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Use of Decision Tree Model for Software Development in the Endodontics Area

Utilização do modelo de árvore de decisão para o desenvolvimento de *software* na área de endodontia

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Abstract. To describe the development process of software to assist dental students and professionals using a decision tree. This is an experimental study with a mixed methodology (qualitative and quantitative) that used professional experience, scientific evidence, and a questionnaire administered to a group of 23 experts(convenience sample) to design the application. Only attributes with more than 60% agreement for diagnosis and indication of clinical procedures related to retreatment were considered endodontic were included. A free collaborative platform was used to develop the decision tree. The study was approved by a Research Ethics Committee. The programming language used was *JavaScript* , the user interfaces were the *ReactNative library* , and the backend was *NodeJS* . The source code was deposited with the National Institute of Industrial Property under number BR512024003192-8 under the Endoretttrademark.Using the decision tree methodology to assist healthcare professionals is an important tool for improving the operational efficiency of healthcare services with an agile and safe approach.

Keywords: Endodontic treatment. Failure. Decision tree.

Resumo. *Este artigo descreve o processo de desenvolvimento de um programa de computador projetado para auxiliar estudantes e profissionais da odontologia por meio do uso de uma árvore de decisão. Trata-se de um estudo experimental com metodologia mista (qualitativa e quantitativa) que utilizou experiência profissional, evidências científicas e um questionário aplicado a um grupo de 23 especialistas (amostra de conveniência) para o projeto do aplicativo. Foram incluídos atributos com taxa de concordância superior a 60% para o diagnóstico e indicação de procedimentos clínicos relacionados ao retratamento endodôntico. Uma plataforma colaborativa gratuita foi utilizada para o desenvolvimento da árvore de decisão. O estudo foi aprovado por um Comitê de Ética em Pesquisa. A linguagem de programação utilizada foi JavaScript; as interfaces de usuário foram criadas utilizando a biblioteca React Native e o backend foi desenvolvido em NodeJS. O código-fonte foi depositado no Instituto Nacional da Propriedade Industrial sob o número BR512024003192-8, sob a marca registrada Endorett. O uso da metodologia de árvore de decisão para apoiar profissionais da saúde é uma ferramenta importante para melhorar a eficiência operacional dos serviços de saúde, com uma abordagem ágil e segura.*

Palavras-chave: *Tratamento endodôntico. Falha. Árvore de decisão.*

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1. Introduction

The failure of endodontic treatment can be influenced by factors ranging from the professional's technical issues to biological limitations. Persistent bacterial contamination, inadequate preparation and filling of the root canal system, the anatomical complexity of the tooth, malocclusion, the quality of the filling material, the technique used, and the presence of fissures or fractures in the root are some factors that may or may not, in combination, contribute to this failure (Sousa et al., 2018).

If initial endodontic therapy fails, the professional may choose some options to preserve the tooth, such as endodontic retreatment or periodontal surgery. However, if tooth preservation is impossible, procedures such as tooth extraction with dental implant rehabilitation may be

indicated, always based on the best scientific evidence and individual patient characteristics (Hori et al., 2021).

Diagnosis and indication for endodontic retreatment also present challenges due to the factors that contributed to the initial treatment failure. Identifying a failure in endodontic treatment can be difficult, as symptoms, such as pain or swelling, can be subtle or nonspecific and can be confused with other dental problems. Furthermore, the patient often presents no immediate complaints, which makes diagnosis even more complicated. Clinical tests, complementary imaging exams, and the professional's experience are necessary for decision-making (Macedo and Neto, 2018).

Endodontic retreatment is indicated in cases of incomplete filling, especially when the filling is more than 2 mm from the radiographic apex and there are signs of periradicular lesions. Other criteria include persistent symptoms such as pain on percussion, fistula, edema, mobility, or difficulty chewing, as well as radiographic findings such as bone rarefactions, increased periodontal space, lack of repair in resorptions, or lesion progression. Endodontic reintervention is also indicated in correctly instrumented but inadequately filled teeth prior to periradicular surgery. However, it is contraindicated when the prognosis is unfavorable, such as in cases of vertical root fracture, crown rupture with periodontal compromise, or excessive wear of the tooth structure (Pereira, 2022).

The presence of radiographic signs, such as periradicular lesions, can often be found in asymptomatic patients. However, clinical signs such as fistula, gingival swelling, and pain demonstrate the need for a thorough evaluation, and it is up to the professional to make the correct diagnosis.

Therefore, complementary exams play a fundamental role in evaluating failures in endodontic treatment, being essential imaging resources for the diagnostic, planning, and treatment stages. However, conventional radiographic images are sometimes insufficient for diagnosis and decision-making, as they may not reveal details of the root anatomy, such as microfractures or the presence of untreated canals. In these cases, computed tomography (CT) offers a more detailed three-dimensional view of the dental and bone structures, allowing the identification of root fissures and the anatomical complexity of the canals that would otherwise be overlooked. It is important to note that these tests are essential to determine the cause of failure and plan appropriate retreatment, ensuring the best possible therapeutic approach (Pereira, 2016).

Radiology in healthcare, in terms of developing innovations to support diagnosis, has gained prominence over the past few decades, and this incorporation of different technologies has transformed the clinical practice of professionals. Among the most promising tools in this context are decision trees, which are computational models that organize a set of structured rules according to the logic of their construction. These tools have assisted healthcare professionals in

making clinical decisions by structuring information in a logical and hierarchical manner (Maia *et al*., 2017).

Decision trees allow healthcare professionals to construct different diagnostic and treatment possibilities based on variables such as patient history, test results, and signs and symptoms, thus suggesting or supporting decision-making. This decision-making can be achieved by combining evidence-based literature, professional experience, and databases with the development of analytical models for pattern recognition and decision-making (Pontes *et al*., 2023; Ribeiro *et al.*, 2024).

Technological tools developed using the decision tree concept are efficient means of building classifiers that predict classes (outcomes) based on attributes of a data set. Therefore, a complex problem is divided into subproblems that can be combined to produce a solution to the complex problem (Maia *et al*., 2017; Lee *et al.,* 2018).

This study aimed to describe the construction of a decision tree as a basis for developing software to assist dental students and professionals in endodontic retreatment, combining exploratory research, scientific literature, and professional experience.

2. Methodology

To develop the decision-making support software for endodontic retreatment, an electronic questionnaire was developed using the REDCap (Research Electronic Data Capture) platform. It included statements related to the perceptions of endodontic specialists with over 10 years of clinical experience regarding relevant aspects (attributes) regarding the degree of importance of clinical and radiographic signs related to the decision-making process for endodontic retreatment. The importance of each attribute was assessed using a five-point Likert scale.

The project was submitted to Plataforma Brasil and approved under number 69208623.8.000.5259. The convenience sample was completed with the participation of 23 specialists, and only those attributes that received more than 60% of the choices were included in the decision tree. The content survey was administered to specialists through an electronic questionnaire using the REDCap platform, consisting of statements about general and specific clinical data of a patient, clinical criteria for pain diagnosis, and radiographic and tomographic criteria of the tooth. The objective of this questionnaire was to establish which attributes the specialists believed to be important for clinical decision-making in cases of endodontic retreatment. For each statement, the specialists indicated the degree of importance of the attribute and provided suggestions and/or considerations about it, based on their clinical experience.

With the analysis of the responses to the completed questionnaires, the authors structured the decision tree sequence based on the principles of the classification method. This method, based

on predictive modeling, reflects a process similar to human experience, using observations to outline a model based on essential characteristics of the phenomenon under study (Garcia, 2003).

The decision tree was constructed on a free-to-use collaborative platform (Creately®), chosen to facilitate information management between researchers and the software development team. The creation flow followed the general sequence of information: user data, radiographic analysis, clinical analysis of the tooth, symptoms, and outcome (Figure 1).

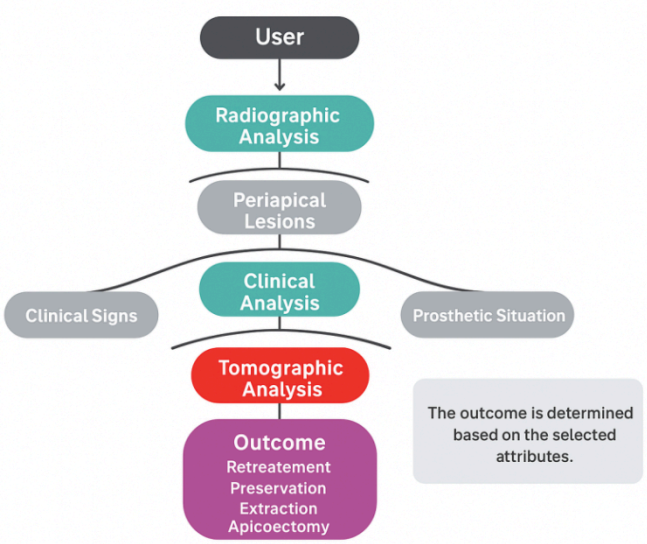

Figure 1 - Flowchart of classified attributes for building the*software* decision tree.

Source: authors' image.

The software development team used the JavaScript programming language, as it is one of the most suitable languages for creating modern applications. It excels in the web development environment and is the primary language used for programming interactive content in browsers. Its compatibility with all modern browsers, such as Google Chrome, Mozilla Firefox, and Microsoft Edge, ensures that the applications developed are widely accessible without the need for additional software or plugins.

The user interfaces (frontend) were built with the React Native library, while the backend (the internal part that stores and processes data) was developed using Node.js, a runtime routine that enables the programming language to run on the server. The MySQL Database Management System was used to store and manage user data and results.

After completion, the software was registered with the National Institute of Industrial Property (INPI) under number BR512024003192-8, and is named Endorett.

3. Results and Discussion

The use of educationally oriented software in the healthcare field has proven to be a promising methodology, promoting greater interactivity and access to knowledge. These tools facilitate learning by providing simulations, videos, podcasts, and virtual learning environments with updated materials, complementing theoretical classes, provided their sources are based on scientific evidence. Specific software applications assist in planning and diagnosis, preparing students for real clinical situations, encouraging autonomous study, and enabling personalized education that respects each student's learning pace.

The present study aimed to present the process of designing and developing software to support clinical decision-making based on a decision tree strategy in the field of Endodontics (Dentistry), describing the steps from attribute identification to the registration phase.

Decision trees are widely used models in artificial intelligence due to their flexibility, robustness, ease of interpretation, and computational efficiency (Garcia, 2003). These models are capable of classifying data and aiding decision-making by segmenting heterogeneous information based on specific attributes (Diniz et al., 2021). In this study, the Endorett software was developed, based on three pillars: professional experience, evidence-based dentistry, and a questionnaire with experts.

The user's journey through the software begins with the entry of radiographic data (presence of lesions), considering that image analysis is one of the main criteria for assessing the success or failure of endodontic treatment. (Figure 2) Studies indicate that the preservation of periapical lesions should occur within four years, with therapeutic success characterized by the absence of clinical and radiographic signs of apical periodontitis or by regression of lesions along with symptom remission (PereirA, 2022). The persistence of lesions, without significant reduction in the expected period, is indicative of failure and may be associated with the presence of chronic inflammatory pathologies, such as periradicular cysts.

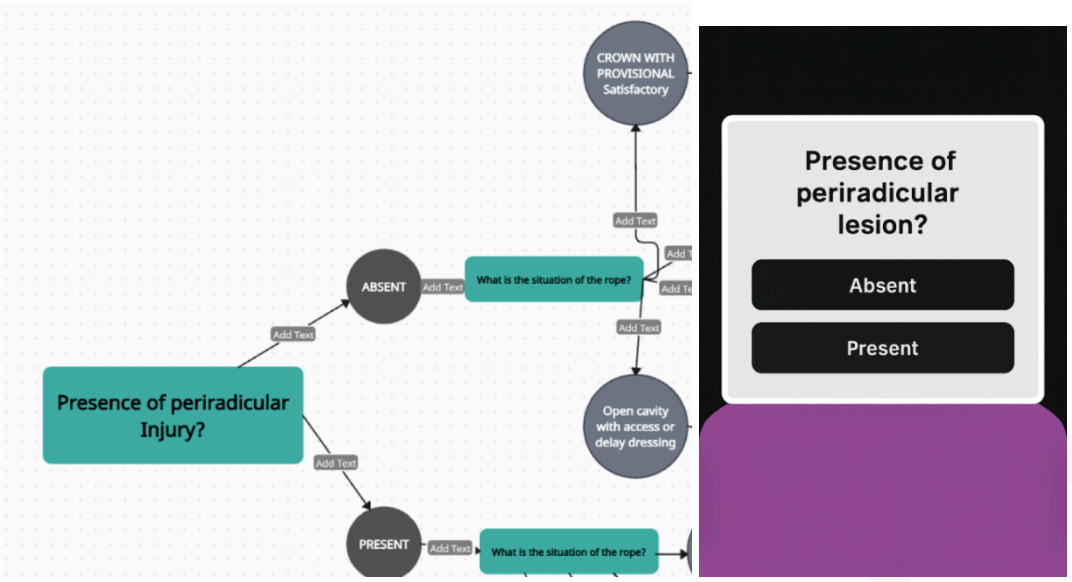

Figure 2 - Partial illustration of the decision tree involving initial attributes and the Endorett application screen for this stage.

Source: authors' image.

The second stage of interaction with the software involves evaluating clinical findings, which are essential for decision-making. Endodontic diagnosis depends on the correlation between radiographic examinations and clinical signs, such as crown condition, periodontal health, occlusal trauma, tooth mobility, fistula presence, and pain (Figure 2). Early identification of signs and symptoms allows for more assertive interventions, avoiding complications resulting from treatment failures (Berutti, 2017).

The clinical decision regarding endodontic retreatment depends on a detailed analysis of technical and biological factors. Difficulties such as obstructed canals, removal of endodontic fillings, and the presence of intraradicular retainers can compromise the success of the procedure. Furthermore, persistent pain after treatment may indicate microbial proliferation, a reaction to irrigating chemicals, or operator technical error (Da Rocha *et al*., 2017; WonG, 2004; Marques, 2020). (Figure 3)

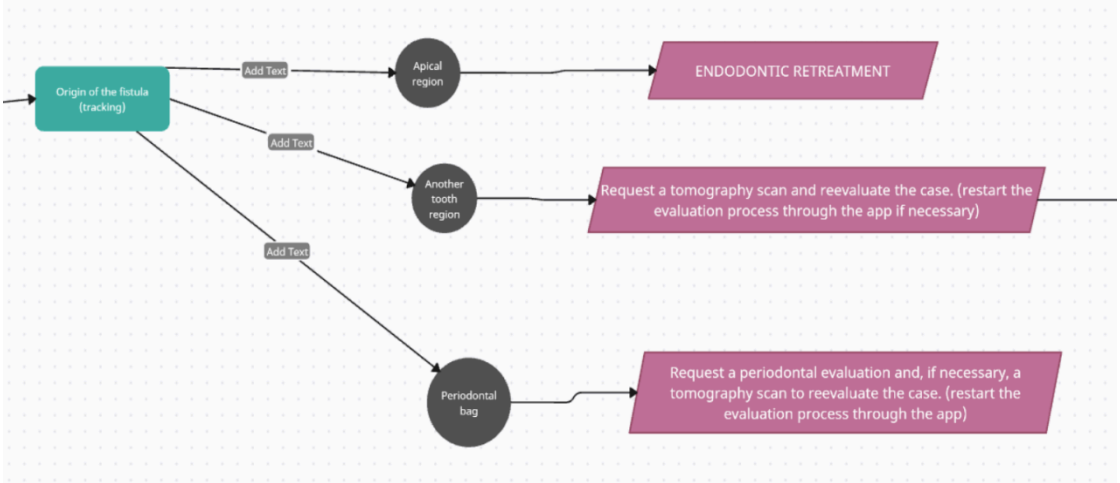

Figure 3 - Partial illustration of the decision tree involving attributes related to clinical aspects (presence of fistula) and possible user guidance outcomes.

Source: authors' image.

The third stage of the process integrates tomographic data, the importance of which is emphasized in the literature for cases of uncertain diagnosis. Cone Beam Computed Tomography (CBCT) allows greater precision in the detection of periapical alterations and the identification of root canals previously overlooked in two-dimensional examinations (Pereira *et al*., 2016; Macedo, 2018). Factors such as apical morphological variations, bone density, and overlapping structures can influence radiographic interpretation, making CBCT an essential resource for conducting treatment (Figure 4).

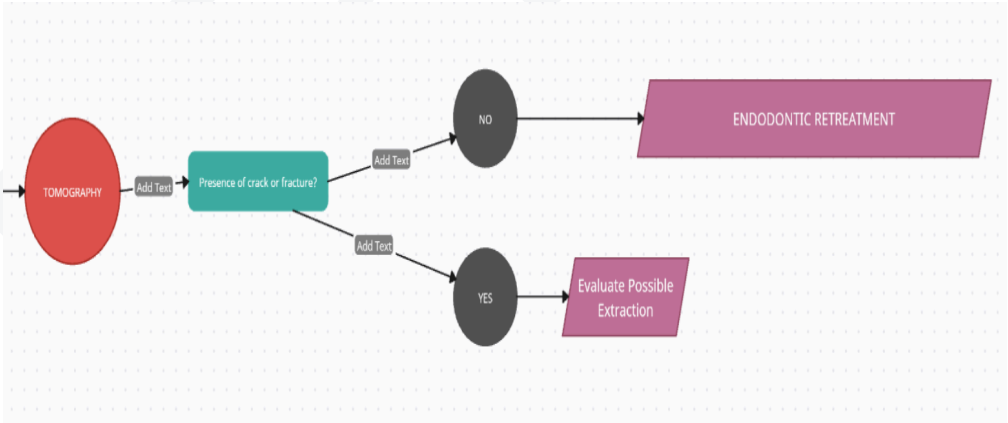

Figure 4 - Partial illustration of the decision tree involving attributes related to tomographic aspects and possible user guidance outcomes.

Source: authors' image.

At the end of the process, the software provides a clinical recommendation based on the data entered, indicating the most appropriate course of action, suggesting additional tests, and offering support for clarifying questions.

Because this is a public institution and with scalability in mind, JavaScript was chosen because it is a high-level, easy-to-learn language with a large developer community, facilitating support and knowledge exchange. Another relevant point is the use of JavaScript in application development, especially with the help of frameworks such as Node.js, which allows JavaScript to be executed on the server side. This enables the creation of systems that share the same codebase for the front-end and back-end, simplifying system maintenance and scalability, in addition to reducing the costs of training teams specialized in different technologies. The widespread adoption of JavaScript in various technology areas, including mobile application development (with frameworks such as ReactNative), games, and even Artificial Intelligence systems, reinforces its versatility and adaptability to different development needs (AbhisheK, 2003; Brito et al., 2018).

The pandemic event that struck the world at the beginning of 2020 spurred the use of information and communication technologies in the fields of health and education. The themes of Telehealth and Digital Health gained prominence, even influencing the implementation of public policies, such as the SUS Digital Program of the Brazilian Ministry of Health (Brazil, 2024).

The application of various technological tools to support professional training processes in healthcare has proven advantageous, facilitating students' understanding and serving as a motivational factor. Researchers also point out that students who frequently use specific technological applications aimed at professional education tend to spend more time studying compared to those who do not use such resources (Silva *et al*, 2024; Golenhofen *et al,* 2019).

The incorporation of technological tools into health-related content provides a more dynamic and immersive environment, enhancing the teaching and training process, which can be used by both undergraduate students and professionals. Authors also emphasize that the development of this type of strategy may influence learning with greater clinical accuracy, as well as the success or failure of endodontic treatment throughout one's professional career (Nobreza *et al*., 2024).

Research also indicates that, in the field of Dentistry, undergraduate students report significant difficulties in learning Endodontics content and often seek complementary studies through different classroom configurations to address their doubts (Tavares *et al*., 2019). Therefore, software developed by universities, grounded in scientific evidence, committed to education, and made available to students and healthcare professionals, represents an advancement in the democratization of such tools.

In addition to software development, the application of artificial intelligence in oral health also holds a promising future, as it can efficiently address, through the analysis of individual and collective determinants, the implementation of optimal public health strategies, cost analyses, effective intervention implementation, and continuing education.

The advancement of digital technologies in healthcare has enabled innovative solutions in dental management, diagnosis, and treatment (Neto *et al*., 2020). Machine learning has emerged as a promising tool for classifying clinical patterns, using algorithms such as artificial neural networks (ANNs) and decision trees (DAs) (Erickson *et al.,* 2017). While ANNs are inspired by neural functioning and have adaptive learning capabilities, DAs segment data intuitively and are widely used for predictive models (Mazzochi, 2024).

Furthermore, the application of fuzzy systems can complement clinical analysis by addressing uncertainties inherent in diagnosis, allowing for a more refined interpretation of variables such as pain intensity or root canal filling quality (Silva, 2023). This qualitative approach contributes to the personalization of treatments, increasing diagnostic accuracy and reducing human error.

The use of decision tree model has the ability to introduce different feature subset and decision rules at various stages of the classification process andit is considered a potential auxiliary tool in the educational process and in the clinical decision-making of professionals (Shoaib *et al*, 2024).

Digital integration enhances the quality of training and brings future professionals closer to innovations in the dental market. Therefore, educational apps play a crucial role in academicand professional developmentduringundergraduatedentistryprograms.

The Endorett software project is currently in the usability and acceptability testing phase, which can be considered a limitation of the research and has, as a future goal, the insertion of artificial intelligence focused on the interface with the end user.

Finally, it is essential to emphasize that, although clinical decision support tools represent a significant advance in endodontics, their implementation must be integrated with professional experience, ensuring that technology acts as an ally in optimizing therapeutic outcomes.

4. Conclusion

The development of decision-tree-based software for Endodontics improves clinical decision-making, assisting students and professionals in choosing the best procedure for teeth that have failed primary endodontic treatment. The applied methodology demonstrates the relevance of decision trees in diagnostic classification and therapeutic selection, organizing clinical, radiographic, and patient history data in a structured manner. The model's transparency and ease of interpretation favor its adoption in dental practice, providing informed and understandable recommendations, thus contributing to the standardization of clinical practices and reducing subjectivity in endodontic retreatment.

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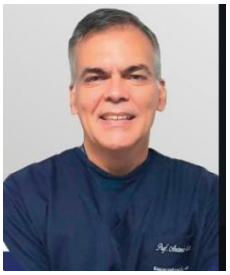

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