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QUALIDADE TÉCNICA E REPARO PERIAPICAL EM RETRATAMENTOS ENDODÔNTICOS: ESTUDO OBSERVACIONAL

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Orientadora: Profª. Drª. Roberta Kochenborger Scarparo

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Resumo

Introdução: Retratamentos endodônticos apresentam maior complexidade técnica e piores prognósticos quando comparados ao tratamento endodôntico inicial. Nesse contexto, uma investigação mais detalhada em relação aos fatores que afetam a exiquibilidade de se obter qualidade técnica satisfatória e reparo periapical é necessária. Técnicas empregadas para mineração de dados são pouco exploradas na área da Odontologia, ainda que apresentem potencial em contribuir com a descoberta do conhecimento. No presente estudo, padrões e fatores de risco relacionados à qualidade técnica e ao reparo periapical de retratamentos endodônticos foram investigados. Árvores de decisão foram geradas, sendo essa técnica complementada pela análise estatística convencional. **Metodologia:** Este estudo observacional incluiu 321 indivíduos com indicação de retratamento endodôntico atendidos por alunos de especialização em Endodontia. Foram coletados dados demográficos, referentes a história médica, ao diagnóstico, ao tratamento e a controles pós-operatórios, os quais foram transferidos para uma base de dados eletrônica. Após o preparo e pré-processamento de dados, foram selecionadas 32 variáveis independentes e 2 variáveis dependentes, as quais compreenderam os desfechos qualidade técnica do retratamento e reparo periapical. Estatísticas descritivas foram conduzidas a fim de determinar a frequência de dados ausentes, a distribuição das variáveis categóricas e a média e desvio-padrão de variáveis numéricas. Foram geradas árvores de decisão para a determinação de padrões relacionados aos desfechos, através do software de mineração de dados Weka (Waikato Environment of Knowledge Analysis, University of Waikato, New Zealand). Análises estatísticas convencionais foram conduzidas com auxílio do Software SPSS (SPSS Inc., Chicago, IL, USA), a fim de determinar fatores que poderiam interferir nos referidos desfechos. **Resultados:** Após o retratamento endodôntico, qualidade técnica satisfatória e reparo periapical foram obtidos em 65,20% e em 80,50% dos casos, respectivamente. A qualidade técnica do retratamento endodôntico foi afetada por vários fatores de risco, incluindo curvatura radicular severa ($p < 0,001$) e alterações na morfologia do canal radicular ($p = 0,002$). As árvores de decisão sugeriram padrões que combinam a ocorrência simultânea de raízes retas e reabsorções radiculares apicais com resultados tecnicamente insatisfatórios. O diâmetro da lesão periapical ($p = 0,018$), o grupo dentário ($p = 0,015$) e a presença de reabsorções apicais ($p = 0,024$) apresentaram associação significativa com o insucesso de retratamentos endodônticos. A análise de mineração de dados sugeriu que lesões periapicais extensas e qualidade da obturação insatisfatória no tratamento endodôntico inicial, apresentam mecanismos de interação entre a infecção intracanal e a resposta do hospedeiro que não foram totalmente elucidados, sendo necessários estudos complementares. **Conclusão:** Qualidade técnica satisfatória é afetada por diversos fatores de risco, entre eles, a presença de curvaturas radiculares severas e alterações na morfologia do canal radicular. A localização dos acidentes de procedimento exerce influência na obtenção da qualidade técnica. Fatores como o diâmetro da lesão periapical, o grupo dentário e as reabsorções radiculares apicais mostraram-se significativamente associados ao insucesso de retratamentos endodônticos.

Palavras-chave: retratamento; mineração de dados; árvores de decisão; Endodontia.

Abstract

Introduction: Non-surgical root canal retreatment presents higher technical complexity and poor prognosis compared to primary endodontic treatment. Within this context, a more detaild investigation on the factors affecting the feasibilty of achieving technical quality and periapical healing in teeth presenting secondary root canal infection is needed. Data mining approach is still little explored in the dentistry field, regardless of its potential to contribute to knowledge discovery. In the present study decision trees were complemented by conventional statistical analysis aiming to investigate patterns and risk factors related to technical quality and healing outcomes in non-surgical root canal retreatment. **Methods:** This observational study included 321 consecutive patients presenting for non-surgical root canal retreatment. Patients were treated by postgraduate students, following standard protocols. Data concerning demographic, medical, diagnostic, treatment and follow-up variables were transferred to an eletronic chart database (ECD). After data preprocessing and preparation a total of 32 independent variables and 2 dependent variables were defined. Basic statistics were tabled and provided the frequency of missing values, the distribution of categorical attributes and the mean and standard deviation values of numeric attributes. Decision trees were generated to predict patterns related to technical quality (satisfactory/unsatisfactory) and periapical healing (healed /failure), using J48 classification algorithm in Weka data mining software (Waikato Environment of Knowledge Analysis, University of Waikato, New Zealand). Statistical tests were performed using SPSS software (SPSS Inc., Chicago, IL, USA). Univariate and multivariate analytic methods were used to determine factors affecting endodontic retreatment technical quality and periapical healing. **Results:** After endodontic retreatment, technical outcome was satisfactory in 65.20%, and periapical healing was observed in 80.50% of the cases. Technical quality of endodontic retreatment was affected by several risk factors, including severity of root curvature ($p < 0.001$) and altered root canal morphology ($p = 0.002$). The decision trees suggested that patterns that combine straight root curvature and apical root resorption may prevent satisfactory technical outcomes. Periapical lesion area ($p = 0.018$), tooth type ($p = 0.015$) and apical resorption ($p = 0.024$) were shown to be significantly associated with endodontic retreatment failure. Data mining analysis suggested that large periapical lesions, as well as poor root filling quality in the initial endodontic treatment, present mechanisms that are not fully understood with regards to the interaction between intracanal infection and host response, which should be further investigated. **Conclusions:** Technical quality of endodontic retreatment is affected by several risk factors, including severity of root curvature and altered root canal morphology. The occurence of procedure accidents is especially relevant in the apical third of the roots, affecting the technical quality. Periapical lesion area, tooth type and apical resorption were shown to be significantly associated with endodontic retreatment failure.

Keywords: retreatment; data mining; decision trees; Endodontics

Sumário

1.APRESENTAÇÃO

A presente dissertação teve como objetivo principal investigar o potencial de características anatômicas, técnicas e patológicas em interferir na qualidade técnica e no sucesso de retratamentos endodônticos realizados no curso de especialização em Endodontia da Universidade Federal do Rio Grande do Sul.

Será apresentada da seguinte forma:

- Introdução;
- Objetivos;
- Artigo científico: o desenvolvimento e os resultados do estudo estão apresentados na forma de artigo científico que será submetido à publicação na revista International Endodontic Journal, fator de impacto 3.015 (Qualis A1, CAPES);
- Considerações finais.

2. INTRODUÇÃO

Dentes com necessidade de retratamento endodôntico correspondem a cerca de 30% da demanda de atendimento de endodontistas (1). Fatores como presença de alterações periapicais, sintomas, tempo decorrido desde a conclusão do primeiro tratamento, ocorrência de exposição do material obturador à cavidade oral e a má qualidade técnica do tratamento anterior têm sido considerados na indicação de retratamentos (1). Ainda assim, tal indicação nem sempre é consensual entre profissionais da Odontologia.

A falha de tratamentos endodônticos tem sido reportada como a recorrência de sintomas clínicos associada à presença de radioluscência apical (2). Nesse sentido, vários fatores têm sido avaliados para determinar o sucesso de tratamentos endodônticos. Em relação aos sinais e sintomas clínicos, pode-se citar dor, edema localizado ou difuso, mobilidade dentária, sensibilidade à percussão e a palpação apical. Quanto aos sinais radiográficos, a presença de radioluscência periapical e reabsorção radicular progressiva têm sido destacados na literatura (3). Instrumentos fraturados, desvios, perfurações, canais não tratados e obturação de baixa qualidade e/ou sem respeitar limite apical apropriado têm sido relacionados como fatores que provavelmente afetam o sucesso do tratamento endodôntico (3-5).

Além do insucesso do tratamento endodôntico, a indicação de retratamentos deve estar baseada no reconhecimento do seu potencial de promover o reparo periapical e eliminar sinais e sintomas. Torabinejad *et al.* (2009), compararam as taxas de sucesso de retratamentos e cirurgias paraendodônticas por dois períodos de acompanhamento. No período de 2-4 anos, observaram uma alta taxa de sucesso para a cirurgia endodôntica (77,8%) em comparação ao retratamento (70,9%). Porém, no período de 4-6 anos, o retratamento apresentou uma taxa de sucesso maior, de 83.0%, em comparação a da cirurgia endodôntica, de 71,8%. A cirurgia paraendodôntica apresentou significante diminuição do sucesso com o aumento do intervalo de *follow-up*. Com base nos resultados deste trabalho, a cirurgia paraendodôntica oferece um maior sucesso inicial, porém o retratamento apresenta um resultado a longo prazo mais favorável (6).

De modo geral, o retratamento tem sido considerado preferível aos procedimentos cirúrgicos e extrações. Um estudo comparativo avaliou a taxa de sucesso do tratamento endodôntico em dentes com lesões perirradiculares. A taxa de sucesso após o primeiro tratamento endodôntico foi de 89,7% e após o retratamento, de 85,7%, não apresentando diferença significativa. De acordo com este estudo, o tratamento/retratamento endodôntico

deve ser considerado como a primeira escolha de tratamento em casos de dentes com lesões periapicais extensas (3).

Entretanto, os diversos estudos conduzidos para verificar o desfecho de retratamentos endodônticos apresentam taxas de sucesso bastante variáveis - entre 45-100%. Geralmente, as taxas de sucesso são inferiores ao primeiro tratamento, o que pode ser justificado pela maior dificuldade de acesso aos canais previamente abordados por falhas durante a remoção do material obturador e pelas características dos microrganismos presentes em infecções secundárias (7). Além disso, inconsistências entre os pesquisadores podem derivar da metodologia utilizada (4, 8).

Nesse sentido, os percentuais de sucesso de retratamentos consideram amostras com grande variabilidade de características anatômicas, clínicas e radiográficas e poucos estudos abordam, de fato, os aspectos que interferem no sucesso de retratamentos endodônticos. As complicações durante a fase operatória do tratamento endodôntico têm significante impacto negativo. De acordo com Imura *et al.* (2007), em uma análise de regressão logística bivariada, a presença de instrumentos fraturados, perfurações e *flare-ups* são associados a uma redução de 22% do sucesso de retratamentos, o que os autores sugerem que seja devido à impossibilidade de controle e a prevenção da infecção intracanal (1).

Sjögren *et. al.* (1990), identificaram taxa global de 62% de reparo periapical em casos de retratamento, sendo o sucesso reduzido em 20% nos dentes que apresentaram radioluscência periapical. A previsibilidade do tratamento nesses casos foi considerada baixa, o que pode ser justificado pela falta de investigação de fatores críticos ao tratamento, como a persistência bacteriana (5). Instrumentos fraturados apresentam potencial de interferir no reparo de retratamentos. Apesar de estudos prévios demonstrarem que sua presença não interfere no reparo periapical, dificuldades de acesso à região apical podem impedir a desinfecção desta porção do canal radicular, a qual continuará a abrigar bactérias, resultando na persistência da doença (2, 9).

Spili *et al.* (2005), avaliaram 8.460 dentes sendo que 277 deles apresentaram um ou mais fragmentos de instrumentos contidos no interior dos canais, resultando em uma prevalência de 3,3%. As fraturas podem resultar do uso incorreto ou demasiado destes instrumentos e ocorrem com maior frequência no terço apical (1).

A manutenção de um instrumento fraturado é defendida em circunstâncias especiais: dentes vitais e preparo químico-mecânico em fase final. Supostamente, o grau de infecção correlaciona-se com a fase de instrumentação. Quando o dente é vital ou quando o acidente

ocorre no final do preparo de dentes contaminados, é provável que o canal apresente uma adequada desinfecção. Por outro lado, se a remoção não é possível e o instrumento endodôntico é ultrapassado, esse é incorporado à obturação, não comprometendo a sua qualidade (10).

A remoção dos instrumentos pode ser beneficiada pelo uso de tecnologias como o microscópio operatório e o uso de pontas ultrassônicas. Porém, em alguns casos, a tentativa de remoção pode levar a formação de degraus, perfurações e alargamento excessivo, enfraquecendo a raiz e predispondo a fraturas. A probabilidade de sucesso da remoção de instrumentos fraturados varia de 53 a 95% (10).

Outro fator relacionado ao reparo de retratamentos são as perfurações. Estas apresentam altas taxas de falha e o seu prognóstico depende do tempo decorrido para reparo, adequado selamento, além da sua localização e dimensões (1).

Segundo de Chevigny *et al.* (2008), em um estudo que avaliou os resultados de retratamentos endodônticos após 4 a 6 anos, a taxa de reparo em dentes com uma perfuração pré-operatória foi 31% menor do que nos dentes sem perfuração. Embora dramática, esta diferença é menor do que a taxa de 47% observada na primeira fase do estudo, com um período de 2 a 4 anos de acompanhamento (11). Os autores sugerem que a diferença entre os dois períodos do estudo possa estar relacionada ao emprego do agregado trióxido mineral (MTA) como material selador em todos os casos da segunda etapa, diminuindo o impacto do acidente sobre o resultado de retratamentos (12).

Apesar de os estudos supracitados abordarem uma série de fatores que podem interferir no sucesso endodôntico, a tomada de decisão por retratamentos ainda é, em boa parte dos casos, subjetiva. Além disso, a viabilidade de se corrigir falhas técnicas de tratamentos anteriores nem sempre é previsível, o que dificulta a determinação de indicações de tratamento com prognósticos precisos. Nesse sentido, análises mais detalhadas de características clínicas e anatômicas e de particularidades relacionadas a acidentes de procedimento devem ser conduzidas a fim de contribuir com seleção de casos e com a previsão de prognósticos confiáveis.

Até o presente momento, os estudos que avaliaram o reparo periapical após o retratamento endodôntico utilizaram como metodologias de análise estatísticas descritivas e/ou regressão logística, afim de identificar possíveis preditores de reparo periapical (1, 5, 11, 12). Em contrapartida, avanços na área de ciências da computação possibilitam o emprego de outras abordagens para registrar e analisar grandes volumes de informações (13). O processo conhecido como *Knowledge Discovery in Database* (KDD) é

amplamente empregada em diversas áreas do conhecimento, e provou ser um ótimo recurso para identificação de padrões compreensíveis e potencialmente úteis (13, 14). Abordagens complementares a análise estatística descritiva e preditiva, incluindo a mineração de dados, são ainda pouco usadas na Odontologia (15, 16), apesar do seu potencial em contribuir com a descoberta de conhecimento (17). Com esta perspectiva, a mineração de dados tem sido recentemente empregada em vários estudos da área médica (18-20).

Uma das técnicas bastante usadas na mineração de dados é a indução de árvores de decisão. Essa ferramenta caracteriza-se por ser de fácil compreensão, uma vez que expõem seus resultados de forma visual e intuitiva. (19, 21). Essa abordagem tem sido empregada em diversas áreas do conhecimento, incluindo a engenharia de produção, admnistração, astronomia, biologia molecular e medicina (17-21). Na Odontologia, as árvores de decisão ainda são pouco exploradas. Mesmo assim, alguns estudos utilizaram essa técnica, provendo informações relevantes para o diagnóstico e para tomada de decisão clínica. (14, 15).

O presente estudo visou identificar fatores de risco e padrões com potencial de afetar a qualidade técnica e o reparo periapical em casos de retratamento endodôntico. Para tanto, árvores de decisão foram empregadas, sendo essa técnica complementada por análises estatística convencional.

3. OBJETIVOS

3.1 Objetivo Geral

O objetivo geral deste estudo é investigar o potencial de características anatômicas, técnicas e patológicas em interferir na qualidade técnica e no reparo periapical de retratamentos endodônticos realizados no curso de especialização em Endodontia da Universidade Federal do Rio Grande do Sul.

3.2 Objetivos Específicos

- Descrever fatores presentes em casos de retratamento endodôntico;
- Gerar árvores de decisão com o objetivo de definir padrões relacionados aos desfechos estudados;
- Identificar fatores associados aos desfechos: qualidade técnica e reparo periapical.

4. ARTIGO CIENTIFÍCO

Title

Root canal retreatment under a data mining perspective: an alternative approach for predicting technical quality and periapical healing

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Running Title: endodontic retreatment technical quality and periapical healing

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Abstract

Introduction: Non-surgical root canal retreatment presents higher technical complexity and poor prognosis compared to primary endodontic treatment. Within this context, a more detaild investigation on the factors affecting the feasibilty of achieving technical quality and periapical healing in teeth presenting secondary root canal infection is needed. Data mining approach is still little explored in the dentistry field, regardless of its potential to contribute to knowledge discovery. In the present study decision trees were complemented by conventional statistical analysis aiming to investigate patterns and risk factors related to technical quality and healing outcomes in non-surgical root canal retreatment. **Methods:** This observational study included 321 consecutive patients presenting for non-surgical root canal retreatment. Patients were treated by postgraduate students, following standard protocols. Data concerning demographic, medical, diagnostic, treatment and follow-up variables were transferred to an eletronic chart database (ECD). After data preprocessing and preparation a total of 32 independent variables and 2 dependent variables were defined. Basic statistics were tabled and provided the frequency of missing values, the distribution of categorical attributes and the mean and standard deviation values of numeric attributes. Decision trees were generated to predict patterns related to technical quality (satisfactory/unsatisfactory) and periapical healing (healed /failure), using J48 classification algorithm in Weka data mining software (Waikato Environment of Knowledge Analysis, University of Waikato, New Zealand). Statistical tests were performed using SPSS software (SPSS Inc., Chicago, IL, USA). Univariate and multivariate analytic methods were used to determine factors affecting endodontic retreatment technical quality and periapical healing. **Results:** After endodontic retreatment, technical outcome was satisfactory in 65.20%, and periapical healing was observed in 80.50% of the cases. Technical quality of endodontic retreatment was affected by several risk factors, including severity of root curvature ($p < 0.001$) and altered root canal morphology ($p = 0.002$). The decision trees suggested that patterns that combine straight root curvature and apical root resorption may prevent satisfactory technical outcomes. Periapical lesion area ($p = 0.018$), tooth type ($p = 0.015$) and apical resorption ($p = 0.024$) were shown to be significantly associated with endodontic retreatment failure. Data mining analysis suggested that large periapical lesions, as well as poor root filling quality in the initial endodontic treatment, present mechanisms that are not fully understood with regards to the interaction between intracanal infection and host response, which should be further investigated. **Conclusions:** Data mining appeared to be an important and valid approach for the prediction of root canal non-surgical retreatment technical quality and periapical healing, providing additional insights to the traditional statistical methods. These technologies should be further explored to support decision making in the dentistry field.

Keywords: retreatment; data mining; decision trees; Endodontics

Introduction

Root canal treatment has been shown to be a predictable procedure with a high degree of success (Imura *et al.* 2007). Even though, failures occur in 14-16% of primary endodontic treatments (Torabinejad *et al*. 2007, Ng *et al*. 2007), and endodontic retreatments account for approximately 30% of the demand for endodontists (Imura *et al*. 2007).

The preference for non-surgical retreatment rather than endodontic surgery is supported by previous investigations. Torabinejad *et al*. (2009) evaluated clinical and radiographic signs of periapical healing and showed that, although in a short follow-up period (2-4 years after treatment) endodontic surgery presented higher success rate (77.8%) compared to endodontic retreatment (70.9%), after 4-6 years endodontic non-surgical retreatment provided better outcomes (83.0% versus 71.8% for surgical procedures). These results are in agreement with another investigation (Kvist & Reit 1999), confirming that late failures are more prone to occur in surgically treated teeth, while a slower healing dynamics can explain increased success rate over time in non-surgically retreated teeth.

On the other hand, it is also well documented that healing rate is significantly higher in primary endodontic treatments (89.7% - 94%) (Imura *et al.* 2007, Moazami *et al.* 2011) compared to non-surgical retreatments (62% - 85.9%) (Sjögren *et al.* 1990, Imura *et al.* 2007). Within this context, persistent microbiological infection is one the foremost cause of failure (Tabassum & Khan 2016).

The presence of clinical symptoms and/or maintenance/progression of periapical radiolucency (Ashraf *et al.* 2007), poor technical quality of the previous endodontic procedures (Sjögren *et al.* 1990) and loss of coronal sealing (Tabassum & Khan 2016) have been guiding dentists decision for retreating root canals. However, there is little information concerning factors that could impact the feasibility of achieving root canal retreatment technical quality and periapical healing, which would be extremely important for case selection.

Several studies evaluated radiographically the technical quality of root fillings, assuming that it may impact root canal treatment outcome (Özbas *et al.* 2011, Ribeiro *et al.* 2017, Fong *et al.* 2017). However, the identification of features and patterns related to the degree of technical difficulty is still to be warranted. This is especially relevant for non-surgical endodontic retreatment, since root canal morphology may be altered by the primary intervention (Gorni & Gagliani 2004), increasing technical complexity.

It is noteworthy that most of the studies evaluating success rates of endodontic retreatment consider samples with broadly variable characteristics (Ashraf *et al*. 2007,

Torabinejad *et al*. 2009, Moazami *et al*. 2011). Moreover, few studies (Imura *et al.* 2007, Ng *et al.* 2011a) address whether demographic, technical, anatomical and pathological features interfere on retreatment predictability.

Factors such as the presence of periapical radiolucency (Sjogren *et al*. 1990) and the incident of interappointment flare-ups (Imura *et al.* 2007) have been associated to reduced success rate of root canal retreatments, but there is no consensus on this (Nair *et al*. 1999). Gorni & Gagliani (2004) stated that the clinical success of a retreatment depends on whether the primary endodontic treatment promoted root canal morphological alterations. The occurrence of separated instruments and root perforations have been described as potential factors affecting clinical and radiographic success of non-surgical retreatment (Imura *et al.* 2007). Nevertheless, other authors have shown that the presence of separated instruments do not affect periapical repair (Spilli *et al.* 2005).

Up to date, studies investigating periapical healing after endodontic retreatment have used descriptive statistics and/or logistic regression to point out possible risk/protective factors (Sjögren *et al.* 1990, Farzaneh *et al.* 2004, Imura *et al.* 2007, de Chevigny *et al.* 2008). On the other hand, advances in the field of computer sciences enable other approaches to improve the ability to record and intelligently analyze large volumes of information (Tan *et al.* 2006). Knowledge Discovery in Database (KDD) is a widely employed methodology and has proved to be a great resource for the identification of valid, new, understandable and potentially useful patterns for several areas of knowledge (Fayyad *et al.* 1996, Tan *et al.* 2006). Complementary approaches to purely statistical descriptive and predictive studies - including data mining strategies – are still little used in the dentistry field (Yu *et al.* 2014, Pitcher *et al*. 2017), although they have significant potential to contribute to knowledge discovery (Tan, 2006). In this regard, data mining has been recently employed in several medical studies (Milosevic *et al.* 2003, Vianna *et al.* 2010, Chen *et al.* 2011, Ferreira *et al.* 2012, Tappeiner *et al.* 2017).

The present study aimed at contributing to the improvement of endodontic retreatment predictability through the identification of frequent patterns and factors affecting technical quality and periapical healing of endodontic retreatment. For this purpose, a predictive data mining functionality was complemented by conventional statistical analysis.

Materials and Methods

Ethical Considerations

The study protocol # 2.004.117 was approved by the Reasearch Comission and by the Committee of Ethical Affairs of the Federal University of Rio Grande do Sul (UFRGS).

The confidentiality of the personal data of the research participants were protected. A suitable code was used to de-identify all data, maintaining anonymity. The present observational study conforms the STROBE guidelines (Vandenbroucke *et al.* 2007).

Study design and population

The target population of this observational study comprised all consecutive patients presenting for non-surgical root canal retreatment carried out by postgraduate students at the specialization course in Endodontics, of UFRGS School of Dentistry, in Porto Alegre, Brazil, from August 2008 to December 2015. Cases with missing data on records related to diagnostic and therapeutic steps of clinical endodontic attendances, as well as patients presenting teeth that underwent previous surgical procedure, presented immature root development and/or were extracted due to non endodontic reasons (root fracture, prosthetic and periodontal reasons) were excluded from analysis.

All treatments were performed according to standard root canal retreatment protocols designated by UFRGS School of Dentistry. In total, 1650 teeth underwent endodontic treatment at the specialization course in Endodontics. From that, 362 underwent root canal retreatment within this period and were eligible to participate in the study. Amongst these, 41 teeth did not present the criteria for the study and were excluded. Among the remaining 321 teeth, 117 had follow-up registries. Figure 1 shows the flowchart of the study sample.

Data collection

In the course of this study, a dedicated database has been designed and implemented. A structured and standardized electronic chart database (ECD), containing models that comprised all clinical data related to history, diagnostic, therapeutic steps of endodontic treatment and follow-up visits was developed. A web application was created for data collection through the PHP programming language, being supported by a database model created in a MySQL database management system (DBMS).

To populate the ECD, retrospective information concerning history, diagnostic, treatment and follow-up controls - obtained from physical records and radiographs - as well as prospective data related to the follow-up visits and radiographs taken during the study development were transferred to the web application.

Data preprocessing and preparation

A total of 239 variables (named as *attributes* in data mining and database literature), related to medical history, dental diagnostic, endodontic retreatment procedures and follow up visits were collected in the DBMS. Data preparation was performed and included elimination, integration, recoding and calculation of attributes. Attributes selection was performed to eliminate unnecessary features, such as patient identity code and date of appointments, and variables with all missing values (not possible to collect from physical records). Different variables repeating information were integrated into new attributes. To facilitate data analysis, some variables were also transformed (recoded) and/or calculated to construct new attributes.

* Attributes related to medical history

Demographic data and information related to medical history, self-reported during history taking, comprised 36 attributes transferred for ECD. After data preprocessing, 7 attributes were considered.

The variable sex (men/women) was selected and the variable age (in years) was calculated based on the birth date and in the date of the first appointment of endodontic retreatment. Additionally, age was transformed in a new ordinal attribute, considering three categories: young (≤ 19 years), adult (20-59 years) and elderly (≥ 60 years). Amongst the medical variables, cardiovascular disease (medical diagnosis on angina, coronary artery disease, stroke and/or myocardial infarction), hypertension (blood pressure ≥ 140mmHg systolic and ≥ 90 mmHg diastolic), diabetes (history of blood glucose tests ≥ 150 mg dL) and smoking habit (current smoker) were considered as a binary attribute (present or absent). Data from medical history were also integrated to create a new binary attribute, which considered the occurrence of any systemic chronic condition (present or absent).

* Attributes related to diagnostic

Diagnostic data observed during dental history taken and clinical and radiographic examination comprised 93 attributes. After data preprocessing 19 of them were defined to analysis.

Teeth number was recoded for obtaining the categorical attributes tooth type (anterior, pre molar or molar) and tooth location (maxilla, mandible). Variables related to the presence of any clinical signal and/or symptom of periapical disease were integrated to create a new categorical attribute (present or absent).

The variables root resorption, canal deviation, root perforations, separated instrument and extruded filling material (present or absent) were selected and considered as binary attributes. Besides, the location of root resorption, canal deviation, separated instrument (coronal, middle or apical third of roots) and location of root perforation (furcation area, coronal, middle or apical third of roots), as well as the type of extruded filling material (sealer, gutta-percha or both materials were included in “present” alternative) were selected as categorical attributes. Additionally, some of the variables related to procedures accidents were integrated, creating a new binary attribute that indicates if one or more of the procedures accidents cited above were present or absent.

The categorical attribute level of root filling (> 2 mm from root apex, between 0 and 2 mm from root apex or beyond root apex) and the attribute root filling quality (satisfactory or unsatisfactory) were created based on the analysis of periapical radiographs retrieved from the physical charts of UFRGS. For the evaluation of root filling quality, the presence of voids and gaps were considered for unsatisfactory category, wile well-condensed root fillings were classified as satisfactory (European Society of Endodontology 2006). Additionally, a new binary attribute was created based on ECD records and radiographs analysis and considered the root canal morphology (RCM) altered if the primary endodontic treatment presented short root filling level (> 2 mm from root apex) and/or canal deviation, root perforation and/or separated instrument. RCM were considered respected when these features were not observed.

Also based on the analysis of radiographs, the attributes root curvature (RC) and periapical status (PS) were calculated. RC was classified according to the stratification suggested by Schneider (1971) as straight (≤ 5°), moderate (10°-20°) or severe (≥25° a 70°). The analysis of PS was performed both by periapical index scores (PAI) suggested by Orstavik *et al.* (1986), and by the determination of periapical lesion area, creating respectively a categorical and a numeric attributes.

Both RC and periapical lesion area were measured by one trained and calibrated examiner, using Image J software (National Institutes of Health, Bethesda, Maryland, USA). Repeated measures and analysis of the radiographs were conducted with a period of 20 days between the first and the second evaluation. Intra-examiner intra-class correlation index (ICC) resulted in value of 0.80 for the determination of lesion area. The intra-examiner agreement for RC resulted on a Kappa index of 0.70 for RC and of 0.80 for PAI. Multi-rooted teeth were classified according to the root exhibiting the most severe RC and the highest PAI score. Also for periapical lesion area, the root presenting highest apical radiolucency was considered.

*Attributes related to endodontic retreatment

Data related to endodontic retreatment comprised 63 variables. From these, 5 remained for analysis after data preprocessing.

The variables related to occurrence of new procedure accident (yes or no), quality and level of root filling after root canal retreatment (classified as previously described) were selected. The number of appointments was recoded into a binary attribute (single or multiple appointments).

Additionally, variables related to the management of pre and/or transoperative procedures accidents were integrated, creating a new binary attribute that considered if technical outcome of accident management was satisfactory or unsatisfactory. Technical outcome of accidents management were considered satisfactory in that cases in which: (a) separated instruments were removed or bypassed, enabling root canal instrumentation/filling in its entire working length; (b) canal deviation was bypassed and the original root canal pathway was accessed enabling proper instrumentation and filling; (c) root perforation was sealed and, the original root canal pathway accessed, enabling proper canal instrumentation and filling. When the outcomes above described were not achieved, technical outcome of accident management was classified as unsatisfactory.

Radiographs taken after completing endodontic retreatment were analyzed by one trained and calibrated examiner (Kappa = 0.78), to determine whether technical quality of endodontic retreatment were satisfactory or unsatisfactory. For this classification, a criteria similar to that one suggested by the European Society of Endodontology (2006) was used, being adapted to include the evaluation of the technical outcome of procedure accidents management for that cases in which they were present. Endodontic retreatment was considered technically satisfactory when well-condensed root fillings were achieved in a working length between 0 and 2 mm from radiographic apex. If procedures accidents were present, the criteria described for the evaluation of its management was applied. When satisfactory outcomes of procedure accidents management were not achieved, technical quality of endodontic retreatment was classified as unsatisfactory. Retreatment performed in multi-rooted teeth presenting at least one root canal that did not fit the criteria for satisfactory technical quality was also defined as technically unsatisfactory.

* Data related to follow-up visits

ECD comprised a total of 29 attributes related to follow-up clinical and radiographic features, being 4 of them considered for data analysis. Attributes such as coronal sealing (present/absent) and type of dental restoration (definitive, temporary or absent) were

selected. The numeric attribute follow-up period (in years) was calculated considering the date of endodontic retreatment end and the date of the follow-up visit.

The criteria suggested by Imura *et al.* (2007) was used to integrate all clinical and radiographic variables related to signs and symptoms collected during follow-up visits and to create the new attribute periapical healing. Periapical healing was classified by a trained and calibrated examiner (Kappa = 0.83) as healed (absence of clinical signs/symptoms and absent or reduced periapical radiolucency) or failure (presence of clinical signs/symptoms and unaltered or increased periapical radiolucency). Teeth extracted due to endodontic reasons were also classified as failure.

Basic Statistical Description of Data

After data preprocessing and preparation, the final dataset comprised a total of 32 attributes used as inputs (independent variables). Two binary class attributes (dependent variables) were defined, and comprised the classification of technical quality of root canal retreatment and periapical healing. For the evaluation of periapical healing, the attribute technical quality of endodontic retreatment was also considered as an independent variable.

Basic statistics on each attribute computed during the scan of the data was tabled and provided the frequency of missing values, the distribution of categorical attributes and the mean and standard deviation values of numeric attributes.

Prediction Test

A .csv file containing the dataset was opened in the Waikato Environment of Knowledge Analysis (Weka - version 3.7) software and later generated a new .arff file to be modeled using the Weka. This software is a well-documented collection of many state-of-the-art machine learning algorithms, freely available on the Web (www.cs.waikato.ac.nz/ml/weka).

To perform predictions related to root canal retreatment technical quality and periapical healing class attributes, J48 classification algorithm was chosen. J48 is an open source Java implementation of the C4.5 algorithm (Quinlan 1993) in the WEKA machine learning tool. For the generation of decision trees, four experiments were performed, being three to predict technical quality of endodontic retreatment and one to predict periapical healing.

For predicting technical quality, in the first and second experiment, all attributes related to demographic data, medical history and diagnostic were selected, being the minimum number of instances per leaf node parameter adjusted in 10 and 7, respectively. In

the third experiment, medical and demographic variables were excluded from the analysis, being only attributes related to diagnostic considered. Besides, procedure accidents and technical errors of the previous endodontic treatment were not evaluated separately, but grouped in the attribute root canal morphology (RCM). For this experiment, the minimum number of instances per leaf node parameter was adjusted in 7.

For predicting the class variable periapical healing, all potential risk factors contained in the dataset – including attributes related to demographic data, medical history, diagnostic, endodontic retreatment and follow-up visits – were considered, being the minimum number of instances per leaf node parameter adjusted in 7.

Accuracy, sensitivity, and specificity for determined cutoff values were calculated. The stability of induced decision trees was tested using cross-validation procedure.

Conventional Statistics

Statistical tests were performed using SPSS software version 15.2 (SPSS Inc., Chicago, IL, USA). Univariate and multivariate analytic methods were used to determine factors affecting endodontic retreatment technical quality. Periapical healing was evaluated by univariate analysis.

To assess factors affecting technical quality of endodontic retreatment, all diagnostic and retreatment variables were considered, except the ones related to PS (PAI and periapical lesion area) and that ones employed to classify this main outcome (level of root fillings, quality of root fillings and outcome of procedure accident management).

To determine factors associated to periapical healing, all variables related demographic data, medical history, diagnostic, endodontic retreatment and follow-up visits were analyzed, and the technical quality of endodontic retreatment was considered an independent variable.

Univariate associations between the selected independent variables and the dependent variables technical quality of endodontic retreatment (satisfactory/unsatisfactory) and periapical healing (healed/failure) were analyzed statistically either by Fisher exact test, t-student test or Mann-Whitney U test. Significance level was set at 0.05.

The multivariate analysis evaluated joint associations among various factors and the technical quality of endodontic retreatment, by using forward stepwise multivariable linear regression models. The independent variables signal/symptom and all variables related to accidents location presented high number of missing values and were not analyzed by multiple logistic regression. The level of significance was set at 0.05 for entry into the regression model.

Results

Distribution of data

A summary of the distribution of prognostic factors of the endodontic retreatment sample (n = 321) is shown in Tables 1-4. Most of the participants (74.75%) aged between 20-59 years old, and 75.52% were women. Hypertension (15.35%) was the most frequently self-reported systemic condition, followed by smoking habit (9.47%), cardiovascular disease (6.96%) and diabetes (3.59%).

Molars were the most frequent tooth type (42.67%), followed by anterior teeth (29.59%) and pre molars (27.72%). Procedure accidents were present in 12.14% of the cases. Unsatisfactory root fillings was detected in 73.52% individuals, being root filling level > 2 mm observed in 68.53% of the study participants. Periapical lesion area measured, in mean, 5.37 mm^2, being classified with the scores 4 and 5 of periapical index in 32.08% and 30.84% of the individuals, respectively. Root resorption was observed in 16 teeth, being all of them located in the apical third of the root.

The occurrence of new procedure accidents was not observed in the study sample. After endodontic retreatment, technical outcome was satisfactory in 65.20%, and 53.84% of preexisting procedure accidents presented satisfactory technical outcome. Follow-up periods presented a mean of 4.05 ± 1.42 years (n = 117). Retreatment success was observed in 80.50% of the cases. Coronal sealing was present in 93.69% of the individuals, but in 10.81% of them a temporary coronal sealing was observed.

Data mining results

Three decision trees were created by means of the J48 classifier to predict variables associated to technical quality of non-surgical endodontic retreatment (Figure 2-5).

The decision tree showed in Figure 2 (tree A) presents an accuracy of 97.06%, sensibility of 65.30% and specificity of 35.40% and can be read as follows: (1) If the tooth type was molar and the root curvature was severe, the endodontic retreatment belongs to class unsatisfactory technical quality of endodontic retreatment, but if root curvature was straight or moderate, the technical quality was satisfactory; (2) If the tooth type was anterior or pre molar the technical quality was considered satisfactory.

When the number of cases was adjusted, the decision tree presented in Figure 3 (tree B) was generated, showing an accuracy of 62.38%, sensibility of 66.70% and specificity of 41.80% being read as follows: (1) If canal deviation was present and located at the apical third of the root, the technical quality of endodontic retreatment was unsatisfactory; (2) If

canal deviation was absent, root curvature was severe and the tooth was located in mandible, the technical quality was unsatisfactory, but if the tooth was located in maxilla, the technical quality was satisfactory; (3) If root curvature was moderate and a separated instrument was present, the technical quality was unsatisfactory; (4) The classification straight root curvature immediately predicted that technical quality was satisfactory.

After grouping RCM and excluding the attributes related to demographic and medical data, the decision tree (Figure 4 – tree C) presented accuracy of 66.66%, sensibility of 69.60% and specificity of 55.40%. This decision tree can be read as follows: (1) If RCM was altered, the technical quality was unsatisfactory; (2) If RCM was respected and root curvature was severe the technical quality was unsatisfactory, but if root curvature was moderate, the technical quality was satisfactory; (3) If RCM was respected, the root curvature was straight and root resorption was present the technical quality was unsatisfactory. When root resorption was absent, the technical quality was satisfactory.

Regarding the binary class periapical healing, J48 classifier generated one decision tree (Figure 5 – tree D), presenting accuracy of 79.66%, sensibility of 84.50% and specificity of 46.70%. This decision tree can be read as follows: (1) If coronal sealing was absent or type of dental restoration was temporary by the time of follow-up visit, periapical healing was classified as healed. (2). If the type of dental restoration was definitive and the technical quality of endodontic retreatment was satisfactory, periapical healing was classified as healed. (3) If the type of dental restoration at the follow-up visit was definitive, technical quality of endodontic retreatment was unsatisfactory, signal/symptom were present by the time of diagnosis and the primary endodontic treatment presented unsatisfactory root fillings, periapical healing was classified as failure; but if root filling quality of the primary endodontic treatment was satisfactory, periapical healing was classified as healed; (4) If the type of dental restoration at the follow-up visit was definitive, technical quality of endodontic retreatment was unsatisfactory, signals/symptoms were absent and the periapical lesion area was greater than 4 mm^2 by the time of diagnostic, periapical healing was classified as failure; but if periapical lesion area was lower than 4 mm^2, periapical healing was classified as healed.

Conventional Statistics results

a) Factors affecting root canal retreatment technical quality

Fisher exact test revealed that the independent variables tooth type ($p < 0.001$), root curvature ($p < 0.001$), procedures accidents ($p = 0.002$), canal deviation location ($p < 0.001$),

extruded filling material (p = 0.005) and root canal morphology (p = 0.002) had a significant association with the technical quality of endodontic retreatment (Table 5).

The stepwise regression model identified root curvature (p < 0.001), root canal morphology (p = 0.038) to be significantly predictive of the outcome technical quality of root canal retreatment at a 0.05 level of significance, while the variable extruded filling material presented a borderline nonsignificant association (p = 0.061) with this main outcome (Table 6).

b) Factors affecting periapical healing

Fisher exact test showed that two independent variables, tooth group (p = 0.015) and root resorption (p = 0.024) were significantly associated with the main outcome periapical healing. In addition, Mann-Whitney U test revealed that periapical lesion area had a significant association (p = 0.018) with this outcome, while periapical index presented a borderline nonsignificant association (p = 0.075). Similarly, age range (p = 0.079) root filling level after retreatment (p = 0.098) and technical quality of endodontic retreatment (p = 0.080) showed a borderline nonsignificant association with periapical healing (Table 7).

Discussion

Non-surgical root canal retreatment presents higher technical complexity and poor prognosis compared to primary endodontic treatment (Imura *et al*. 2007, American Association of Endodontists, 2005). Even though, up to date, no study deeply assessed factors affecting the feasibility of achieving technical quality in secondary endodontic treatment. Moreover, only few studies (Sjögren *et al.* 1990, Imura *et al*. 2007, Ng *et al.* 2011a) considered the fundamental differences between these treatment modalities when evaluated predictive factors affecting periapical healing. Due to these reasons, this investigation performed a more detailed analysis, focusing on non-surgical retreatment.

Root canal retreatment showed satisfactory technical quality in 65.20% of the current study sample. A recent meta-analysis that included studies evaluating primary endodontic treatment performed by undergraduate students showed 48% of acceptable technical outcomes, based on both length and density of root fillings (Ribeiro *et al.* 2017). The higher technical quality rate presented herein, in spite of the technical complexity of root canal retreatment, may be related to the operator level of experience, since the present investigation assessed treatments performed by postgraduate students. Moreover, technologies such as nickel-titanium files, electronic apex locator, ultrasonics and operative

microscope were available for the retreatments performed in this study, while the use of mechanized instrumentation served as an exclusion criteria for the referred meta-analysis. Accordingly, Donnelly *et al.* (2017) showed that the use of technologies improve the technical standards of endodontic treatment.

Root filling level between 0 and 2 mm from root apex was not achieved in most of the samples classified as technically unsatisfactory. Similarly, other studies point out that under or overfilling are the most common causes of unsatisfactory technical quality of endodontic treatment (Chueh *et al.* 2003, Ribeiro *et al.* 2017). Procedures accidents management had a satisfactory outcome in 53.84% of this study sample. This data could not be compared since it is omitted in other studies.

Periapical healing was observed in 80.50% of the patients that attended to follow-up visits. This outcome is similar to the observed in another study evaluating endodontic retreatments performed by postgraduate students, which showed complete periapical healing in 80.00% of the cases (Ng *et al.* 2011a). Another investigation (Imura *et al.* 2007), in which non-surgical retreatment was performed by one specialist, also presented equivalent results (85.90% of teeth were healed at the recall period).

To complement statistical descriptive analysis, Knowledge Discovery in Database (KDD) was employed in conjunction with conventional statistical methods, aiming to evaluate features associated to endodontic retreatment technical quality and periapical healing (Fayyad *et al.* 1996). KDD is a process that includes data selection, preprocessing, data transformation to translation of raw data into relevant information (Vianna *et al.* 2010). Within this context, data mining can be defined as an essential step of KDD in which intelligent methods are applied to extract data patterns (Han *et al.* 2012a)

The induction of decision trees was preferred amongst a number of data mining functionalities because this analysis can handle multidimensional data. Moreover, the representation of acquired knowledge in tree form is intuitive and generally easy to assimilate, since it consists in a visual and analytical decision support tool (Chen *et al.* 2011, Han *et al.* 2012b). In this regard, decision tree induction algorithms have been used for classification in several application areas, such as manufacturing and production, financial analysis, astronomy, molecular biology and medicine (Milosevic *et al.* 2003, Vianna *et al.* 2010, Han *et al.* 2012b, Ferreira *et al.* 2012). Although yet little explored in the dentistry field, some recent studies using decision trees classifiers provided useful knowledge that can aid in the diagnosis of periapical cyst (Pitcher *et al*. 2017) and in the clinical decision making regarding the need of further intervention in persistent apical periodontitis (Yu *et al.* 2014).

For the analysis performed herein, J48 classifier - a Weka's implementation of an improved version of landmark C4.5 decision tree program - was used to generate decision trees. J48 algorithm defines the possible decision tree by means of a hill-climbing search based on the statistical property measure called information gain. Information gain measure defines how well a given attribute separates the training examples according to their class attribute and selects the candidate attribute at each step of the tree. An advantage of such method is that it automatically handles nonlinearity and interactions. Output includes a "decision tree" which is immediately useful for prediction (Quinlan 1993, Milosevic *et al.* 2003). The possibility of decision trees generating additional knowledge is related to differences regarding methods of data analysis. Instead of assuming a data model, which is essential to the conventional statistical methods, these algorithms classifiers attempt to work directly on the data without making any assumption about them. Moreover, instead of predicting risk factors, decision trees provide frequent patterns associated to an outcome (Leung 2009).

In the current study, patterns that associate the attributes root curvature, RCM and root resorption to predict technical quality of endodontic retreatment provided further information to that one assessed by conventional statistics. While the absence of root canal morphological alterations was associated with unsatisfactory technical quality by both univariate and multivariate regression analysis, the decision tree C (Figure 4) showed that severe root curvatures predict unsatisfactory technical quality of endodontic retreatment, even in that cases in which RCM was respected in the primary endodontic treatment. Accordingly, Tang *et al.* (2011) demonstrated that root curvatures might hamper working length accessibility, and Eleftheriadis & Lambrianidis (2005) showed that severe curvature is one of the most significant factors affecting the incidence of procedure errors, such as ledges and root perforations.

Data mining also suggest that the root curvatures appear to affect technical quality of non-surgical retreatment mainly in molars, as demonstrated in decision tree A (Figure 2). In this regard, Donnelly *et al.* (2017) suggested that endodontic treatment in single-rooted teeth are more likely to show acceptable technical outcomes than in multi-rooted teeth, which may be related to anatomy complexity and higher frequency of moderate and severe root curvature in molars (Cheung & Chang 2003). In agreement, Fisher exact test showed a significant association between tooth type and technical quality of endodontic retreatment.

The association of root resorption with unsatisfactory technical quality was not assessed by regression methods. Nevertheless, in such cases in which respected RCM, straight root and root resorption were simultaneously observed, this attribute appeared to be

relevant in data mining analysis. It is possible that the absence of root curvatures and root canal morphological alterations promote easier accessibility to the root canal apical third, which together with the presence of apical resorption have favored root filling extrusion, thus affecting endodontic retreatment technical quality. Root resorption may alter the shape and position of the apical foramen and apical constriction, increasing the chance of overinstrumentation and subsequent overfilling of the root canal (Malueg *et al.* 1996)

Data mining also indicated that endodontic retreatment technical quality in root canals presenting severe curvatures was easier to be achieved in that teeth located in the maxilla than in the ones located in the mandible. This outcome was not detectable by conventional statistical analysis. Differently from J48 classifier, Fisher exact test evaluated the effect of tooth location considering the entire sample. On the other hand, the decision tree revealed that a particular pattern - that includes the absence of canal deviation, the occurrence of severe root curvatures and the tooth location on the mandible - tends to result in unsatisfactory technical quality of root canal non-surgical retreatment. In agreement, a previous study evaluating primary root canal treatment observed that adequate fillings were more frequently found in maxillary than in mandibular teeth and in straight than in curved root canals (Barrieshi-Nusair *et al.* 2004).

While Fisher exact test showed a significant association between the overall occurrence of procedure accidents and unsatisfactory quality of root canal retreatment, data mining analysis showed more punctual relations. Decision tree B (figure 3) identified an association between unsatisfactory root canal retreatment and a repeated pattern in which separated instruments were present in teeth with moderate root curvature and absent canal deviation. The significance of separated instruments in the technical quality of endodontic retreatment was not confirmed neither by Fisher exact test, nor by multivariate regression analysis. This may be explained by the low number of samples (thirteen) presenting this feature. Another study evaluated the relation between root curvature and separated endodontic instruments, showing that fragments localized before the curvature presented higher chances to be bypassed or removed from the root canal than fragments localized inside or beyond the curvature. (Hülsmann & Schinkel, 1999). Moreover, Kosti *et al*. (2011) investigated the effect of root canal curvature on the failure of NiTi files and concluded that fracture were significantly more frequent in curved roots.

Both data mining and Fisher exact test showed that samples presenting root canal deviation in the apical third were more likely to be associated to unsatisfactory technical quality of endodontic retreatment compared to that ones in which deviation from the normal canal path occurred in the middle or cervical thirds of the root. Previous studies (Wilcox &

Swift 1991, Kapalas & Lambrianidis 2000, Eleftheriadis & Lambrianidis 2005) demonstrated that frequency of ledged root canals was significantly greater in molars than in anterior teeth. Mesiobuccal, mesiolingual and distal buccal root canals exhibited a significantly higher ledge prevalence compared to distal and palatal root canals, which was certainly affected by root curvature (Eleftheriadis & Lambrianidis 2005). On the other hand, these studies did not evaluate the feasibility of achieving an adequate instrumentation and obturation in root canals that present deviations in different thirds of the root, which was demonstrated herein.

Together, the results discussed above revealed that technical quality of endodontic retreatment is affected by procedure accidents and that satisfactory outcomes are more prone to be achieved when the errors occur in the middle and coronal third of the root in comparison to that ones affecting the apical third. These data should be considered in the determination of endodontic retreatment technical complexity.

The presence of extruded filling material in the primary endodontic treatment showed a significant association with unsatisfactory technical quality of non-surgical root canal retreatment when analyzed by Fisher exact test, and presented a borderline nonsignificant association in multivariate regression analysis. On the other hand, this attribute was not selected in the decision trees. Probably, the lower number of samples presenting this feature according to the attribute selection in earlier steps of the decision trees had an effect in this outcome. The impact of overfilling occurrence prior to endodontic retreatment was not evaluated by previous studies. According to univariate statistical analysis, it should be considered as a determinant of higher technical complexity of endodontic retreatment. In this regard, Gutiérrez *et al.* (1996), using scanning electron microscopy, found that overinstrumentation of root canals - which undoubtedly favors overfilling - provoked a variety of changes in root canals apical third, consisting of different types of apical cementum perforations and/or the production of zipping. These features might contribute to the difficulties in achieving proper apical stop and hermetic obturation of root canals, thus affecting endodontic retreatment technical quality.

Regarding the prediction of periapical healing, both Mann-Whitney U test and J48 algorithm showed that larger periapical lesion area is associated with failure. This outcome is in line with other investigations that analyzed periapical lesion size as a continuous variable and found significant influence on healing for both primary and secondary endodontic treatment (Chugal *et al.* 2001, Ng *et al.* 2011b). In this study, the area of preoperative periapical lesion appeared to be a more sensitive predictor of periapical healing than PAI.

It has been suggested that larger lesions could reflect cystic transformation or extra-

radicular infections, which would render non-surgical root canal retreatment ineffective (Nair 2006). On the other hand, decision tree D (Figure 5) showed that periapical lesion area is especially relevant for predicting healing when unsatisfactory technical quality of endodontic retreatment is identified. This pattern suggests that periapical lesion size may modify the interactions between intrarradicular infection and host responses. In this regard, small radiolucencies were likely to heal even when ideal technical outcomes were not achieved, whereas microorganism quantities and virulence were sub-critical to sustain the inflammation of the periapex (Nair *et al.* 2005). On the other hand, healing in teeth associated to larger periapical lesions appeared to depend on satisfactory technical quality of endodontic retreatment. Previous investigations showed that microorganism counts (Murad *et al.* 2014) and particular features of microbial diversity (Sundqvist 1976) and host response (Nair 2005) are associated to periapical lesion size. Notwithstanding, further studies are needed to elucidate differences in the biological interactions taking place in the pathogenesis of large periapical lesions.

Considering conventional statistical analysis, the technical quality of root canal non-surgical retreatment showed a borderline nonsignificant association with periapical healing. With regard to the importance of endodontic treatment technical outcomes, previous studies evaluated separately the variables that compound the classification used in the present investigation. Sjögren *et al.* (1990) observed that, in endodontically retreated teeth, the extent of root filling to apex affects treatment success. In agreement, Ng *et al.* (2011a) found a significant association between the apical extent of root filling and failure of both primary and secondary root canal treatment. While overfilling might favor delayed healing - or even treatment failure - caused by a foreign body reaction (Nair *et al.* 1990), underfilling is frequently related to the inability to debride the apical segment of root canal, which may harbor persistent intracanal infection (Nair 2006). Moreover, Sjögren *et al.* (1990) showed that retreated teeth presenting adequate condensed root fillings exhibited higher success rate than teeth presenting inadequately sealed root canals.

As observed in the decision tree D (Figure 5), unsatisfactory root filling quality in the primary endodontic treatment appeared to favor treatment failure. Previous studies revealed that root filling materials constitute substrate layers compatible with the physicochemical surface features of various microorganisms, thus allowing for bacterial adhesion and biofilm formation (Takemura *et al.* 2004, Senges *et al.* 2011). Therefore, besides being harbored within inaccessible areas of root canal system, such as isthmuses and ramifications, microorganisms that survive root canal chemomechanical disinfection are capable to attach obturation materials, which could be favored by poor root fillings. In a study comparing the bacterial flora of standard root canal sample collection with sample retrieved from obturation

materials, Karygianni *et al*. 2015 recovered nine bacterial species solely from the filling materials. The authors emphasized the microbiological importance of additional obturation material sampling in persistent/secondary infections to improve the understanding of the etiology of endodontic infections associated with post-treatment apical periodontitis. These findings, added to the pattern showed herein by data mining, suggest that further investigations are required to evaluate whether root fillings quality of the previous endodontic treatment affects the antimicrobial efficacy of the available protocols used for root canal disinfection in non-surgical retreatment.

In disagreement with Gorni & Gagliani (2004), neither decision tree C (Figure 4) nor Fisher exact test showed a significant association between endodontic retreatment failure and RCM altered in the primary root canal treatment. Differently from the criteria used herein, the authors included cases presenting internal root resorption unsealed by former treatment in the RCM altered group, and the presence of separate files and inadequate levels of instrumentation and filling were enclosed in the RCM respected category. Moreover, the referred investigation observed the impact of preoperative morphological alterations on endodontic retreatment success, but did not assess the technical quality of endodontic retreatment. In this regard, other features related to the technical outcome could have affected healing.

A previous study emphasized that coronal sealing plays a major role in teeth survival following endodontic treatment (Ray & Trope 1995). Moreover, a meta-analysis performed by Gillen *et al*. (2011) revealed that poor clinical outcomes might be expected in that cases showing inadequate root filling or inadequate coronal restoration. On the other hand, neither the decision tree D (Figure 5) nor Fisher exact test found significant association between coronal sealing and periapical healing. These differences can be related to the low number of samples presenting absent coronal restoration in this study. Besides, the possibility of recent losses of coronal sealing might have influenced healing outcome. An *in vitro* study assessed salivary penetration through root fillings as related to time, and found that the amount of salivary penetration should be considered clinically significant only in obturated root canals that have been exposed to the oral cavity for at least 3 months (Magura *et al.* 1991). Unfortunately, the period of absent teeth restoration could not be evaluated through the available data.

The attributes root resorption and tooth type were not selected in decision tree, probably because of the attributes selection determined by J48 algorithm. These variables presented significant association with periapical healing when analyzed by Fisher exact test, in agreement with other studies. Root resorption has been described in the literature as a risk factor for endodontic retreatment failure (Ng *et al.* 2011a). As previously discussed, extrusion of filling materials beyond the apical foramen is more frequently in teeth presenting root

apical resorptions, which should impact periapical healing (Nair *et al.* 1990). Besides, morphological alterations - added to an increased susceptibility to overinstrumentation and overfilling in teeth presenting apical resorption - certainly play a role in preventing satisfactory apical seal, thus favoring leakage in these situations. Within this context, poor adaptation of the filling material to the irregularities of the root canal should enable that substantial amounts of tissue fluid and inflammatory exudates percolate and continue to support growth of microorganisms with proteolytic capacity (Bergenholtz & Spangberg 2004).

With regards to tooth type, anatomical challenges that impact root canal non-surgical retreatment technical quality also increase the difficulties for elimination of root canal infection, which probably contributed to impact periapical healing. Accordingly, Imura *et al.* (2007) and Ng *et al.* (2011a) have also observed lower success rate for endodontic retreatment performed in molars. Differently from these studies, in the present investigation anterior teeth were found to present lower healing rate than premolars (Table 7). This outcome is not in line with the technical quality of endodontic retreatment observed for these teeth type (Table 5), which is probably related to the simultaneous occurrence of other risk factors not assessed by this analysis.

Overall, the results discussed above, confirm that data mining functionalities have potential to contribute to knowledge discovery, providing additional insights on the causes of unsatisfactory technical outcomes and healing failures in root canal non-surgical retreatment. On the other hand, decision trees present limitations that include the possibility of omitting the analysis of important predictors. In this regard, the complementation of data mining analysis by means of conventional statistical analysis was performed. The reduced number of samples that fits in some of the subclasses generated in decision trees could have influenced the lower accuracy in some of the experiments, which should be considered a limitation of this study. Even so, most of the attributes observed in the decision trees were confirmed to be associated or presented a borderline nonsignificant significance with the evaluated outcomes.

Conclusion

The main findings of this study showed that technical quality of endodontic retreatment is affected by several risk factors, including severity of root curvature and altered root canal morphology. The decision trees confirmed the relevance of root curvatures for predicting technical quality, but also suggested that patterns that combine straight root curvature and apical root resorption may prevent satisfactory technical outcomes. The analysis performed herein suggested that the occurrence of procedure accidents is

especially relevant in the apical third of the roots, which should be considered to classify case complexity. Periapical lesion area, tooth type and apical resorption were shown to be significantly associated with endodontic retreatment failure. Moreover, data mining analysis suggested that large periapical lesions, as well as poor root filling quality in the initial endodontic treatment, present mechanisms that are not fully understood with regards to the interaction between intracanal infection and host response, which should be further investigated.

Data mining appeared to be an important and valid approach for the prediction of root canal non-surgical retreatment technical quality and periapical healing, providing additional insights to traditional statistical methods. These technologies should be further explored to contribute with discovery knowledge and to support decision making in the dentistry field.

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Conflict of Interest

The authors have stated explicitly that there were no conflict of interests in connection with this study.

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TABLES

Table 1. Distribution of attributes related to demographic data and medical history (n = 321)

Variables (n)		n (%)
Age (309)	Young	5 (1.61%)
	Adult	231 (74.75%)
	Elderly	73 (23.62%)
	Missing values	12
Sex (318)	Man	84 (26.47%)
	Woman	234 (75.52%)
	Missing values	3
Cardiovascular disease (306)	Absent	284 (89.87%)
	Present	22 (6.96%)
	Missing values	15
Hypertension (306)	Absent	259 (84.64%)
	Present	47 (15.35%)
	Missing values	15
Diabetes (306)	Absent	295 (96.40%)
	Present	11 (3.59%)
	Missing values	15
Smoking habit (306)	Absent	277 (90.52%)
	Present	29 (9.47%)
	Missing values	15

Table 2. Distribution of attributes related to diagnostic (n = 321)

Variables (n)		n (%)	Mean (n/%)
Signal/symptom (245)	Absent	77 (31.42%)	
	Present	168 (68.57%)	-
	Missing values	76	
Tooth type (321)	Anterior	95 (29.59%)	
	Pre molar	89 (27.72%)	-
	Molar	137 (42.67%)	
Tooth location (321)	Maxilla	191 (59.50%)	
	Mandible	130 (40.49%)	-
Level root filling (321)	> 2 mm	220 (68.53%)	
	0-2 mm	92 (28.66%)	-
	Beyond the apex	9 (2.80%)	
Root filling quality (321)	Satisfactory	85 (26.47%)	
	Unsatisfactory	236 (73.52%)	-
Root curvature (321)	Straight	173 (53.89%)	
	Moderate	115 (35.82%)	-
	Severe	33 (10.28%)	
Periapical status (PAI) (321)	1	70 (21.80%)	
	2	47 (14.64%)	
	3	2 (0.62%)	-
	4	103 (32.08%)	
	5	99 (30.84%)	
Periapical lesion area	-	-	5.37 ± 15.08
Root resorption (321)	Absent	305 (95.01%)	
	Present	16 (4.98%)	-
Root resorption location (16)	Cervical	0	
	Middle	0	-
	Apical	16 (100%)	
Canal deviation (321)	Absent	309 (96.26%)	
	Present	12 (3.73%)	-
Canal deviation location (12)	Coronal	2 (16.66%)	
	Middle	3 (25%)	-

	Apical	7 (58.33%)	
Root perforations (321)	Absent	310 (96.57%)	
	Present	11 (3.42%)	-
Root perforations location (11)	Furcation area	3 (27.27%)	
	Coronal	4 (36.36%)	-
	Middle	3 (27.27%)	
	Apical	1 (9.09%)	
Separated instruments (321)	Absent	308 (95.95%)	-
	Present	13 (4.04%)	
Separated instruments location (13)	Coronal	2 (15.38%)	
	Middle	6 (46.15%)	-
	Apical	5 (38.46%)	
Extruded filling material (321)	Absent	313 (97.50%)	
	Present	8 (2.48%)	-
Procedures accidents (321)	Absent	282 (87.85%)	
	Present	39 (12.14%)	-
Root canal morphology (321)	Respected	291 (90.65%)	
	Altered	30 (9.34%)	-

Table 3. Distribution of attributes from endodontic retreatment characteristics (n=321)

Variables (n)		**n (%)**
Level of root filling after retreatment (321)	> 2 mm	51 (15.88%)
	0-2 mm	211 (65.73%)
	Beyond the apex	59 (18.38%)
Number of appointments (321)	Multiple Appointments	302 (94.08%)
	Single Appointments	19 (5.91%)
Technical outcome of accident management (39)	Satisfactory	21 (53.84%)
	Unsatisfactory	18 (46.15%)
Technical quality of endodontic retreatment (319)	Satisfactory	208 (65.20%)
	Unsatisfactory	111 (34.79%)
	Missing values	2

Table 4. Distribution of attributes related to follow-up visits (n=117)

Variables (n)		n (%)	Mean (sd)
Coronal sealing (111)	Absent	7 (6.30%)	-
	Present	104 (93.69%)	
	Missing values	6	
Type of dental restoration (111)	Definitive	95 (85.58%)	
	Temporary	12 (10.81%)	-
	Absent	4 (3.60%)	
	Missing values	6	
Follow-up period (years) (117)	-	-	4.05 ± 1.42
Periapical healing (117)	Healed	95 (80.50%)	-
	Failure	22 (19.49%)	

Table 5. Prognostic factors associated with the technical quality of endodontic retreatment (n = 321)

Variables		n	Satisfactory technical quality of endodontic retreatment - n(%)	p value
Signal/symptom (245)	Absent	77	48 (62.3%)	**0.566**
	Present	168	112 (66.3%)	
	Missing values	76	-	
Tooth type (321)	Anterior	95	71 (74.7%)	**0.001***
	Pre molar	89	65 (73%)	
	Molar	137	72 (53.3%)	
Tooth location (321)	Maxilla	191	131 (68.6%)	**0.150**
	Mandible	130	77 (60.2%)	
Root curvature (321)	Straight	173	128 (74%)	**<0.001***
	Moderate	115	67 (58.8%)	
	Severe	33	13 (40.6%)	
Root resorption location (321)	Absent	305	200 (66%)	**0.280**
	Apical third	16	8 (50%)	
Canal deviation (321)	Absent	309	203 (66.1%)	**0.119**
	Present	12	5 (41.7%)	
Canal deviation location (12)	Coronal	2	2 (100%)	**<0.001***
	Middle	3	3 (100%)	
	Apical	7	0 (0)	
Root perforations (321)	Absent	310	202 (65.4%)	**0.743**
	Present	11	6 (60%)	
Root perforations location (11)	Furcation area	3	1 (33.3%)	**0.121**
	Coronal	4	2 (66.7%)	
	Middle	3	3 (100%)	
	Apical	1	0 (0)	
Separated instruments (321)	Absent	308	201 (65.7%)	**0.386**
	Present	13	7 (53.8%)	
Separated instruments location (13)	Coronal	2	2 (100%)	**0.235**
	Middle	6	3 (50%)	
	Apical	5	2 (40%)	
Extruded filling material (321)	Absent	313	206 (66.2%)	**0.005***
	Present	8	2 (66.7%)	

Procedures accidents (321)	Absent	282	192 (68.3%)	**0.002***
	Present	39	16 (42.1%)	
Root canal morphology (321)	Respected	291	197 (67.9%)	**0.002***
	Altered	30	11 (37.9%)	
Number of appointments (321)	Multiple Appointments	302	193 (64.3%)	**0.225**
	Single Appointment	19	15 (78.9%)	

*statistical significance.

Table 6. Stepwise foward logistic regression analysis for technical quality of root canal non-surgical retreatment (*n* = 321)

Prognostic factor	OR	95% CI	p Value
Root curvature	.480	.336 - .686	**<.0001**
Root Canal Morphology	.401	.169 - .950	**.038**
Extruded filling material	.302	.086 - 1.055	**.061**

Table 7. Prognostic factors associated with endodontic retreatment periapical healing (n = 117)

Variables		N	Success (n/%)	p Value
Age (114)	Young	1	1 (100%)	**0.079**
	Adult	84	64 (76.2%)	
	Elderly	29	27 (93.1%)	
	Missing values	3	-	
Sex (116)	Man	34	26 (76.5%)	**0.610**
	Woman	82	67 (81.7%)	
	Missing value	1		
Systemic chronic condition (110)	Absent	47	39 (83%)	**0.631**
	Present	63	49 (77.8%)	
	Missing values	7	-	
Signal/symptom (84)	Absent	21	15 (71.4%)	**0.370**
	Present	63	51 (81%)	
	Missing values	33	-	
Tooth type (117)	Anterior	33	25 (72.7%)	**0.015***
	Pre molar	37	35 (94.6%)	
	Molar	47	35 (74.5%)	
Tooth location (117)	Maxilla	69	56 (81.2%)	**0.816**
	Mandible	48	38 (79.2%)	
Level root filling (117)	> 2 mm	34	28 (82.4%)	**0.916**
	0-2 mm	79	63 (79.7%)	
	Beyond the Apex	4	3 (75%)	
Root filling quality (117)	Satisfactory	40	31 (77.5%)	**0.627**
	Unsatisfactory	77	63 (81.8%)	
Root curvature (117)	Straight	67	53 (79.1%)	**0.552**
	Moderate	35	30 (85.7%)	
	Severe	15	11 (73.3%)	
Periapical status (PAI) (117)	1	16	14 (87.5%)	**0.075**
	2	16	14 (87.5%)	
	3	-	-	
	4	45	39 (87.6%)	
	5	40	27 (67.5%)	
Periapical lesion area		117	-	**0.018*** [a]
Root resorption (117)	Absent	113	93 (82.3%)	**0.024***

	Present	4	1 (25%)	
Canal deviation (117)	Absent	111	90 (81.1%)	**0.336**
	Present	6	4 (66.7%)	
Canal deviation location (6)	Coronal	1	0 (0)	**0.208**
	Middle	1	1 (100%)	
	Apical	4	3 (75%)	
Root perforations (117)	Absent	115	93 (80.9%)	**0.356**
	Present	2	1 (50%)	
Separated instruments (117)	Absent	111	90 (81.1%)	**0.336**
	Present	6	4 (66.7%)	
Separated instruments location (6)	Coronal	1	0 (0)	**0.148**
	Middle	3	2 (66.7%)	
	Apical	2	2 (100%)	
Extruded filling material (116)	Absent	112	91 (81.3%)	**0.101**
	Gutta-percha	1	0 (0)	
	Endodontic sealer	3	3 (100%)	
	Both	-	-	
	Missing	1		
Procedures acidents (117)	Absent	100	82 (82%)	**0.322**
	Present	17	12 (70.6%)	
Root canal morphology (117)	Respected	105	86 (81.9%)	**0.249**
	Altered	12	8 (66.7%)	
Level root filling after retratment (117)	> 2 mm	72	62 (86.1%)	
	0-2 mm	23	15 (65.2%)	**0.098**
	Beyond the apex	22	17 (77.3%)	
Number of appointments (117)	Multiple appointments	108	87 (80.6%)	**0.999**
	Single appointment	9	7 (77.8%)	
Technical outcome of accident management (17)	No	9	7 (77.8%)	**0.620**
	yes	8	5 (62.5%)	
Type of dental restoration (110)	Definitive	94	80 (85.1%)	**0.691**
	Temporary	12	11 (91.7%)	
	Absent	4	3 (75%)	
	Missing values	7	-	

Follow-up period (years)		117	-	**0.444[b]**
Technical quality of endodontic retreatment (115)	Satisfactory	71	62 (87.3%)	**0.080**
	Unsatisfactory	44	32 (72.7%)	
	Missing values	2		

***** statistical significance [a] Mann-Whitney U test [b] t Student test

FIGURES

Figure 1. Flowchart of the study sample

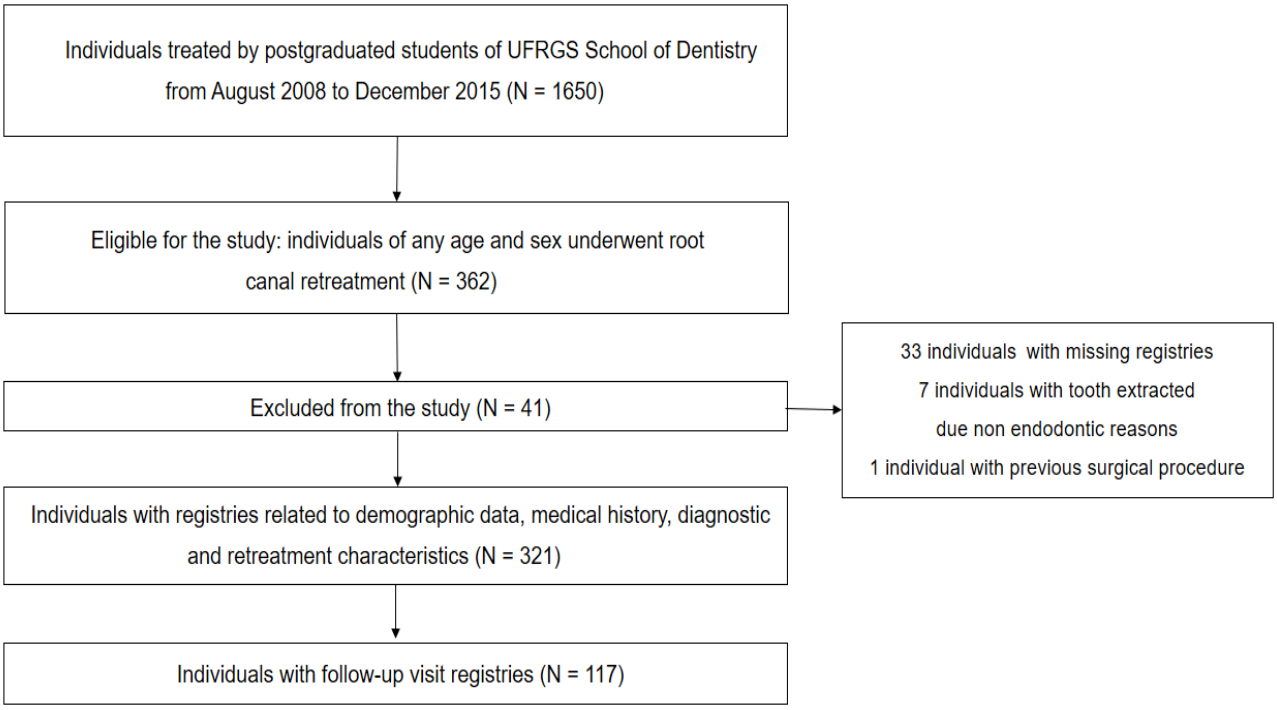


Figure 2. Decision tree A: Prediction technical quality of non-surgical root canal retreatment, including attributes related to demographic data, medical history and diagnostic characteristics

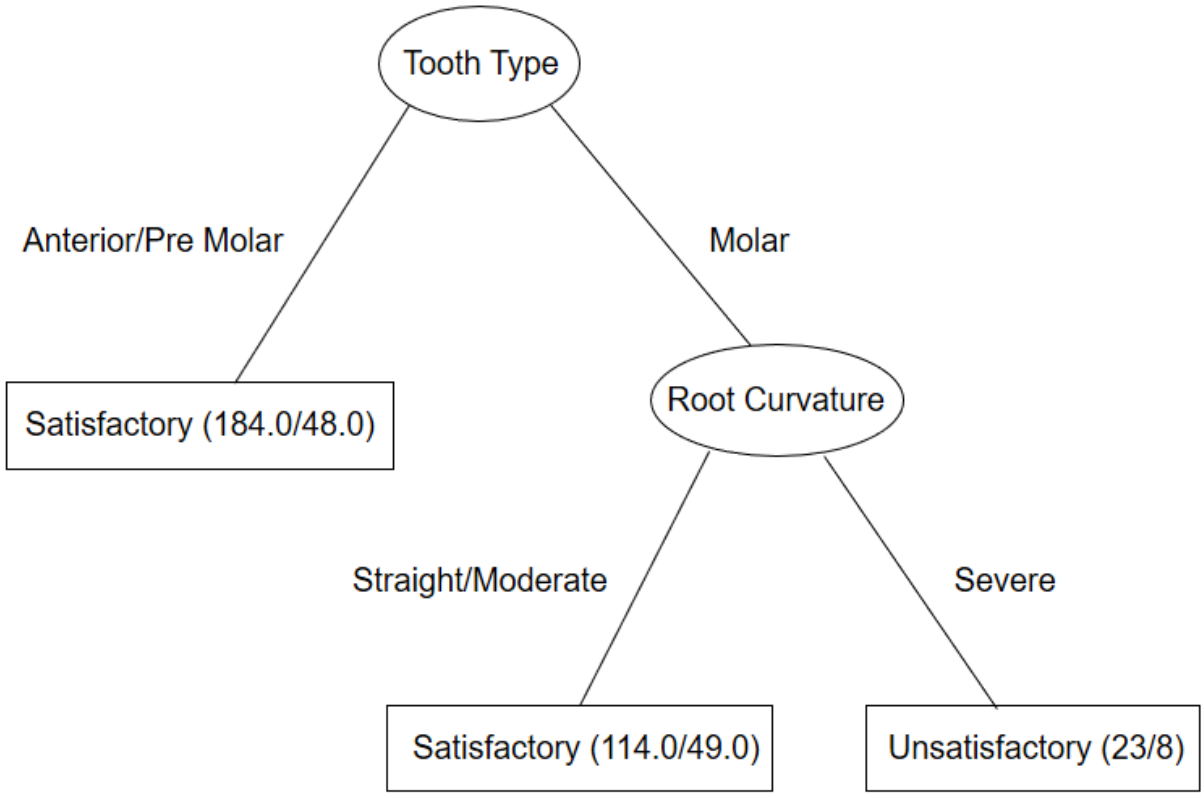


Figure 3. Decision tree B: Prediction technical quality of non-surgical root canal retreatment, including attributes related to diagnostic characteristics

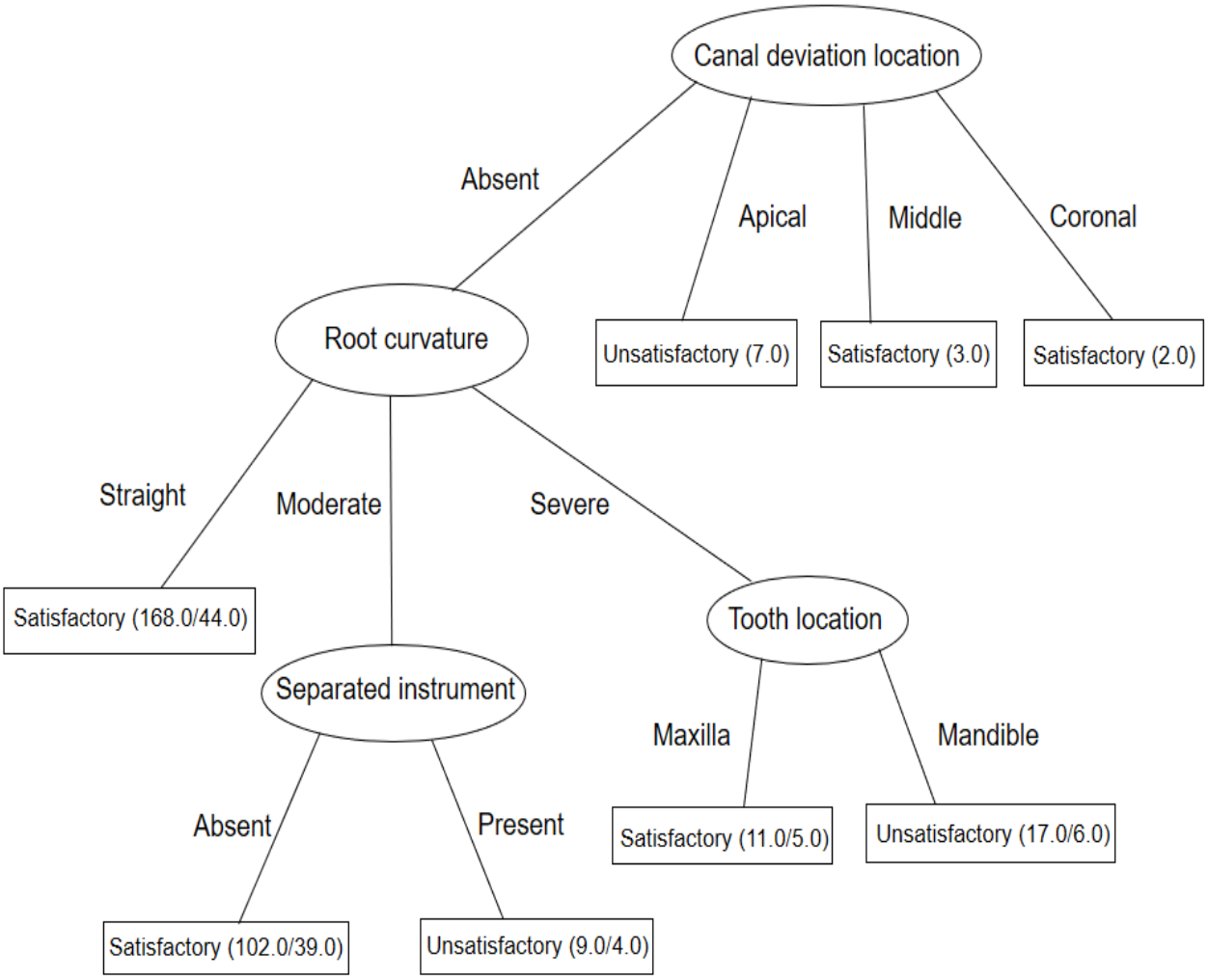


Figure 4. Decision tree C: Prediction technical quality of non-surgical root canal retreatment, including attributes related to demographic data, medical history and diagnostic characteristics

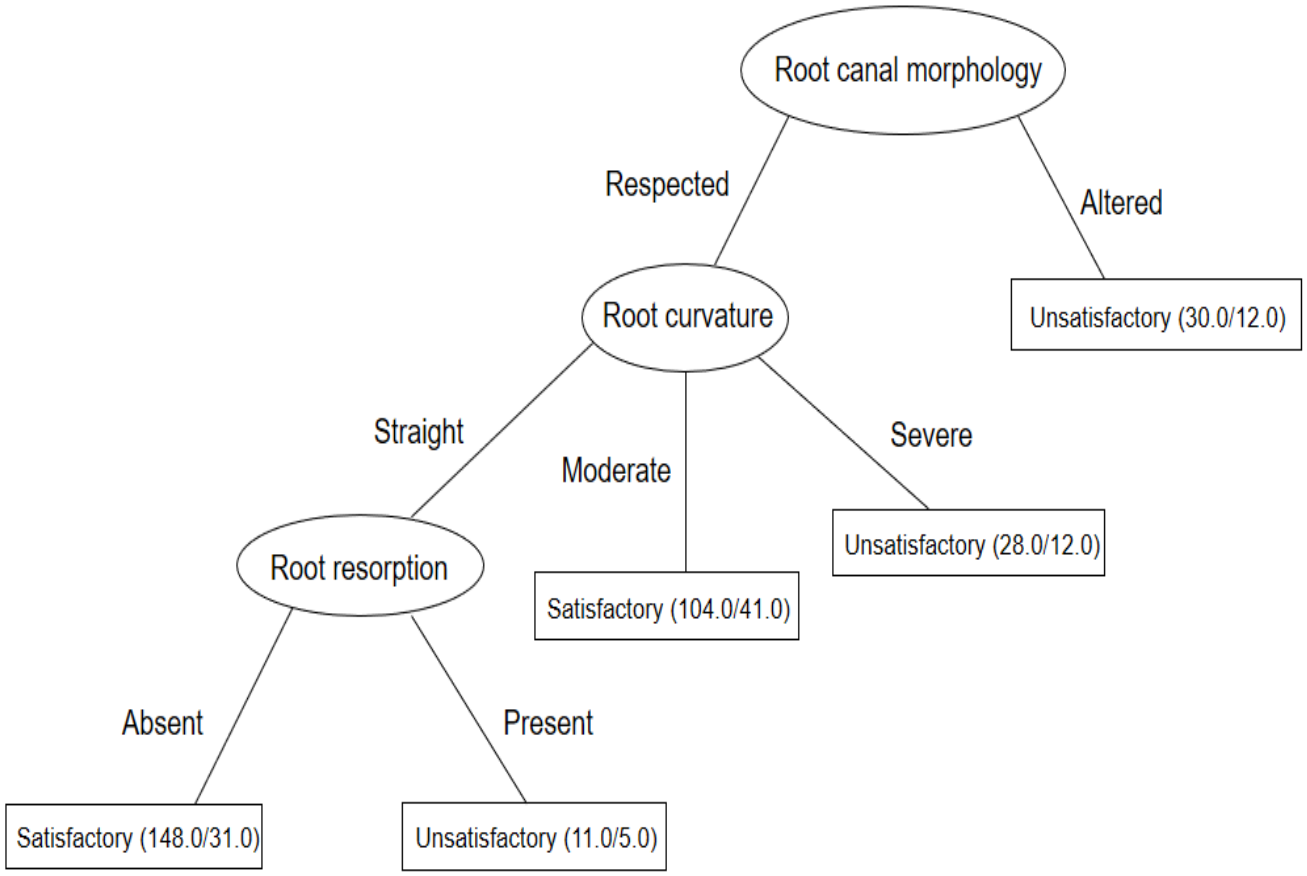
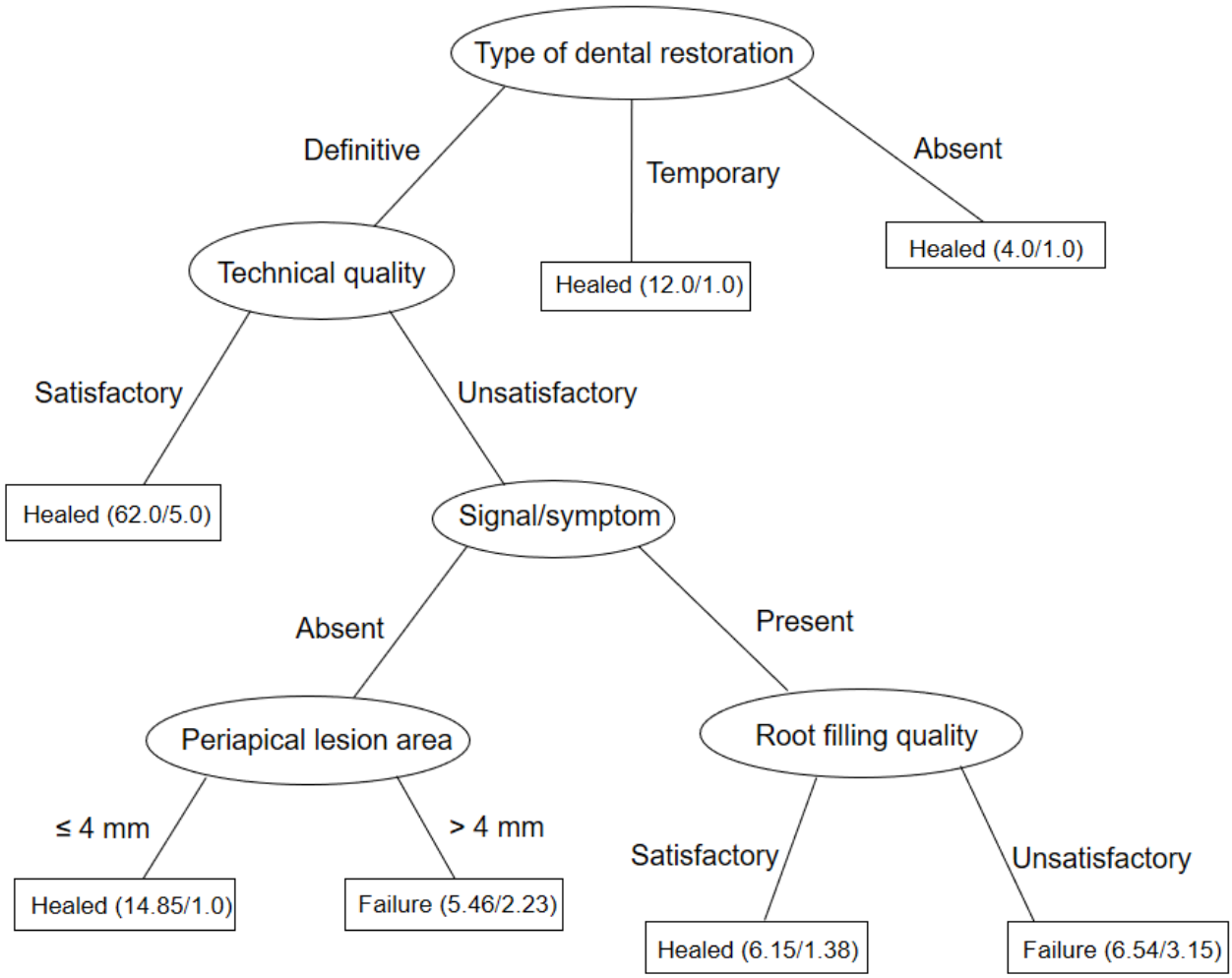


Figure 5. Decision tree D: Prediction periapical healing of non-surgical root canal retreatment, including attributes related to demographic data, medical history, diagnostic and endodontic retreatment characteristics and follow-up data.



5. CONSIDERAÇÕES FINAIS

Os resultados deste estudo mostraram que a qualidade técnica do retratamento endodôntico é afetada por diversos fatores de risco, incluindo curvaturas radiculares severas e alterações na morfologia do canal radicular. As árvores de decisão geradas, além de confirmarem a importância desses fatores, possibilitaram a identificação de padrões até então não explorados para a predição desse desfecho. Dentre estes, padrões que relacionam raízes retas e a presença de reabsorções radiculares apicais com resultados técnicamente insatisfatórios podem ser destacados.

Além disso, os resultados desse estudo sugerem que acidentes de procedimento localizados no terço apical dos canais radiculares representam, em comparação aos acidentes localizados nos terços médio e cervical, um maior desafio para obtenção de qualidade técnica satisfatória. Nesse sentido, a localização do acidente de procedimento deveria ser considerada na classificação de complexidade de casos.

De acordo com os dados da análise estatística, diâmetro da lesão periapical, o grupo dentário e as reabsorções radiculares apicais mostraram-se significativamente associados ao insucesso de retratamentos endodônticos. Já os padrões gerados pela mineração de dados sugerem uma investigação mais aprofundada acerca do potencial de fatores como a extensão de alterações periapicais e a qualidade das obturações do tratamento endodôntico inicial interferirem nos mecanismos de interação entre a infecção intracanal e a resposta do hospedeiro.

De acordo com os presentes resultados, a mineração de dados parece ser uma abordagem importante e válida para a predição da qualidade técnica e do reparo periapical de casos de retratamento endodôntico, apresentando potencial em prover a descoberta de conhecimento complementar ao obtido por meio de análise estatística convencional. Estes recursos deveriam ser melhor explorados na área da Odontologia, visando dar suporte à construção do conhecimento e a tomadas de decisão terapêuticas.

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ANEXO 1 – TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

TERMO DE CONSENTIMENTO LIVRE ESCLARECIDO

Titulo do Projeto: "Q**ualidade técnica e reparo periapical em retratamentos endodônticos: estudo observacional.**"

Pesquisadores:
- Profa. Dra. Roberta Kochenborger Scarparo (Faculdade de Odontologia da Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, RS CPF 979828570-00

-Bruna Signor, aluna do Mestrado em Clínica Odontológica – Endodontia/UFRGS CPF – 018685410-29. Esclarecimentos sobre a pesquisa poderão ser obtidos pelo telefone (54) 9674 6198 ou pelo email b.signor@hotmail.com.

Caro (a) paciente, neste estudo, iremos avaliar os retratamentos endodônticos realizados por alunos do curso de Especialização em Endodontia da UFRGS. O tratamento de canal consiste na remoção do "nervo do dente", isso ocorre por diversos motivos, entre eles, quando este "nervo" está morto ou inflamado. A realização deste tratamento promove uma limpeza e desinfecção dos canais e, após esta etapa, os canais serão obturados e vedados para evitar que o paciente volte a sentir dor e a lesão, que antes existia, seja curada. Porém, em alguns casos, o primeiro tratamento de canal pode não obter o resultado desejado. Isso se deve a vários motivos, como o organismo do paciente, a maneira como foi realizado este tratamento, se após o término do tratamento de canal o dente não foi restaurado ou coberto por uma prótese, entre outros. Nestes casos em que o primeiro tratamento não deu certo, torna-se necessário um segundo tratamento, chamado de retratamento de canal. Para realizar o retratamento, o dentista irá remover a obturação que os canais já apresentavam, limpar, desinfectar e obturar novamente o dente em questão. Com este retratamento é esperado que o paciente não apresente mais sintomas como dor e inchaço.

O objetivo deste trabalho é avaliar os retratamentos que já foram realizados através de um exame feito por um dentista e por radiografias do dente em questão. Além do beneficio que o paciente terá em saber se o seu tratamento teve sucesso, este estudo irá auxiliar mais dentistas a embasarem os seus próximos tratamentos. Nos casos em que o retratamento não obteve sucesso, o paciente será devidamente encaminhado para receber tratamentos de acordo com o caso. A participação neste trabalho não lhe trará riscos no que diz respeito ao atendimento odontológico, uma vez que não serão modificados protocolos e indicações de tratamento, somente avaliação clínica e radiográfica dos procedimentos já realizados. Existe o risco de exposição à radiação ionizante (no momento da tomada de radiografia), porém os pesquisadores estão cientes da importância de itens de proteção, como o avental de chumbo e o protetor de tireóide. Para garantir a confidencialidade dos dados informados, todos os pesquisadores assinarão um termo em que se comprometem em seguir as diretrizes de segurança da informação e mantê-las em sigilo. Você pode se desvincular da pesquisa a qualquer momento, sem que isso traga qualquer prejuízo ao seu atendimento nesta Faculdade.

Eu, _____, fui informado sobre os objetivos, riscos, benefícios desta pesquisa, e concordo em participar de uma avaliação para o desenvolvimento desta pesquisa. Estou ciente de que todos os dados que forneci e que possam identificá-lo serão mantidos em sigilo. Compreendo que a minha única vinculação com a pesquisa será no momento da assinatura deste termo, que foi por/para mim lido, compreendido e todas minhas dúvidas foram esclarecidas pelos pesquisadores. A qualquer momento poderei entrar em contato com a responsável pela pesquisa, Bruna Signor, aluna do Mestrado em Clínica Odontológica – Endodontia/UFRGS, para quaisquer esclarecimentos sobre a mesma, pelo telefone: (54) 9674 6198.

PORTO ALEGRE, _____ DE _____ DE 20_____.

_____ _____

Assinatura do paciente Bruna Signor