). If more than 1 paper is cited the references should be in year order and separated by "," e.g. (Pitt Ford & Roberts 1990, Tobias *et al*. 1991).

Reference list: All references should be brought together at the end of the paper in alphabetical order and should be in the following form.

(i) Names and initials of up to six authors. When there are seven or more, list the first three and add *et al.*
(ii)Year of publication in parentheses
(iii) Full title of paper followed by a full stop (.)
(iv) Title of journal in full (in italics)
(v) Volume number (bold) followed by a comma (,)
(vi) First and last pages

Examples of correct forms of reference follow:

Standard journal article
Bergenholtz G, Nagaoka S, Jontell M (1991) Class II antigen-expressing cells in experimentally induced pulpitis. *International Endodontic Journal* **24**, 8-14.

Corporate author
British Endodontic Society (1983) Guidelines for root canal treatment. *International Endodontic Journal* **16**, 192-5.

Journal supplement
Frumin AM, Nussbaum J, Esposito M (1979) Functional asplenia: demonstration of splenic activity by bone marrow scan (Abstract). *Blood* **54** (Suppl. 1), 26a.

Books and other monographs

Personal author(s)
Gutmann J, Harrison JW (1991) *Surgical Endodontics*, 1st edn Boston, MA, USA: Blackwell Scientific Publications.

Chapter in a book
Wesselink P (1990) Conventional root-canal therapy III: root filling. In: Harty FJ, ed. *Endodontics in Clinical Practice*, 3rd edn; pp. 186-223. London, UK: Butterworth.

Published proceedings paper
DuPont B (1974) Bone marrow transplantation in severe combined immunodeficiency with an unrelated MLC compatible donor. In: White HJ, Smith R, eds. Proceedings of the Third Annual Meeting of the International Society for Experimental Rematology; pp. 44-46. Houston, TX, USA: International Society for Experimental Hematology.

Agency publication
Ranofsky AL (1978) Surgical Operations in Short-Stay Hospitals: United States-1975. DHEW publication no. (PHS) 78-1785 (Vital and Health Statistics; Series 13; no. 34.) Hyattsville, MD, USA: National Centre for Health Statistics.8

Dissertation or thesis
Saunders EM (1988) In vitro and in vivo investigations into root-canal obturation using thermally softened gutta-percha techniques (PhD Thesis). Dundee, UK: University of Dundee.

URLs

Full reference details must be given along with the URL, i.e. authorship, year, title of document/report and URL. If this information is not available, the reference should be removed and only the web address cited in the text.
Smith A (1999) Select committee report into social care in the community [WWW document]. URL http://www.dhss.gov.uk/reports/report015285.html [accessed on 7 November 2003]

5.4. Tables, Figures and Figure Legends

Tables: Tables should be double-spaced with no vertical rulings, with a single bold ruling beneath the column titles. Units of measurements must be included in the column title.

Figures: All figures should be planned to fit within either 1 column width (8.0 cm), 1.5 column widths (13.0 cm) or 2 column widths (17.0 cm), and must be suitable for photocopy reproduction from the printed version of the manuscript. Lettering on figures should be in a clear, sans serif typeface (e.g. Helvetica); if possible, the same typeface should be used for all figures in a paper. After reduction for publication, upper-case text and numbers should be at least 1.5-2.0 mm high (10 point Helvetica). After reduction, symbols should be at least 2.0-3.0 mm high (10 point). All half-tone photographs should be submitted at final reproduction size. In general, multi-part figures should be arranged as they would appear in the final version. Reduction to the scale that will be used on the page is not necessary, but any special requirements (such as the separation distance of stereo pairs) should be clearly specified.

Unnecessary figures and parts (panels) of figures should be avoided: data presented in small tables or histograms, for instance, can generally be stated briefly in the text instead. Figures should not contain more than one panel unless the parts are logically connected; each panel of a multipart figure should be sized so that the whole figure can be reduced by the same amount and reproduced on the printed page at the smallest size at which essential details are visible.

Figures should be on a white background, and should avoid excessive boxing, unnecessary colour, shading and/or decorative effects (e.g. 3-dimensional skyscraper histograms) and highly pixelated computer drawings. The vertical axis of histograms should not be truncated to exaggerate small differences. The line spacing should be wide enough to remain clear on reduction to the minimum acceptable printed size.

Figures divided into parts should be labelled with a lower-case, boldface, roman letter, a, b, and so on, in the same typesize as used elsewhere in the figure. Lettering in figures should be in lower-case type, with the first letter capitalized. Units should have a single space between the number and the unit, and follow SI nomenclature or the nomenclature common to a particular field. Thousands should be separated by a thin space (1 000). Unusual units or abbreviations should be spelled out in full or defined in the legend. Scale bars should be used rather than magnification factors, with the length of the bar defined in the legend rather than on the bar itself. In general, visual cues (on the figures themselves) are preferred to verbal explanations in the legend (e.g. broken line, open red triangles etc.)

Figure legends: Figure legends should begin with a brief title for the whole figure and continue with a short description of each panel and the symbols used; they should not contain any details of methods.

Permissions: If all or part of previously published illustrations are to be used, permission must be obtained from the copyright holder concerned. This is the responsibilty of the authors before submission.

Preparation of Electronic Figures for Publication: Although low quality images are adequate for review purposes, print publication requires high quality images to prevent the final product being blurred or fuzzy. Submit EPS (lineart) or TIFF (halftone/photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Do not use pixel-oriented programmes. Scans (TIFF only) should have a resolution of 300 dpi (halftone) or 600 to 1200 dpi (line drawings) in relation to the reproduction size (see below). EPS files should be saved with fonts embedded (and with a TIFF preview if possible). For scanned images, the scanning resolution (at final image size) should be as follows to ensure good reproduction: lineart: >600 dpi; half-tones (including gel photographs): >300 dpi; figures containing both halftone and line images: >600 dpi.

Further information can be obtained at Wiley Blackwell's guidelines for figures: **http:/authorservices.wiley.com/bauthor/illustration.asp.**

Check your electronic artwork before submitting it: **http://authorservices.wiley.com/bauthor/eachecklist.asp**

5.6. Guidelines for reporting of DNA microarray data

The *International Endodontic Journal* gives authors notice that, with effect from 1st January 2011, submission to the *International Endodontic Journal* requires the reporting of microarray data to conform to the MIAME guidelines. After this date, submissions will be assessed according to MIAME standards. The complete current guidelines are available at **http://www.mged.org/Workgroups/MIAME/miame_2.0.html**. Also, manuscripts will be published only after the complete data has been submitted into the public repositories, such as GEO (**http://www.ncbi.nlm.nih.gov/geo/**) or ArrayExpress (**http://www.ebi.ac.uk/microarray/submissions_overview.html**), in MIAME compliant format, with the data accession number (the identification number of the data set in the database) quoted in the manuscript. Both databases are committed to keeping the data private until the associated manuscript is published, if requested.

Prospective authors are also encouraged to search for previously published microarray data with relevance to their own data, and to report whether such data exists. Furthermore, they are encouraged to use the previously published data for qualitative and/or quantitative comparison with their own data, whenever suitable. To fully acknowledge the original work, an appropriate reference should be given not only to the database in question, but also to the original article in which the data was first published. This open approach will increase the availability and use of these large-scale data sets and improve the reporting and interpretation of the findings, and in increasing the comprehensive understanding of the physiology and pathology of endodontically related tissues and diseases, result eventually in better patient care.

5.7. Supporting Information

Publication in electronic formats has created opportunities for adding details or whole sections in the electronic version only. Authors need to work closely with the editors in developing or using such new publication formats.

Supporting information, such as data sets or additional figures or tables, that will not be published in the print edition of the journal, but which will be viewable via the online edition, can be submitted. It should be clearly stated at the time of submission that the supporting information is intended to be made available through the online edition. If the size or format of the supporting information is such that it cannot be accommodated on the journal's website, the author agrees to make the supporting information available free of charge on a permanent Web site, to which links will be set up from the journal's website. The author must advise Wiley Blackwell if the URL of the website where the supporting information is located changes. The content of the supporting information must not be altered after the paper has been accepted for publication.

The availability of supporting information should be indicated in the main manuscript by a paragraph, to appear after the References, headed 'Supporting Information' and providing titles of figures, tables, etc. In order to protect reviewer anonymity, material posted on the authors Web site cannot be reviewed. The supporting information is an integral part of the article and will be reviewed accordingly.

Preparation of Supporting Information: Although provision of content through the web in any format is straightforward, supporting information is best provided either in web-ready form or in a form that can be conveniently converted into one of the standard web publishing formats:

- Simple word-processing files (.doc or .rtf) for text.
- PDF for more complex, layout-dependent text or page-based material. Acrobat files can be distilled from Postscript by the Publisher, if necessary.
- GIF or JPEG for still graphics. Graphics supplied as EPS or TIFF are also acceptable.
- MPEG or AVI for moving graphics.

Subsequent requests for changes are generally unacceptable, as for printed papers. A charge may be levied for this service.

Video Imaging: For the on-line version of the Journal the submission of illustrative video is encouraged. Authors proposing the use such media should consult with the Editor during manuscript preparation.

Article Promotion Support

Wiley Editing Services offers professional video, design, and writing services to create shareable video abstracts, infographics, conference posters, lay summaries, and research news stories for your research – so you can help your research get the attention it deserves.

6. GRAPHICAL ABSTRACT

Authors are invited to submit a graphical abstract along with their manuscript to be published in the International Endodontic Journal’s:

- Online table of contents.
- Content alert emails.
- Within the article.

The graphical abstract should visually convey the key findings of the report and present a clear message to the reader. It should be used as a means of attracting the readers’ attention and promoting further engagement with the article.

To create an effective graphical abstract, authors should focus on presenting to the reader what they can learn from the report, communicating only the key message.

Guidelines for designing a Graphical Abstract:

1. Creating a graphical abstract does ***not*** mean just copying and pasting a figure from the manuscript.
2. Use text sparingly, so the graphical abstract does not become cluttered, but ensure that you have clearly stated the purpose of the report, research design, clinical case and the outcome of the study or case. Use language consistent with terms and definitions in the article that are free of editorialization (personal opinion) or bias.
3. Use only images that you have a legal right to use. Authors are responsible for obtaining permission to use any images that they include from outside sources, including articles, web pages, stock photo sites or Google image searches. Any needed permissions must be submitted along with your graphical abstract or identified in the Acknowledgements section of your manuscript.
4. Exclude imagery that can be viewed as advertisement, such as trade names, logos, or images of trademarked items.
5. The Graphical Abstract should be submitted along with the manuscript though our ScholarOne platform and uploaded with the file designation “Graphical Abstract”.
6. Required file properties:
    - Resolution: 700 pixels (width) x 600 pixels (height).
    - Font size: at least 12pt.
    - Font: Calibri.
    - File size should not exceed 1MB.
7. A good example of how a graphical abstract should look can be seen here: https://onlinelibrary.wiley.com/doi/10.1111/joim.13141

Please contact the editorial office at **IEJeditor@cardiff.ac.uk** if you have any questions.

7. AFTER ACCEPTANCE

Upon acceptance of a paper for publication, the manuscript will be forwarded to the Production Editor who is responsible for the production of the journal.

7.1. Figures

Hard copies of all figures and tables are required when the manuscript is ready for publication. These will be requested by the Editor when required. Each Figure copy should be marked on the reverse with the figure number and the corresponding author’s name.

7.2 Proof Corrections

The corresponding author will receive an email alert containing a link to a web site. A working email address must therefore be provided for the corresponding author. The proof can be downloaded as a PDF (portable document format) file from this site. Acrobat Reader will be required in order to read this file. This software can be downloaded (free of charge) from the following Web site: **www.adobe.com/products/acrobat/readstep2.html**. This will enable the file to be opened, read on screen, and printed out in order for any corrections to be added. Further instructions will be sent with the proof. Hard copy proofs will be posted if no e-mail address is available; in your absence, please arrange for a colleague to access your e-mail to retrieve the proofs. Proofs must be returned to the Production Editor within three days of receipt. As changes to proofs are costly, we ask that you only correct typesetting errors. Excessive changes made by the author in the proofs, excluding typesetting errors, will be charged separately. Other than in exceptional circumstances, all illustrations are retained by the publisher. Please note that the author is responsible for all statements made in his work, including changes made by the copy editor.

7.3 Early Online Publication Prior to Print
International Endodontic Journal is covered by Wiley Blackwell's Early View service. Early View articles are complete full-text articles published online in advance of their publication in a printed issue. Early View articles are complete and final. They have been fully reviewed, revised and edited for publication, and the authors' final corrections have been incorporated. Because they are in final form, no changes can be made after online publication. The nature of Early View articles means that they do not yet have volume, issue or page numbers, so Early View articles cannot be cited in the traditional way. They are therefore given a Digital Object Identifier (DOI), which allows the article to be cited and tracked before it is allocated to an issue. After print publication, the DOI remains valid and can continue to be used to cite and access the article.

7.4 Online Production Tracking
Online production tracking is available for your article through Blackwell's Author Services. Author Services enables authors to track their article - once it has been accepted - through the production process to publication online and in print. Authors can check the status of their articles online and choose to receive automated e-mails at key stages of production. The author will receive an e-mail with a unique link that enables them to register and have their article automatically added to the system. Please ensure that a complete e-mail address is provided when submitting the manuscript. Visit **http://authorservices.wiley.com/bauthor/** for more details on online production tracking and for a wealth of resources including FAQs and tips on article preparation, submission and more.

7.5 Author Material Archive Policy
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a. The paragraph is the ideal unit of organization. Paragraphs typically start with an introductory sentence that is followed by sentences that describe additional detail or examples. The last sentence of the paragraph provides conclusions and forms a transition to the next paragraph. Common problems include one-sentence paragraphs, sentences that do not develop the theme of the paragraph (see also section "c," below), or sentences with little to no transition within a paragraph.

b. Keep to the point. The subject of the sentence should support the subject of the paragraph For example, the introduction of authors' names in a sentence changes the subject and lengthens the text. In a paragraph on sodium hypochlorite, the sentence, "In 1983, Langeland et al, reported that sodium hypochlorite acts as a lubricating factor during instrumentation and helps to flush debris from the root canals" can be edited to: "Sodium hypochlorite acts as a lubricant during instrumentation and as a vehicle for flushing the generated debris (Langeland et al, 1983)." In this example, the paragraph's subject is sodium hypochlorite and sentences should focus on this subject.

c. Sentences are stronger when written in the active voice, that is, the subject performs the action. Passive sentences are identified by the use of passive verbs such as "was," "were," "could," etc. For example: "Dexamethasone was found in this study to be a factor that was associated with reduced inflammation," can be edited to: "Our results demonstrated that dexamethasone reduced inflammation." Sentences written in a direct and active voice are generally more powerful and shorter than sentences written in the passive voice.

d. Reduce verbiage. Short sentences are easier to understand. The inclusion of unnecessary words is often associated with the use of a passive voice, a lack of focus, or run-on sentences. This is not to imply that all sentences need be short or even the same length. Indeed, variation in sentence structure and length often helps to maintain reader interest. However, make all words count. A more formal way of stating this point is that the use of subordinate clauses adds variety and information when constructing a paragraph. (This section was written deliberately with sentences of varying length to illustrate this point.)

e. Use parallel construction to express related ideas. For example, the sentence, "Formerly, endodontics was taught by hand instrumentation, while now rotary instrumentation is the common method," can be edited to "Formerly, endodontics was taught using hand instrumentation; now it is commonly taught using rotary instrumentation." The use of parallel construction in sentences simply means that similar ideas are expressed in similar ways, and this helps the reader recognize that the ideas are related.

f. Keep modifying phrases close to the word that they modify. This is a common problem in complex sentences that may confuse the reader. For example, the statement, "Accordingly, when conclusions are drawn from the results of this study, caution must be used," can be edited to "Caution must be used when conclusions are drawn from the results of this study."

g. To summarize these points, effective sentences are clear and precise, and often are short, simple and focused on one key point that supports the paragraph's theme.

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Abstract Headings
Introduction, Methods, Results, Conclusions

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