UNIVERSIDADE FEDERAL DE JUIZ DE FORA
CAMPUS GOVERNADOR VALADARES
PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIAS APLICADAS À SAÚDE

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Comportamento forense de pinos odontológicos sob altas temperaturas: avaliações macroscópicas e imaginológicas

Governador Valadares
2025

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Dissertação apresentada ao Programa de Pós-Graduação em Ciências Aplicadas à Saúde, da Universidade Federal de Juiz de Fora, Campus Governador Valadares, como requisito parcial à obtenção do título de Mestre em Ciências Aplicadas à Saúde, área de concentração Biociências.

Orientadora: Profa. Dra. Francielle Silvestre Verner

Governador Valadares

2025

Ficha catalográfica elaborada através do programa de geração
automática da Biblioteca Universitária da UFJF,
com os dados fornecidos pelo(a) autor(a)

Moreira, Gabrielle Cristiny .
Comportamento forense de pinos odontológicos sob altas temperaturas : avaliações macroscópicas e imaginológicas / Gabrielle Cristiny Moreira. -- 2025.
54 p. : il.

Orientadora: Francielle Silvestre Verner
Dissertação (mestrado acadêmico) - Universidade Federal de Juiz de Fora, Campus Avançado de Governador Valadares, Faculdade de Odontologia. Programa de Pós-Graduação em Ciências Aplicadas à Saúde, 2025.

1. Odontologia forense. 2. Identificação humana. 3. Incineração. 4. Materiais dentários. 5. Radiografia dentária. I. Verner, Francielle Silvestre , orient. II. Título.

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Aprovada em 21 de janeiro de 2025.

BANCA EXAMINADORA

Profa. Dra. Francielle Silvestre Verner - Orientadora
Universidade Federal de Juiz de Fora

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Juiz de Fora, 06/01/2025.

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Dedico este trabalho ao meu pai, Elias Silva Moreira, que, embora tenha sido ausente em alguns momentos, sempre se orgulhou das minhas realizações e apoiou minha independência e dedicação. Seu senso de humor, simpatia e firmeza me acompanharam ao longo da vida. Sinto sua falta e sei o quanto estaria orgulhoso desta conquista.

AGRADECIMENTOS

À minha mãe Marlene, que sempre me ensinou o verdadeiro valor da educação, do trabalho árduo e da dedicação. Sua força diante das adversidades e seu apoio constante foram fundamentais para a conclusão de mais uma etapa. Agradeço também à minha irmã Yasmin, cuja presença, mesmo à distância, sempre me trouxe ânimo nos momentos mais desafiadores. Sou imensamente grata a ambas.

Ao meu namorado Felipe Calvo e à sua família que foram essenciais para a conclusão da minha pesquisa. A ele, agradeço por sempre acreditar em mim, pela companhia e pelo apoio emocional constante, especialmente nos momentos mais difíceis. À sua família, sou grata pela acolhida e pelo carinho, que me proporcionaram um ambiente de conforto e apoio ao longo deste período. Sem o suporte e a dedicação de todos, esta conquista não seria possível.

Agradeço à minha orientadora Francielle Silvestre Verner, que se tornou não apenas uma referência profissional, mas também uma grande amiga ao longo desses anos. Sua orientação, confiança e apoio foram essenciais para superar desafios que, muitas vezes, pareciam insuperáveis. A segurança e a presença constante de sua sabedoria me permitiram manter a perseverança diante das dificuldades que a pesquisa impõe, e sem seu auxílio, certamente não teria chegado até aqui. Sou profundamente grata por tê-la como mentora e por Deus tê-la colocado em meu caminho.

Aos meus amigos da pós-graduação que compartilharam comigo seus conhecimentos, suas inseguranças e momentos de amizade, sou muito grata a todos.

Aos professores da banca de qualificação Prof. Dr. Rodrigo Furtado de Carvalho, Prof. Dr. Ricardo Henrique Alves da Silva, Prof. Dr. Rodrigo Richard da Silveira, Prof. Dr. Maurício Augusto Aquino de Castro, Prof. Dr. Rafael Binato Junqueira, agradeço pelas orientações, auxílio e contribuições essenciais para conclusão deste trabalho.

Aos membros da banca de defesa Prof. Dr. Francisco Haiter Neto, Prof. Dr. Leonardo Custódio de Lima, Prof. Dr. Jean Soares Miranda e por Prof. Dr. Lucas de Paula Lopes Rosado por aceitarem o convite, certamente suas considerações serão imprescindíveis para o sucesso do trabalho.

Ao Departamento de Odontologia na pessoa da Chefe de Departamento, Profa. Dra. Sibele Nascimento de Aquino. Ao Instituto de Ciências da Vida, na pessoa do Diretor, Prof. Dr. Leandro de Morais Cardoso. Ao Campus Governador Valadares, na pessoa do Diretor Geral, Prof. Dr. Ângelo Márcio Leite Denadai. E à Universidade Federal de Juiz de Fora, na pessoa da Magnífica Reitora, Profa. Dr. Girlene Alves da Silva, agradeço pela elevada qualidade do ensino ofertado.

Ao Programa de Pós-Graduação em Ciências Aplicadas à Saúde, na pessoa do coordenador, Prof. Dr. Pedro Henrique Berbert de Carvalho, e a todos os professores do programa, por todo apoio e conhecimento que adquiri ao longo dos anos no curso.

À Faculdade de Odontologia da Universidade Federal de Minas Gerais (UFMG), pela disponibilização dos laboratórios de Radiologia Odontológica e Materiais Dentários para conclusão desta pesquisa, além do ambiente acolhedor em que fiz novos amigos.

Ao laboratório Clélio Prótese Dentária (Belo Horizonte, Minas Gerais, Brasil), pelo empréstimo do forno mufla, material essencial para realização da pesquisa, além da atenção e dedicação fornecida durante minha estadia.

À Angelus Odontologia e à FGM Dental Group, agradeço pela doação dos subsídios necessários para realização desta pesquisa, sem conflitos de interesse, além da parceria e confiança depositada neste trabalho.

À Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) – pelo apoio financeiro concedido, código de financiamento 001, essencial para o desenvolvimento deste trabalho e conclusão desta minha formação.

“Só as grandes paixões são capazes de grandes ações”

(ASSIS, 1881)

RESUMO

O objetivo neste estudo foi avaliar o comportamento físico de retentores intrarradiculares submetidos a altas temperaturas para fins forenses. Foram selecionados 126 dentes incisivos bovinos. Todos os dentes foram tratados endodonticamente e distribuídos, de forma aleatória em seis grupos (n=21), de acordo com os diferentes materiais: pino de fibra de vidro Exacto Angelus™, pino de fibra de vidro Reforpost™ Angelus™, pino de fibra de vidro Whitepost System DC FGM™, pino de fibra de carbono Reforpost™ Angelus™, pino de metal Reforpost™ I Angelus™ e pino metálico de Ni-Cr. Posteriormente, cada grupo foi dividido aleatoriamente em três subgrupos (n=7), de acordo com as temperaturas de incineração de 600, 800 e 1000 °C. Todos os dentes foram preparados e os pinos cimentados de acordo com seu material. Para a reconstrução coronária foi utilizada resina composta micro-híbrida. Todos os dentes foram fotografados e radiografados de modo padronizado antes e após a incineração. Macroscopicamente, as raízes foram avaliadas pós-incineração de forma qualitativa, quanto à formação de trincas ou fraturas radiculares, assim como mudanças de cor, por meio de fotografias. Já a avaliação radiográfica considerou aspectos qualitativos das raízes como formação de trincas ou fraturas radiculares, e dos pinos dentários aspectos como adaptação interna, mudanças de dimensão/ou formato, mudanças na radiopacidade, presença de áreas radiolúcidas ("bolhas"), além da densidade óptica de cada material. Análise qualitativa da densidade óptica dos pinos foi avaliada nas radiografias periapicais utilizando a ferramenta histograma do software ImageJ™. Todas as imagens foram analisadas por um único avaliador, previamente treinado, em ambiente com iluminação reduzida. Análises estatísticas foram conduzidas adotando-se nível de significância de 5%. Macroscopicamente, não houve associação significativa entre as faixas de temperatura e a formação de trincas ou fraturas radiculares, assim como radiograficamente, com exceção das amostras restauradas com fibra de vidro Reforpost™ Angelus™. Em relação à cor, foram observadas as cores marrom e cinza a 600°C, e branca a 800°C e 1000°C. A análise radiográfica dos pinos mostrou associação entre as faixas de temperatura e as alterações avaliadas, com exceção do pino de metal pré-fabricado Angelus™ I Reforpost™. Nos momentos pré- e pós-incineração, houve diferença significativa na densidade óptica dos pinos de fibra de vidro Reforpost™ Angelus™, Whitepost System DC FGM™ e pino de fibra de carbono

Reforpost™ Angelus™. O estudo concluiu que os diferentes materiais não interferem nas alterações macroscópicas apresentadas pela raiz, entretanto, os pinos apresentaram alterações radiográficas e de radiopacidade, a depender do material e faixa de temperatura avaliada. Sendo assim, o estudo contempla dados importantes para determinar as alterações dos diferentes tipos de pinos intrarradiculares contribuindo para o processo de identificação humana.

Palavras-chave: altas temperaturas; identificação humana; incineração; materiais dentários; odontologia forense; radiografia dentária.

ABSTRACT

To evaluate the physical behavior of intraradicular retainers subjected to high temperatures for forensic purposes. A total of 126 bovine teeth were selected. All teeth were endodontically treated and randomly assigned to six groups (n=21) according to the different materials: Exacto Angelus™ glass fiber post, Reforpost™ Angelus™ glass fiber post, Whitepost System DC FGM™ glass fiber post, Reforpost™ Angelus™ carbon fiber post, Reforpost™ I Angelus™ metal post, Ni-Cr metal post. Subsequently, each group was randomly divided into three subgroups (n=7), according to the ashing temperatures of 600, 800 and 1000 °C. All teeth were prepared and cemented according to their material. Micro-hybrid composite resin was used for coronal reconstruction. All teeth were photographed and radiographed in a standardized way before and after incineration. Macroscopically, the roots were assessed qualitatively after incision, in terms of the formation of cracks or root fractures, as well as color changes, using photographs. The radiographic evaluation considered qualitative aspects of the roots, such as the formation of cracks or root fractures, and aspects of the dental posts, such as internal adaptation, changes in dimension and/or shape, changes in radiopacity, the presence of radiolucent areas (“bubbles”), as well as the optical density of each material. Qualitative analyses of the optical density of the posts and dentin was assessed in periapical images using the ImageJ™. All images were analyzed by a single, previously trained evaluator in a dimly lit environment. Statistical analyses were carried out using a significance level of 5%. Macroscopically, there was no significant association between the temperature ranges and the formation of cracks or root fractures, as well as radiographically, with the exception of samples restored with Reforpost™ Angelus™ glass fiber. In terms of color, brown and gray were observed at 600°C, and white at 800°C and 1000°C. Radiographic analysis of the posts showed an association between the temperature ranges and the changes assessed, with the exception of the Angelus™ I Reforpost™ prefabricated metal post. At the pre- and post-incineration moments, there was a significant difference in the mean density of the posts of the materials: Angelus™ Reforpost™ glass fiber post, Whitepost System DC FGM™ glass fiber post, Angelus™ Reforpost™ carbon fiber post. The study concluded that the different materials do not interfere in the macroscopic changes presented by the root, however, the posts showed radiographic and radiopacity changes, depending on the material and temperature range evaluated. Therefore, the study provides important data for determining the changes in the different types of intraradicular posts, contributing to the process of human identification.

Keywords: hot temperatures; human identification; incineration; dental materials; forensic dentistry; dental radiography.

SUMÁRIO

1 INTRODUÇÃO

A identificação humana post-mortem é uma área de estudo da Odontologia e Medicina Legal com o objetivo de individualizar uma pessoa ou objeto a fim de garantir a preservação de seus direitos, assim como cobrar seus deveres (CARVALHO et al., 2009). Sendo assim, a Odontologia Legal é imprescindível em investigações envolvendo incidentes de grandes proporções como acidentes de trânsito, desastres naturais, ataques terroristas, queimadas e explosões (ALBUQUERQUE NETO et al., 2015; INTERPOL, 2023).

No dia 9 de agosto em Vinhedo, São Paulo, o avião da companhia aérea Voepass sofreu um acidente que vitimou 62 pessoas, sendo 12 identificadas pela arcada dentária (ABRAPOL, 2024) o estado de carbonização dos corpos representou uma dificuldade para realização da identificação dos indivíduos. No caso de cadáveres queimados, espostejados, carbonizados, ou apenas restos humanos, o processo de identificação por métodos convencionais, como reconhecimento visual ou impressões digitais, impossibilita uma correta identificação da vítima, devido às condições *post-mortem* (PM), associadas a destruição da epiderme e áreas de necrose nos tecidos subjacentes (ARAMBURO et al., 2015).

Segundo a Interpol (2023) o processo de identificação consiste em 5 fases: cena, ou seja, processamento de restos mortais e bens no local do desastre (fase 1); PM, exame detalhado de restos mortais humanos no necrotério (fase 2); *ante-mortem* (AM), coleta de dados de pessoas desaparecidas de várias fontes (fase 3); reconciliação, correspondência de dados PM e AM (fase 4); revisão de ações e preparação (fase 5). Portanto, todo registro dentário disponível AM como prontuários, modelos de estudo, escaneamento digital e exames de imagem, sejam radiografias ou tomografias, correspondem a informações importantes para concluir o processo de identificação (CARVALHO et al., 2009).

Detalhes anatômicos dos elementos dentários possuem informações auxiliares indispensáveis no processo de reconhecimento forense, visto que podem ser utilizados como parâmetro de comparação o formato, tamanho, presença ou ausência de alterações patológicas, além dos tratamentos dentários realizados durante a vida, com diferentes tipos de materiais odontológicos (ARAMBURO et al., 2015; SPADACIO, 2007).

Além da diversidade de características e disposição da dentição humana, o tratamento dental nunca é o mesmo entre duas pessoas, de forma que a compreensão da diversidade de materiais dentários se torna um aspecto fundamental para realização de uma correta identificação humana (YAZDANIAN et al., 2022).

Os materiais dentários são resistentes a condições extremas de calor e frio, sujeitos a alterações e parâmetros específicos advindos de temperaturas variáveis (BAGDEY et al., 2014). Considerando que o exame radiográfico fornece características dentárias como morfologia de câmaras pulpares e canais radiculares, além da radiopacidade de materiais, a existência de evidências radiográficas é fundamental para identificações positivas (SILVA et al., 2016).

Os pinos ou retentores intrarradiculares são materiais dentários comumente utilizados na clínica odontológica para restauração de coroas parcial ou totalmente destruídas, devido a perdas estruturais decorrentes de lesões cariosas, procedimentos restauradores anteriores, extensão de acesso endodôntico, fraturas ou traumatismos dentários (MARCHIONATTI et al., 2017; TEÓFILO; ZAVANELLI; DE QUEIROZ, 2005). A depender do caso, o cirurgião-dentista pode optar pela restauração com um retentor metálico fundido, ou um pino pré-fabricado (metálico, de carbono ou de fibra de vidro) como forma de garantir o sucesso clínico de dentes tratados endodonticamente, e restabelecer estética e função (MARTINS et al., 2021; PRADO et al., 2014).

Devido a importância dos dentes no processo de identificação em casos de grandes acidentes com carbonização das vítimas, é fundamental a realização de estudos que avaliem o comportamento dos materiais odontológicos frente a elevadas temperaturas. Até o momento foram encontrados estudos avaliando o comportamento de resina composta, cimento de ionômero de vidro, amálgama, materiais endodônticos, materiais cerâmicos, braquetes ortodônticos, facetas estéticas e implantes (ARCOS et al., 2015; ARCOS et al., 2016; BERKETA, JAMES, MARINO, 2010; BERKETA, JAMES, MARINO, 2011; BERKETA et al., 2014; BRANDÃO et al., 2007; COLMENARES et al., 2020; POL; GOSAVI, 2014; POL et al., 2015; VANDRANGI et al., 2016; VINCENTI et al., 2018). No entanto, apenas dois estudos avaliaram o comportamento de retentores intrarradiculares dos materiais pino de titânio e pino de fibra de vidro (ARAMBURO et al., 2013; ARAMBURO et al., 2015). Devido à quantidade de materiais e marcas comerciais disponíveis no mercado odontológico, é necessário um estudo aprofundado em relação aos materiais disponíveis e suas alterações frente a altas temperaturas.

Portanto, examinar o efeito de altas temperaturas nos dentes e retentores intrarradiculares, tanto de forma macroscópica quanto radiográfica, irá contribuir para determinar aspectos relacionados ao comportamento destes materiais ao serem incinerados, permitindo a obtenção de dados imprescindíveis para a documentação pericial. Desta forma, o objetivo do presente estudo foi avaliar o comportamento de retentores intrarradiculares submetidos a altas temperaturas, com finalidade forense. O estudo considerou como hipótese nula que os retentores intrarradiculares não sofrem alterações quando submetidos a altas temperaturas.

2 ARTIGO CIENTÍFICO

Artigo científico enviado para publicação no periódico *Forensic Science International* (ANEXO A), Qualis CAPES Interdisciplinar A2. A estruturação do artigo baseou-se nas instruções aos autores preconizadas pelo periódico disponível no link: https://www.sciencedirect.com/journal/forensic-science-international/publish/guide-for-authors

“This research was part of Dr. Moreira’s thesis submitted in partial fulfillment of the master’s degree in health science at the Federal University of Juiz de Fora, Governador Valadares Campus”

Forensic behavior of dental posts under high temperatures: macroscopic and imaging evaluations

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Acknowledgements

The authors are grateful to:

Angelus™ and FGM™ Dental Group for providing dental materials for this research, without conflict of interests.

Federal University of Minas Gerais for providing radiographic examinations.

Laboratório Clélio Prótese Dentária (Belo Horizonte, Minas Gerais, Brazil, Zip-code: 30130-905) for providing the muffle type oven (EDG 10P-S 3000, EDG™, SP, Brazil) for incineration of the samples.

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001.

Declaration of interest statement:

The authors deny any conflict of interest related to this study.

Author contributions:

Gabrielle Cristiny Moreira: Conceptualization, Methodology, Formal analysis and investigation, Writing - original draft preparation, Writing - review and editing. **Maurício Augusto Aquino de Castro:** Methodology, Writing - review and editing. **Rodrigo Richard da Silveira:** Methodology, Writing - review and editing. **Rafael Binato Junqueira:** Methodology, Writing - review and editing. **Rodrigo Furtado de Carvalho:** Methodology, Writing - review and editing. **Francielle Silvestre Verner:** Conceptualization, Methodology, Formal analysis, Writing - review and editing, Project administration.

Funding sources:

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001.

Abstract

Objective: To evaluate the physical behavior of intraradicular dental post subjected to high temperatures for forensic purposes. Methods: One hundred and twenty-six incisive bovine teeth were selected. The samples were randomly distributed into six groups (n=21), according to the different posts: Exacto glass fiber Angelus™, Reforpost™ glass fiber Angelus™, Whitepost System DC glass fiber FGM™, Reforpost™ carbon fiber Angelus™, Reforpost™ I Metallic Angelus™, Ni-Cr post. Then, they were randomly divided into three subgroups (n=7), according to the temperatures of incineration (600, 800 and 1000 °C). All teeth were photographed and radiographed pre- and post-incineration. The optical density of the posts was evaluated using ImageJ™ software. Results: Macroscopically, there was no association between temperature ranges and formation of cracks or root fractures, as well as radiographically, except for Reforpost™ Angelus™ glass fiber. Brown and gray colors were seen in root at 600°C, white at 800°C and 1000°C. In radiographic analysis, the materials showed a significant difference, with the temperature ranges and changes evaluated, except for Reforpost™ I metallic Angelus™. The analysis of the mean optical density of posts at pre- and post-incineration range moments revealed a significant difference between the materials Reforpost ™ glass fiber Angelus ™, Whitepost System DC glass fiber FGM™, Reforpost™ carbon fiber Angelus™. Conclusions: Different posts do not interfere with the macroscopic changes shown by the root. However, the posts showed radiographic and radiopacity changes depending on the material and temperature range evaluated, which is important data for determining their changes and contributing to the identification of victims.

Keywords: Dental materials; Dental radiography; Forensic dentistry; Hot temperatures; Human identification; Incineration.

1 Introduction

The human dentition is the hardest structure of the body, extremely resistant to high temperatures and long burial periods [1,2]. This particularity makes it very efficient in solving crimes and identifying individuals or human remains, with the morphological characteristics of the dentition such as shape, size, presence or absence of pathological changes, as well as dental treatments carried out during life, with different types of dental materials, being indispensable auxiliary information in the forensic recognition process [2,3,4].

The victim identification process consists of five phases: scene, processing of remains and assets at the disaster site (phase 1); post-mortem (PM), detailed examination of human remains in the morgue (phase 2); ante-mortem (AM), collection of missing persons data from various sources (phase 3); reconciliation, i.e. matching PM and AM data (phase 4); review of actions and preparation (phase 5) [5].

All available information (AM and PM), such as plaster models, clinical examinations, imaging tests and photographs, must be collected and documented. Photography is essential for producing evidence and interpretation of the expert report, especially in conjunction with radiographic examination, which provides characteristics such as the morphology of pulp chambers, root canals and the radiopacity of materials, essential information for determining positive identifications [6,7].

Dental materials are resistant to extremes of heat and cold, subject to changes and specific parameters arising from varying temperatures [8]. Intraradicular posts are dental materials commonly used in the dental clinic to restore crowns that have been partially or totally destroyed due to structural losses resulting from carious lesions, extensive endodontic access or fractures [9]. Depending on the case, the dentist may opt for restoration with metal (conventional cast post core or prefabricated metal posts), fiber or ceramic posts as a way of ensuring the clinical success of endodontically treated teeth and restoring their aesthetics and function [10,11].

Due to the importance of teeth in the identification process in cases of major accidents involving the charring of victims, it is essential to carry out studies evaluating the behavior of dental materials in the face of high temperatures. However, to the best of our knowledge, the literature is still lacking in evaluating the behavior of intraradicular posts [12,13].

Therefore, examining the effect of high temperatures on dental roots restored with intraradicular posts, both macroscopically and radiographically, would help to determine aspects related to the behavior of these materials when incinerated, allowing to obtain essential data for forensic documentation. Thus, the aim of this study was to evaluate the physical behavior of intraradicular posts subjected to high temperatures for forensic purposes. The tested null hypothesis was that intraradicular posts do not undergo changes when subjected to high temperatures.

2 Materials and methods

2.1 Type of study, sample selection and preparation

This was an observational ex-vivo study, submitted to the Ethics Committee for the Use of Animals (CEUA) at the Federal University of Juiz de Fora and approved (protocol no. 013/2020).

For sample size calculation, initially the authors reviewed sample sizes used in previous studies. Arcos et al. (2015), Arcos et al. (2016), Aramburo et al. (2015), and Aramburo et al. (2013) used three samples for each temperature range, while Merlati et al. (2004) used four to five samples, and Lima et al. (2024) used eight. Considering that the most comparable studies to the present research used only three samples (Aramburo et al., 2015; Aramburo et al., 2013), it was deemed appropriate to double this number. Therefore, an initial plan was made to use six samples per group. Following the pre-incineration evaluation of the optical density of the dental posts, these values were used to calculate the power of the test using the G*Power software (ANOVA fixed effects, omnibus, one-way; effect size $f = 26.2866006$; $\alpha = 0.05$; power $= 0.95$; number of groups = 6). The analysis indicated an actual power of 1. To account for the possibility of sample loss during the study, it was decided to add one additional sample per group, resulting in a total of seven samples per group.

Thus, one hundred twenty-six freshly extracted single-rooted bovine incisors were selected and preserved in formaldehyde (0.30 g.mL-1). They were from animals that had been slaughtered for commercial purposes, regardless of the study. All the teeth selected underwent a chemical disinfection process with immersion in 5% sodium hypochlorite (Asfer™, São Caetano do Sul, SP, Brazil) for around one hour.

After this period, the teeth were stored submerged in a distilled water solution during all the methodological stages. The teeth had their crowns removed using a carborundum disk mounted on a straight piece, under constant irrigation, to obtain 18 mm long roots. After sectioning, the mesio-distal and buccal-lingual dimensions of the roots were measured with a digital caliper (Starrett® 799A, Starrett, Itu, Brazil) to standardize and include roots with the approximate buccal-lingual and mesio-distal dimensions. Curved roots, and/or roots with incomplete apex, and/or roots with cracks/fractures were excluded.

2.2 Endodontic treatment

All the roots (n=126) were treated with rotary instruments (ProTaper Universal, Denstply Maillefer™, Petrópolis, RJ, Brazil), and filled with gutta-percha (Denstply Maillefer™, Petrópolis, RJ, Brazil) and zinc oxide and eugenol-based cement (Endofill, Denstply Maillefer™, Petrópolis, RJ, Brazil), using the lateral and vertical condensation technique. The quality of the fillings were evaluated by periapical radiographies, performed with photostimulable phosphor plates (PSP) (Vista Scan®, Dürr Dental, Beitigheim-Bissingen, Germany) and the acquisition parameters, kilovoltage peak (kVp) and milliamp (mA) were kept fixed according to the device's features (Spectro 70X, Dabi Atlante™, SP, Brazil), at 70 kVp, 8 mA, and the exposure time was kept constant at 0.25 seconds (s).

The roots were randomly distributed into six groups (n=21), according to the different intraradicular posts divided into fiber posts: glass fiber post (Exacto, Angelus™, Londrina, PR, Brazil), glass fiber post (Whitepost System DC, FGM™, Joinville, SC, Brazil), glass fiber post (Reforpost™, Angelus™, Londrina, PR, Brazil) carbon fiber post (Reforpost™, Angelus™, Londrina, PR, Brazil); and metal posts: prefabricated metal post (Reforpost™ I, Angelus™, Londrina, PR, Brazil), nickel-chromium alloy (Ni-Cr) cast metal post. Subsequently, each group was randomly divided into three subgroups (n=7), according to the incineration temperatures of the roots: 600, 800 and 1000 °C. The distribution of the 126 roots in the respective groups is shown in figure 1.

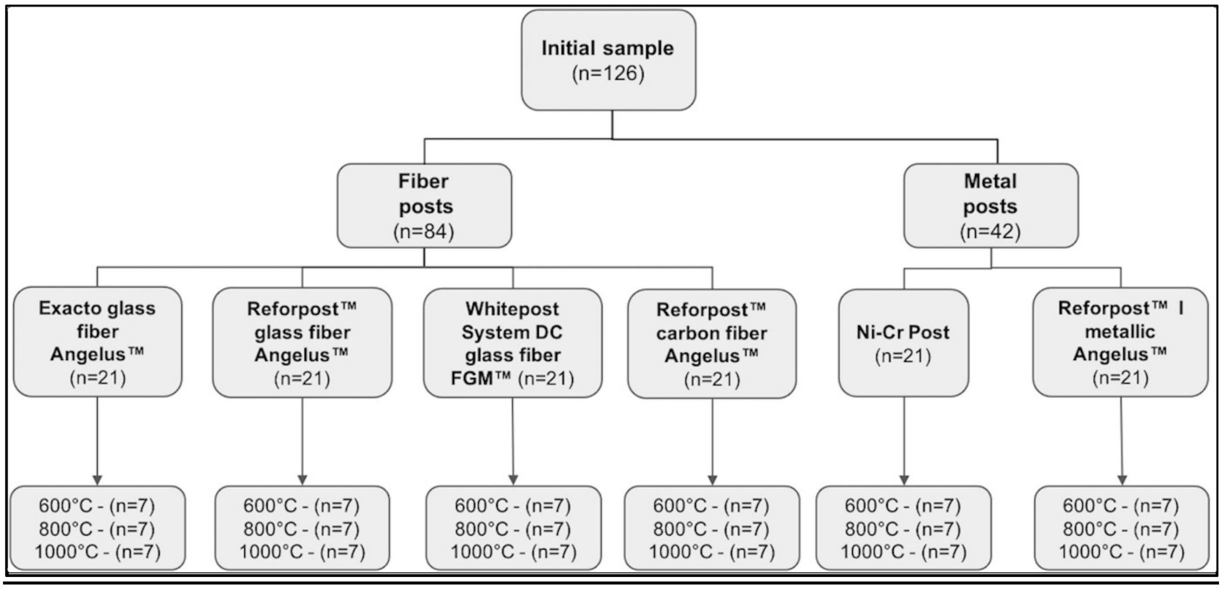

Figure 1: Flowchart illustrating the randomization of teeth according to the material and the incineration temperature.

2.3 Preparation of posts spaces

To prepare the space for the posts, the root filling material was removed using heated Paiva-type presses (Golgran™, São Caetano do Sul, SP, Brazil) and specific drills for preparing the root canal, according to the type and size of post to be used.

2.4 Cast metal post and prefabricated metal post

The canal modeling technique was used to make the metal post, using a prefabricated polycarbonate post (Pinjet, Angelus™, Londrina, PR, Brazil) adapted to the diameter and length of the unobstructed canal. After complete polymerization, the stick was cut at the incisal level, and the coronal part was prepared. Once the anatomical shapes of both the canal and the crown had been obtained, the post was sent to the laboratory for casting. Ni-Cr alloy cast metal posts were made.

The cast metal posts and prefabricated metal posts (Reforpost™ I, Angelus™, Londrina, PR, Brazil) were adapted inside the canal. Before cementation, the canal was decontaminated using 37% phosphoric acid for 15 s (Condac, FGM™), rinsed thoroughly with distilled water (60 s) and dried with absorbent paper cones. Zinc phosphate cement (SS White, Maquira™, Maringá, PR, Brazil) was used for cementation. Finally, the post was inserted into the canal and held in position under active digital pressure for 60 s until it had set. The excess cement was removed.

2.5 Prefabricated glass fiber and carbon fiber posts

The root canals were uncovered with the drill corresponding to the post system used. The surface of the posts was treated starting with etching with 37% phosphoric acid (15 s), washing with water (15 s) and air drying (15 s). The post was then silanized by applying the coupling agent (Prosil, FGM™; Silano, Angelus™) to its entire surface with a brush and resting the post on a glass plate for four minutes. It was then dried with an air jet (15 s). This procedure was carried out on all the posts. A two-step total acid etching adhesive system (Ambar, FGM™) associated with a conventional dual resin cement (Allcem, FGM™) was used for cementation. The canal was first conditioned with 37% phosphoric acid for 15 s (Condac, FGM™), rinsed thoroughly with distilled water (60 s) and dried with absorbent paper cones. After this stage, the dentin adhesive (Ambar, FGM™) was applied to the root canal using a microbrush (Cavibrush, FGM™), its excess was removed with paper cones and photoactivation with a high-power LED 1200mW/cm2 (Radii Cal, SDI™, Australia) was carried out on the coronal surface for 30 s. For cementation, equal portions of the base and catalyst pastes of the resin cement (Allcem, FGM™) were manipulated and inserted into the canal using a lentulo drill. After this stage, the post was inserted into the canal, held in position under digital pressure for 60 s, the excess cement was removed and the cement was photoactivated for 40 s (Radii Cal, SDI™) on the occlusal surface of the post.

2.6 Coronary Reconstruction

Micro-hybrid composite resin (Opallis, FGM™) was used for coronary reconstruction using standardized plastic matrices. To make the matrices, a human central incisor (coronary portion 10 mm high) was molded with addition silicone (Express XT, 3M ESPE™, Sumaré, São Paulo, Brazil) and dies with Durone Type IV special stone plaster (Dentsply™, Petrópolis, Brazil) were obtained. Initially, the root dentin was etched for 15 s with 37% phosphoric acid (Condac, FGM™), rinsed thoroughly with water and dried with absorbent paper. Subsequently, a layer of dentin conventional two-step adhesive (Ambar, FGM™) was applied to the dentin with a microbrush (Cavibrush, FGM™), a light jet of air was used to evaporate the solvent and homogenize the thickness of the adhesive and photoactivation was carried out for 30 s (RadiiCal, SDI™). For reconstruction, the matrices were filled with composite resin and positioned on the coronary surface of the root. Photoactivation was carried out for 20 s per side (Radii Cal, SDI™). The matrices were removed using a scalpel blade (Lamedid Solidor™, Guarulhos, São Paulo, Brazil), finished with an ultra-fine diamond drill (Drill 3118F, KG Sorensen™, Cotia, SP, Brazil), sanding disks (Sof-Lex, 3M ESPE™, St Paul, MN, USA) and polished with silicone tips (Poligloss, Microdont™, São Paulo, SP, Brazil).

2.7 Acquisition of photographic images

To perform macroscopic evaluation in a standardized and reproducible way, quality digital photographics were obtained. A Digital Single Lens Reflex (DSLR) camera (Nikon D3200, Nikon, Nishi-Ōi, Shinagawa, Tokyo, Japan) and 105 mm macro lens and a portable mini photo studio were used. The following parameters were set for the photographs: aperture (f/2.0), shutter speed (1/60 s), aperture quantity, ISO (800), autofocus and fill flash. All teeth were positioned at a predefined distance of 12.5 centimeters (cm) from the upper opening, so that all photographs were taken in a similar 90-degree position. For better visualization, the teeth were placed on a standard green background. The sample was photographed before and after the incineration process.

2.8 Acquisition of radiographic images

After the roots had been completely prepared (restoration with posts and coronary reconstruction), they were positioned in a wax phantom to simulate the dental socket, which was placed in a specific acrylic device for taking periapical radiographs using the parallelism technique and soft tissue simulation. On the side of the phantom (tooth + wax block), an aluminum step-wedge with a purity of over 99% was positioned, containing 11 steps, each one millimeter thick, to ensure the standardization of optical density of the images. A semi-direct PSP digital acquisition system was used (Vista Scan™, Dürr Dental, Beitigheim-Bissingen, Germany). The acquisition parameters, kilovoltage peak (kVp) and milliamp (mA) were kept fixed according to the device's characteristics (Spectro 70X, Dabi Atlante™, SP, Brazil), at 70 kVp, 8 mA, and the exposure time was kept constant at 0.25 s. All images were taken in the orthoradial position. The PSPs were scanned on the PerioPlus® scanner (Dürr Dental™, Beitigheim-Bissingen, Germany) with a resolution of 25 lp/mm. After incineration, the roots were radiographed again, following the same protocols described above. The images were saved in .JPEG format.

2.9 Incineration process

In order to apply high temperatures, the teeth were distributed in seven individual trays made of refractory lining material to facilitate handling. The muffle type oven (EDG 10P-S 3000, EDG™, SP, Brazil) was previously calibrated at three different temperatures ranges (600, 800 and 1000 °C). The initial temperature of the oven was pre-set at 34°C (room temperature), with a gradual increase until the temperature proposed for each group was reached. The teeth were kept for 15 minutes at the final temperature determined. After that, the individual trays with the teeth were removed from the oven and left to cool to room temperature [8,14-17] (Figure 2). The procedure was repeated successively for all groups. Since teeth exposed to high temperatures can undergo many changes to their structure, when they were at room temperature, they were covered with hair spray (Aspa, Aerojet Química Industrial Ltda™, Duque de

Caxias, RJ, Brazil) which allowed the sample to be handled after incineration [18,19].

Figure 2: Demonstration of the incineration process. The image on the left shows the muffle oven at an initial temperature of 34 °C. On the right, you can see ceramic crucibles organized inside the oven. The lower right shows two samples after incineration resting at room temperature.

2.10 Macroscopic evaluation

The roots were qualitatively assessed macroscopically, through the photographies, for changes as a result of incineration, considering: no changes visible to the naked eye, cracks in the dentin, fractures in the dentin without separation of fragments, fractures in the dentin with separation of fragments, complete root disintegration (Figure 3); as well as color changes [20] (Figure 3). All analyses were carried out by a single and previously trained evaluator, using a 15.6” Dell Inspiron i15-i1100-M35PB Full HD i5 monitor™ (Dell Technologies, SP, Brazil) in a room with reduced ambient lighting.

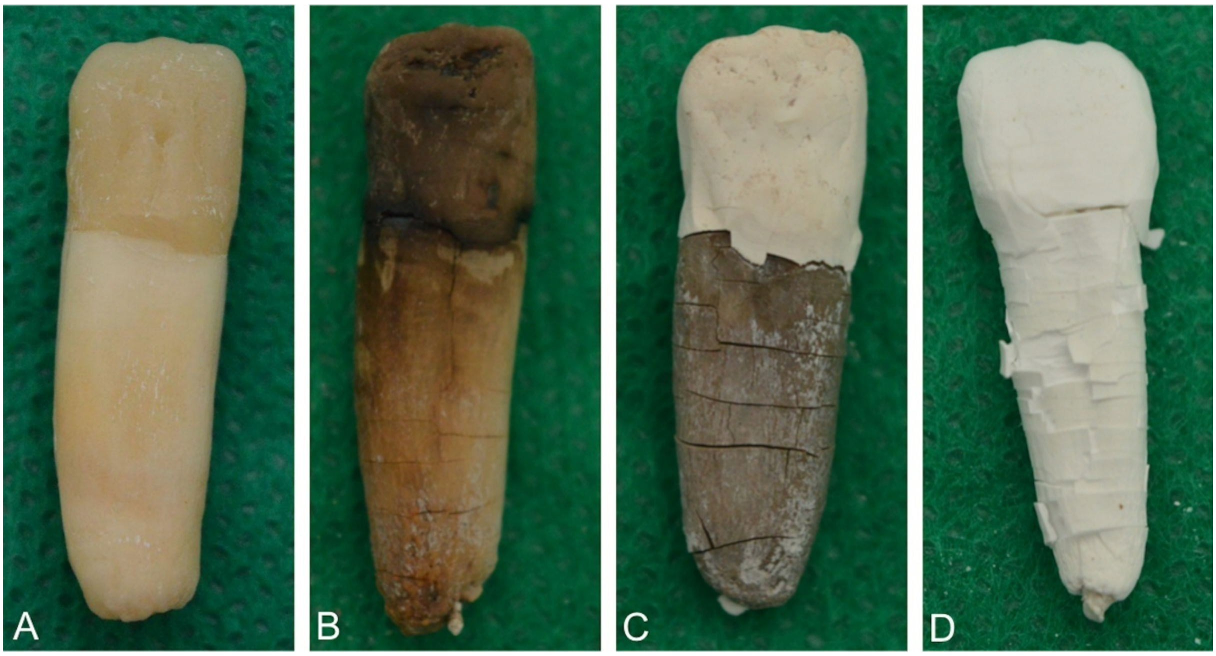

Figure 3: Macroscopic evaluation: A - No changes visible to the naked eye, pre-incineration; B - Cracks in the dentin, root in brown color (Reforpost™ glass fiber Angelus™, 600°C); C - Fractures in the dentin without separation of fragments, root in gray color (Whitepost System DC glass fiber FGM™, 600°C); D - Fractures in the dentin with separation of fragments, root in white color (Reforpost™ glass fiber Angelus™, 1000°C).

2.11 Radiographic evaluation

The radiopacity of the posts on periapical radiographs before and after incineration was assessed by optical density. It was measured using histogram tool in the ImageJ™ software, in three predetermined regions of the intraradicular posts (cervical – the upper limit of the post; apical – the lower limit of the post; medium – midpoint between upper and lower limits). For this purpose, a standardized square region of interest (ROI) (0.4 x 0.4 mm) was delimited in the described regions of the posts (Figure 4). The final optical density of each post was considered the mean of the three regions analyzed. The same size ROI was also delimited in each step of the aluminum step-wedge, to analyze its optical density too, ensuring that the radiographic acquisition was standardized.

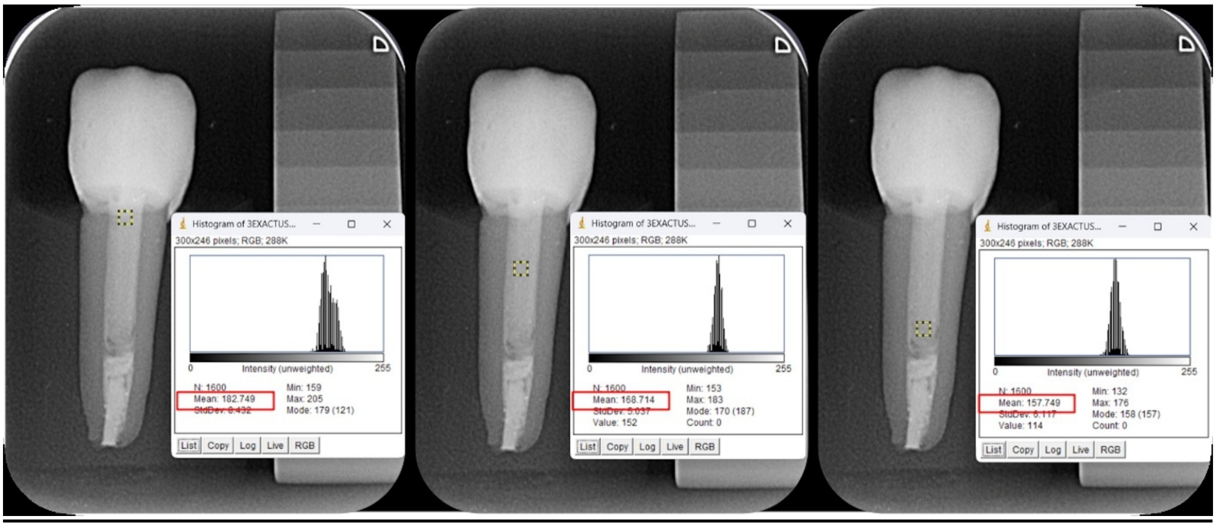

Figure 4: Demonstration of the selection of the three ROIs in the intraradicular post (Exacto glass fiber Angelus™, pre-incineration), and the histogram tool to obtain optical density values, using ImageJ™ software.

In addition, a qualitative radiographic assessment of the roots was carried out, following the criteria of Savio et al. [20] and Woisetschläger et al. [21]: no radiographic changes; fissures in the dentin; fractures in the dentin without separation of fragments; fractures in the dentin with separation of fragments; complete root disintegration (Figure 5).

Regarding the posts, the following were considered: no changes (no changes in adaptation, dimension or shape); internal maladjustment between the post and the dentin wall, with no changes in dimension and/or shape; internal maladjustment between the post and the dentin wall, with changes in dimension and/or shape; changes in the radiopacity of the post, with the presence of one or more radiolucent areas (“bubbles”) (Figure 5).

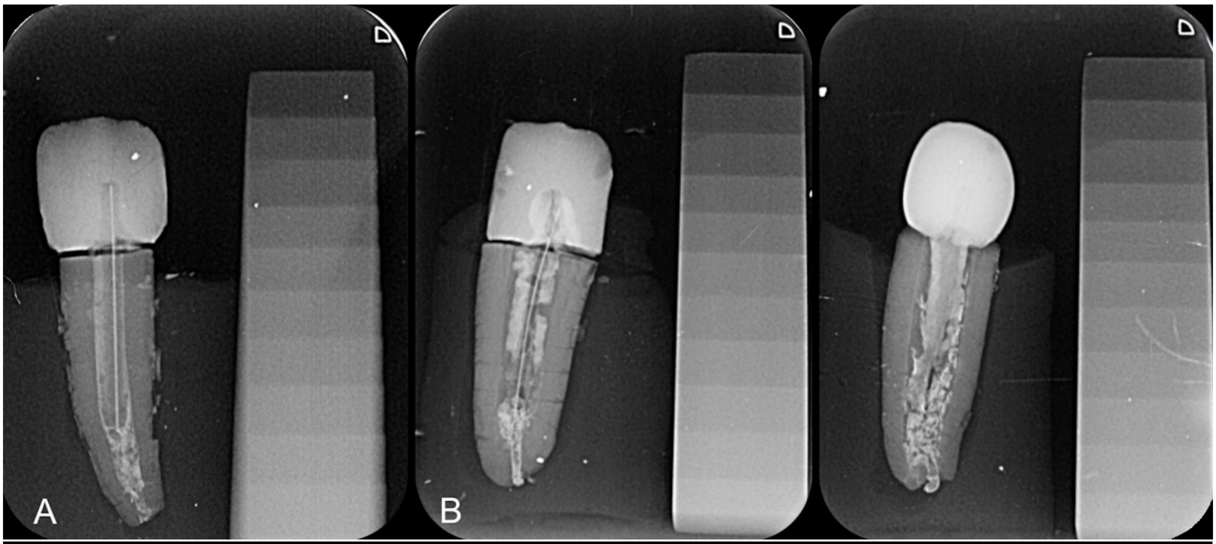

Figure 5: Radiographic evaluation of dental root and post: A (600°C) - Root: fractures in the dentin with separation of fragments; Post (Reforpost™ glass fiber Angelus™): no changes; B (1000°C) - Root: fractures in the dentin without separation of fragments; Post (Reforpost™ carbon fiber Angelus™): internal maladjustment between the post and the dentin wall, with changes in dimension and/or shape; C (1000°C) - Root: Fissures in dentin; Post (Whitepost System DC glass fiber FGM™): internal maladjustment between the post and the dentin wall, with changes in dimension and/or shape; changes in the radiopacity of the post, with the presence of bubbles.

All analyses were carried out by a single, previously trained evaluator using a 15.6” Dell Inspiron i15-i1100-M35PB Full HD i5 monitor™ (Dell Technologies, SP, Brazil) in a room with reduced ambient lighting. After 15 days, 20% of the samples were reevaluated to calculate an intra-rater agreement, which showed excellent agreement (intraclass correlation coefficient of 0.98).

2.12 Statistical analysis

Descriptive and inferential statistics were performed. The association between macroscopic and radiographic changes suffered by roots and intraradicular posts in relation to different temperatures was determined by Fisher's Exact Test. The comparison of the mean optical density among the different materials pre- and post-incineration ranges was verified by the ANOVA one way, with Tukey test as a post hoc.

All analyses were performed with IBM SPSS Statistics™ version 25 (IBM Corp, Armonk, NY, USA), at 5% level of significance.

3 Results

3.1 Macroscopic and radiographic evaluation

Macroscopically, there was no significant association between the temperature ranges and the formation of cracks or root fractures (Table 1). In general, the highest frequency of macroscopic alterations found was dentin fracture with separation, with the exception of the following post and temperature, where dentin fractures without separation was also highly observed: Reforpost™ Glass fiber Angelus™ (50%) and Whitepost System DC glass fiber FGM™ (57.1%) at 600°C; and Reforpost™ carbon fiber Angelus™ (71.4%) at 1000°C. Radiographically there was also no association, with the exception of samples restored with Reforpost™ glass fiber Angelus™ (p= 0.014) (Table 2).

Table 1. Relative frequency of the macroscopic changes of the roots subjected to high temperatures.

Materials	Temperature	Fissures in dentin	Dentin fractures without separation	Dentin fractures with separation	P value*
Exacto glass fiber Angelus™	600°C	0%	16.7%	83.3%	
	800°C	0%	14.3%	85.7%	0.742
	1000°C	0%	0%	100%	
Reforpost™ glass fiber Angelus™	600°C	0%	50%	50%	
	800°C	0%	14.3%	85.7%	0.412
	1000°C	0%	28.6%	71.4%	
Whitepost System DC glass fiber FGM™	600°C	0%	57.1%	42.9%	0.060

	800°C	0%	0%	100%	
	1000°C	14.3%	28.6%	57.1%	
Reforpost™ carbon fiber Angelus™	600°C	0%	14.3%	85.7%	
	800°C	0%	14.3%	85.7%	0.052
	1000°C	0%	71.4%	28.6%	
Reforpost™ I Metallic Angelus™	600°C	0%	0%	100%	
	800°C	28.6%	0%	71.4%	0.300
	1000°C	0%	0%	100%	
Ni-Cr Post	600°C	0%	14.3%	85.7%	
	800°C	0%	28.6%	71.4%	0.829
	1000°C	0%	42.9%	57.1%	

*P Value: Fisher's Exact Test.

Table 2. Relative frequency of the radiographic changes of the roots subjected to high temperatures.

Materials	Temperature	Fissures in dentin	Dentin fractures without separation	Dentin fractures with separation	P value*
Exacto glass fiber Angelus™	600°C	28.6%	0%	71.4%	
	800°C	0%	14.3%	85.7%	0.509
	1000°C	0%	14.3%	85.7%	
Reforpost™ glass fiber Angelus™	600°C	50%	0%	50%	
	800°C	0%	0%	100%	0.014
	1000°C	0%	28.6%	71.4%	
Whitepost System DC glass fiber FGM™	600°C	57.1%	28.6%	14.3%	
	800°C	0%	14.3%	85.7%	0.072
	1000°C	28.6%	14.3%	57.1%	

Reforpost™ carbon fiber Angelus™	600°C	28.6%	14.3%	57.1%	0.351
	800°C	0%	57.1%	42.9%	
	1000°C	14.3%	57.1%	28.6%	
Reforpost™ I Metallic Angelus™	600°C	14.3%	14.3%	71.4%	0.863
	800°C	14.3%	28.6%	57.1%	
	1000°C	28.6%	0%	71.4%	
Ni-Cr Post	600°C	42.9%	57.1%	0%	0.268
	800°C	57.1%	28.6%	14.3%	
	1000°C	33.3%	16.7%	50%	

*P Value: Fisher's Exact Test.

There was a significant association between the temperature ranges and the color presented by the root after incineration in all materials (p<0.001) (Table 3). At 600°C, gray color was the most prevalent for roots restored with the materials Reforpost™ carbon fiber Angelus™, Reforpost™ I metallic Angelus, and brown color for Whitepost System DC glass fiber FGM™ and Ni-Cr Post. Exacto glass fiber Angelus™ and Reforpost™ glass fiber Angelus™ showed a frequency of 50% for both colors. At 800°C and 1000°C, all the roots were white (100%) regardless of the restorative material used.

Figure 6 shows photographs of the samples before and after incineration in different temperatures range (600, 800, 1000°C), according to tested material.

Table 3. Relative frequency of the macroscopic changes in the color of roots subjected to high temperatures.

Materials	Temperature	White	Brown	Gray	P value*
Exacto glass fiber Angelus™	600°C	0%	50%	50%	<0.001
	800°C	100%	0%	0%	
	1000°C	100%	0%	0%	

Reforpost™ glass fiber Angelus™	600°C	0%	50%	50%	<0.001
	800°C	100%	0%	0%	
	1000°C	100%	0%	0%	
Whitepost System DC glass fiber FGM™	600°C	0%	71.4%	28.6%	<0.001
	800°C	100%	0%	0%	
	1000°C	100%	0%	0%	
Reforpost™ carbon fiber Angelus™	600°C	0%	28.6%	71.4%	<0.001
	800°C	100%	0%	0%	
	1000°C	100%	0%	0%	
Reforpost™ I Metallic Angelus™	600°C	0%	14.3%	85.7%	<0.001
	800°C	100%	0%	0%	
	1000°C	100%	0%	0%	
Ni-Cr Post	600°C	0%	85.7%	14.3%	<0.001
	800°C	100%	0%	0%	
	1000°C	100%	0%	0%	

*P Value: Fisher's Exact Test.

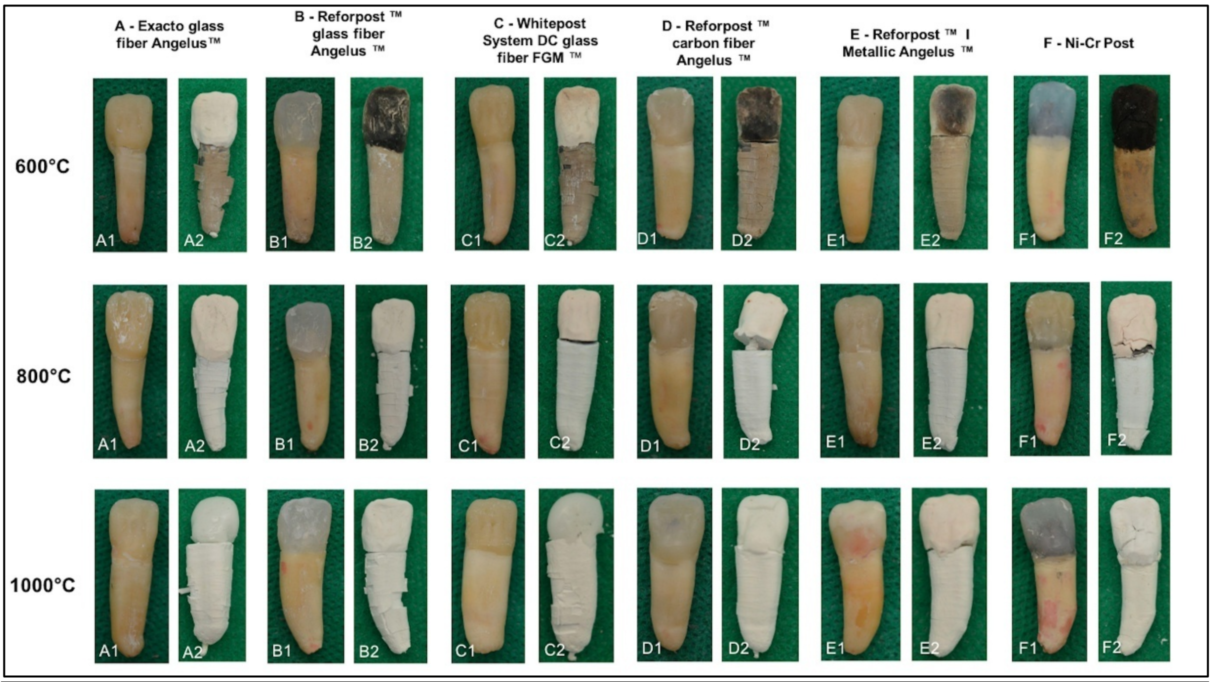

Figure 6: Photographs of the samples before (1) and after (2) incineration in different temperatures range (600, 800, 1000°C), according to material (A - Exacto glass fiber Angelus™, B - Reforpost™ glass fiber Angelus™, C- Whitepost System DC glass fiber FGM™, D - Reforpost™ carbon fiber Angelus™, E - Reforpost™ I Metallic Angelus™, F - Ni-Cr post).

In relation to the radiographic analysis of the intraradicular posts, all materials showed a significant difference, with the association between the temperature ranges and the changes evaluated, except for the Reforpost™ I metallic Angelus™ samples ($p=1.00$), which showed no changes in all the temperature ranges (Table 4). At 600°C, most of the samples of intraradicular posts of all materials were unchanged. At 800°C, both Exacto glass fiber Angelus™ (57.1%) and Ni-Cr Post (100%) remained unchanged, while Whitepost System DC glass fiber FGM™ (57.1%), Reforpost™ carbon fiber Angelus™ (42.9%) and Reforpost™ glass fiber Angelus™ (57.1%) showed material internal maladjustment. At 1000°C Exacto glass fiber Angelus™ (66.7%), Reforpost™ carbon fiber Angelus™ (85.7%), Reforpost™ glass fiber Angelus™ (57.1%) and Whitepost System DC glass fiber FGM ™ (57.1%) showed internal maladjustment of the posts, dimensional change, radiopacity change and “bubbles”. Ni-Cr post (85.7%) showed internal maladjustment. Figure 7 shows examples of periapical radiographies of the samples before and after incineration in different temperatures range (600, 800, 1000°C), according to tested material.

Table 4. Relative frequency of the radiographic changes of the posts subjected to high temperatures.

Materials	Temperature	No changes	Maladjustment of posts	Maladjustment of posts and dimensional change	Maladjustment of posts, dimensional change, radiopacity change	Maladjustment of posts, dimensional change, radiopacity change and bubbles	P value*
Exacto glass fiber Angelus™	600°C	100%	0%	0%	0%	0%	<0.001
	800°C	57.1%	28.6%	14.3%	0%	0%	
	1000°C	0%	0%	33.3%	0%	66.7%	
Reforpost™ glass fiber Angelus™	600°C	83.3%	16.7%	0%	0%	0%	0.002
	800°C	42.9%	57.1%	0%	0%	0%	
	1000°C	0%	14.3%	28.6%	0%	57.1%	
Whitepost System DC glass fiber FGM™	600°C	85.7%	14.3%	0%	0%	0%	<0.001
	800°C	28.6%	57.1%	14.3%	0%	0%	
	1000°C	0%	14.3%	14.3%	14.3%	57.1%	
Reforpost™ carbon fiber Angelus™	600°C	85.7%	14.3%	0%	0%	0%	<0.001
	800°C	28.6%	42.9%	28.6%	0%	0%	
	1000°C	0%	0%	14.3%	0%	85.7%	
Reforpost™ I Metallic Angelus™	600°C	100%	0%	0%	0%	0%	1.000
	800°C	100%	0%	0%	0%	0%	
	1000°C	100%	0%	0%	0%	0%	
Ni-Cr Post	600°C	100%	0%	0%	0%	0%	<0.001
	800°C	100%	0%	0%	0%	0%	
	1000°C	14.3%	85.7%	0%	0%	0%	

*P Value: Fisher's Exact Test.

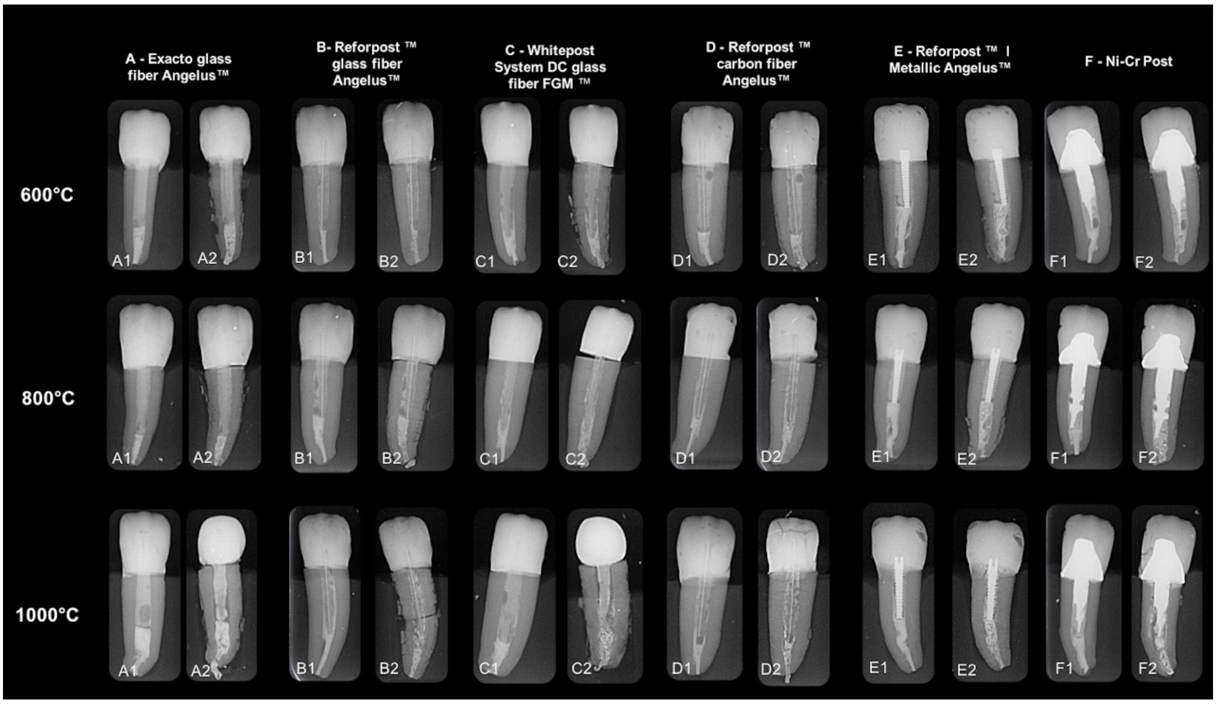

Figure 7: Imaging showing radiographies of the samples before (1) and after (2) incineration in different temperatures range (600, 800, 1000°C), according to material (A - Exacto glass fiber Angelus™, B - Reforpost™ glass fiber Angelus™, C- Whitepost System DC glass fiber FGM™, D - Reforpost™ carbon fiber Angelus™, E - Reforpost™ I Metallic Angelus™, F - Ni-Cr post).

3.2 Radiopacity evaluation

In the analysis of the mean optical density (radiopacity) of the intraradicular posts in periapical examinations at the pre- and post-incineration range moments (Table 5), it was found that there was a significant difference of the following materials: Reforpost ™ glass fiber Angelus ™, Whitepost System DC glass fiber FGM™ and Reforpost™ carbon fiber Angelus™. There was a gradual increase in the average density value of the Reforpost™ glass fiber Angelus™ and Whitepost System DC glass fiber FGM™ material as the temperature increased. However, the Reforpost™ carbon fiber Angelus™ showed a gradual reduction in the mean density value as the temperature increased.

The Reforpost™ glass fiber Angelus™ material showed a difference between the pre-incineration values and the temperature of 600°C, and between the values of 600°C and 1000°C. Whitepost System DC glass fiber FGM™ showed a difference only between the pre-incineration values and 600°C, while Reforpost™ carbon fiber Angelus™ showed a difference between the pre-incineration values and 1000°C.

According to the mean optical density of intraradicular posts pre-incineration, carbon fiber posts had lower radiopacity, while (Ni-Cr) cast metal posts had high radiopacity.

Table 5. Mean and standard deviation (SD) of the optical density mean values obtained of post periapical radiograph in the respective temperature ranges.

Materials	Mean density (SD)				
	Pre-incineration	Post-incineration			
		600 °C	800 °C	1000 °C	P value
Exacto glass fiber Angelus™	163.10 (9.96) A	153.72 (3.37) A	161.22 (10.73) A	160.57 (12.75) A	0.211
Reforpost ™ glass fiber Angelus ™	153.46 (6.55) AC	142.04 (10.63) B	147.86 (3.51) AB	155.86 (6.43) C	0.002
Whitepost System DC glass fiber FGM™	159.12 (5.20) A	150.13 (7.93) B	154.17 (8.34) AB	159.10 (5.95) AB	0.012
Reforpost™ carbon fiber Angelus™	150.16 (6.72) A	146.55 (7.43) AB	144.71 (7.74) AB	140.01 (10.60) B	0.031
Reforpost ™ I metallic Angelus ™	210.86 (2.48) A	210.68 (2.67) A	208.29 (2.87) A	209.82 (1.78) A	0.128
Ni-Cr Post	215.25 (15.96) A	215.17 (3.31) A	215.42 (6.00) A	211.96 (4.84) A	0.931

*P Value: One-way ANOVA. Different capital letters indicate a significant difference between values on the same line.

4 Discussion

Disaster victims are identified based on the assessment of various factors, such as the damage present in the human remains, the time of exposure and associated changes in the condition of the remains; aspects that will have an influence on the nature and quality of the post-mortem data, as well as determining the method of identification to be carried out under such circumstances [5]. The morphological characteristics of dentition as well as changes in dental materials in the face of high temperatures can be used to assist in the entire recognition process [22,23].

The study considered the following null hypothesis: intraradicular posts do not undergo changes when subjected to high temperatures. To achieve the proposed objective, macroscopic and radiographic analyses were obtained, as well as the optical density of different intraradicular posts. The results showed that the null hypothesis could not be accepted since, despite being resistant, intraradicular posts showed radiographic and radiopacity changes depending on the material and temperature range evaluated. The macroscopic changes were presented by the roots independently of the materials used for the intraradicular posts.

Bovine teeth show similarities to human teeth, such as the same percentage of intertubular dentin, similar fractions of solid tissue, and a greater number of dentinal tubules close to the pulp. It should be noted that in relation to radiodensity, bovine root dentin is similar to human root dentin, ensuring that bovine teeth are suitable substitutes for human teeth [24,25] in *ex-vivo* studies. Furthermore, this study used bovine teeth with similar mesio-distal and buccal-lingual size and consequently the same dentin thickness, which allowed adequate protection for all the intraradicular posts, ensuring sample standardization. Also, the use of human teeth would be not viable due to the large number of samples needed to carry out the study, as well as ensuring similar dentin thickness standards.

The oven handling time of 15 minutes was set based on previous studies [3,15-17,23,26] as well as the tested temperatures of 600, 800 and 1000 °C [3,12,15-17, 18-21,27-31]. Previous studies have evaluated the behavior of materials, submitted to high temperatures, such as amalgam, composite resin, glass ionomer cement, zinc oxide and eugenol cement, porcelain veneers, ceramic crowns, orthodontic brackets and dental implants macroscopically and/or radiographically [3,8,16-21,27-29,32-36]. However, to the best of our knowledge, only the study by Aramburo et al. [2] evaluated the response macroscopic and radiographic of titanium and glass fiber posts. The current study expanded the number of intraradicular posts evaluated, due to the wide variety of posts available on the market, covering both metal and fiber posts from different brands, as well as analyzing the radiopacity of the materials.

The macroscopic and radiographic behavior of crack formation and root fractures has been observed in other studies at lower temperature ranges, such as 200 and 400 °C [3, 8, 15,17-21]. Thus, when the 600°C temperature range is reached, the dental tissue already shows cracks and fractures. This result is in line with the study by Woistschalager et al. [21], in which, in the 600, 800 and 1000°C temperature ranges, the radiographic aspects observed in the roots were maintained, with the elements showing cracks in the dentin.

The changes are the result of the evaporation of water present in the dentin with the increase in temperature [26, 37]. Therefore, from 600°C onwards, the dentin presents a reduction in the diameter of the dentinal tubules, being subsequently, at 800°C, dentinal tubules was covered by debris, and finally, at 1000°C, presenting a smaller structure covered by granules [15].

In relation to color, the result is similar to previous studies with a prevalence of gray color at 600°C, due to the carbonization of dentin [19, 21]. The color variation shown at 600°C may be the result of the presence of both dentin and cementum tissues in the root. According to Vázquez, Rodríguez and Moreno [19], at 600 °C, dentin is gray while cementum is light brown, so when macroscopic visualization is performed, one can see a predominance of one or the other tone present in the tissues. At 800°C the appearance is white and opaque [3,8] and at 1000°C it is white due to incineration of tissues [17, 19, 21, 30]. It should be noted that the macroscopic assessment was carried out with the naked eye by a single observer. For more precise determinations, it is recommended to use other evaluation methods, such as spectrophotometry and colorimetry. However, the availability of materials, technological equipment and professionally trained human resources is not a reality in all forensic medical institutes, so macroscopic and radiographic analyses are low-cost practices that are close to everyday forensic practice [38].

The posts have different compositions depending on the material and the commercial brand, which can influence the changes observed and the analysis of radiopacity. Radiopaque agents are added to the materials to allow better visualization of the radiographic image without compromising their properties and ISO 4049/2009 is the document responsible for establishing the radiopacity requirements for dental materials [39].

In relation to the composition according to the manufacturer the research materials: Exacto glass fiber Angelus™ is composed of glass fibers (80%) and epoxy resin (20%); Reforpost™ glass fiber Angelus™ is composed of glass fibers (80%), pigmented resin (19%) and stainless steel filament (1%); Whitepost System DC glass fiber FGM™ has glass fibers (80%+-5%), epoxy resin (20%+-5%), inorganic filler (silica), silane and polymerization promoters; Reforpost™ carbon fiber Angelus™ features glass fibers (72%), pigmented resin (22%) and stainless steel filament (6%); Reforpost™ I metallic Angelus™ features only stainless steel.

Reforpost™ I metallic Angelus™ is the only material that showed no radiographic changes when the temperature was increased. Its composition includes only stainless steel, a metallic material with high thermal conductivity, i.e. it is capable of transmitting thermal energy more efficiently and is resistant to deformation by external forces and corrosion [40], properties that give the material resistance when compared to other materials that have compounds that are susceptible to degradation by the action of temperatures.

The results of radiographic analysis of the intraradicular posts corroborate with the study by Aramburo et al. [12] which shows the internal maladjustment of intraradicular posts at 800 and 1000°C. Considering that the cements used to cementation the posts are important for guaranteeing their bond to the walls of the root canals, the compromise or loss of the cementing material could lead to internal maladjustment of the intraradicular posts [12]. Therefore, the dental forensic expert must consider that the presence of internal maladjustment of intraradicular posts may be associated with degradation of the cement, not directly with the composition or alteration of the post.

The presence of variations in the densities of materials according to temperature range, pre- and post-incineration, was also verified in the study by Lima et al. [41], which included different endodontic cements. It was shown that each material reacts differently to exposure to high temperatures, reinforcing the need for further research into the density of dental materials subjected to high temperatures.

The intraradicular posts showed great resistance to high temperatures [12, 13]. In addition to their composition, this resistance tends to be a result of the protection offered by the dental tissues covering the material.

The decrease in the density of fiber intraradicular posts after incineration may be associated with the loss of inorganic charge and degradation of the properties of the radiopacifier materials, which did not occur with metal intraradicular posts. Due to the great resistance of metal posts, as suggested by the study by Berketa, James and Marino [32] carried out on dental implants, it would be interesting to produce intraradicular posts with an individual series of marked numbers, information that would increase the source of evidence for human identification.

Finally, the study had some limitations, as it was not possible consider some of variables present in vivo, such as the protection offered by the hard and soft tissues surrounding the dental elements during the incineration process, these structures being capable of protecting the elements from the direct action of the fire; it should also be considered that the adhesive cementation technique is a sensitive technique, subject to failures in the preparation and cementation of the intraradicular posts. Furthermore, the materials were subjected to controlled temperature ranges, however, the nature of fires does not present a constant temperature, but tends to fluctuate, therefore this variable is not truly replicable. When evaluating samples for forensic analysis, other factors must be considered, such as exposure time, type of fire, speed of temperature increase, as well as the substances used to extinguish the fire [2,4].

5 Conclusion

Intraradicular posts showed radiographic changes depending on the material and temperature range evaluated. In the highest temperature range, all the fiber posts showed significant internal maladjustment of posts, dimensional change, radiopacity change and bubbles, while the metal posts showed no changes (prefabricated metal post) or only internal maladjustment of the post (Ni-Cr post). In terms of radiopacity, each material showed its own change parameters when subjected to high temperatures, so the data of this study represent important information for use in forensic dentistry.

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3 CONCLUSÃO

Macroscópica e radiograficamente, a formação de trincas ou fraturas radiculares não foram associadas às faixas de temperatura avaliadas neste estudo. Entretanto, a avaliação macroscópica determinou que a cor é uma alteração relevante, sendo observadas as cores cinza e marrom a 600°C e branca a 800 e 1000°C. Radiograficamente, os pinos intrarradiculares apresentaram uma associação entre as faixas de temperatura e as alterações avaliadas, com exceção das amostras de pinos metálicos pré-fabricados, que permaneceram inalteradas em todas as faixas de temperatura.

Em termos de radiopacidade, cada material apresentou parâmetros de alteração próprios quando submetidos a altas temperaturas. Os pinos intrarradiculares mostraram resistência a altas temperaturas, e suas alterações são informações importantes para uso em odontologia forense.

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ANEXO A- Comprovante de submissão do artigo

FSI-D-24-01347 - Confirming your submission to Forensic Science International   Caixa de entrada ×

Cristina Cattaneo <em@editorialmanager.com>   00:06 (há 11 horas)
para mim

Traduza para o português

Forensic behavior of dental posts under high temperatures: macroscopic and imaging evaluations
Original Research Article

Dear Ms. Moreira,

Your submission entitled "Forensic behavior of dental posts under high temperatures: macroscopic and imaging evaluations" has been received by journal Forensic Science International. It has been assigned the following manuscript number: **FSI-D-24-01347**.

You will be able to check on the progress of your paper by logging on to the Editorial Manager as an author. The URL is https://www.editorialmanager.com/fsi/.

Thank you for submitting your work to this journal.

Kind regards,

Elsevier Editorial Office
Forensic Science International

ANEXO B – Aprovação do Comitê de Ética no Uso de Animais (CEUA)

SERVIÇO PÚBLICO FEDERAL
UNIVERSIDADE FEDERAL DE JUIZ DE FORA
COMISSÃO DE ÉTICA NO USO DE ANIMAIS -CEUA

PARECER

O protocolo nº013/2020 intitulado "Avaliação de retentores radiculares submetidos a altas temperaturas com finalidade forense", sob a responsabilidade do Coordenador(a): Francielle Silvestre Verner recebido em 24/06/2020, foi avaliado na reunião de 30/06/2020, e **aprovado**.

O Certificado definitivo será enviado posteriormente.

Juiz de Fora, 01 de Julho de 2020.

Coordenação CEUA-UFJF

Vice- Coordenação CEUA-UFJF