

EVALUATION OF MICROLEAKAGE AFTER ENDODONTIC FILLING IN TEETH WITH APICAL WIDENING: A SYSTEMATIC REVIEW

AVALIAÇÃO DA MICROINFILTRAÇÃO APÓS OBTURAÇÃO ENDODÔNTICA EM DENTES COM ALARGAMENTO APICAL: UMA REVISÃO SISTEMÁTICA

EVALUACIÓN DE LA MICROFILTRACIÓN TRAS LA OBTURACIÓN ENDODÓNCICA EN DIENTES CON ENSAYO APICAL: UNA REVISIÓN SISTEMÁTICA



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ABSTRACT

Evaluation of microleakage after endodontic filling in teeth with apical widening: a systematic review Endodontic therapy aims at reducing the number of bacteria and their by products in the root canal system, in addition to promoting healing of the periapical tissue through chemical-mechanical preparation, followed by hermetic filling and coronal sealing. The appropriate degree of apical widening, and its influence on the quality of the endodontic obturation remain controversial. The purpose of this study was to perform a systematic review to investigate the effects of apical widening on apical microleakage after root canal filling. The eligible study design was ex vivo models. Electronic searches were conducted in PubMed/MEDLINE, Scopus, Web of Science, SciELO, and Cochrane Library up to April 2022. Six studies meeting the inclusion criteria were selected for qualitative analysis. The relationship between apical widening and apical infiltration evaluated in the studies revealed that four studies showed $p > 0.05$, showing no statistical difference between apical size and increased infiltration, while two studies showed $p < 0.05$, showing a difference between the groups. According to the results of the studies evaluated in this systematic review apical enlargement alone does not influence an increase in apical infiltration after obturation. However, further randomized clinical trial studies are needed to corroborate this finding.

Keywords: Apical Enlargement. Endodontic Treatment. Microleakage.

RESUMO

Avaliação da microinfiltração após obturação endodôntica em dentes com alargamento apical: uma revisão sistemática A terapia endodôntica visa reduzir o número de bactérias e seus subprodutos no sistema de canais radiculares, além de promover a cicatrização do

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tecido periapical por meio de preparo químico-mecânico, seguido de obturação hermética e selamento coronário. O grau apropriado de alargamento apical e sua influência na qualidade da obturação endodôntica permanecem controversos. O objetivo deste estudo foi realizar uma revisão sistemática para investigar os efeitos do alargamento apical na microinfiltração apical após obturação do canal radicular. O delineamento do estudo elegível foi o de modelos *ex vivo*. Buscas eletrônicas foram conduzidas no PubMed/MEDLINE, Scopus, Web of Science, SciELO e Cochrane Library até abril de 2022. Seis estudos que atenderam aos critérios de inclusão foram selecionados para análise qualitativa. A relação entre alargamento apical e infiltração apical avaliada nos estudos revelou que quatro estudos apresentaram $p > 0,05$, não demonstrando diferença estatística entre o tamanho apical e o aumento da infiltração, enquanto dois estudos apresentaram $p < 0,05$, demonstrando diferença entre os grupos. De acordo com os resultados dos estudos avaliados nesta revisão sistemática, o alargamento apical isoladamente não influencia no aumento da infiltração apical após a obturação. No entanto, mais estudos clínicos randomizados são necessários para corroborar esse achado.

Palavras-chave: Alargamento Apical. Tratamento Endodôntico. Microinfiltração.

RESUMEN

Evaluación de la microfiltración después de la obturación endodóntica en dientes con ensanchamiento apical: una revisión sistemática La terapia endodóntica tiene como objetivo reducir la cantidad de bacterias y sus subproductos en el sistema del conducto radicular, además de promover la cicatrización del tejido periapical a través de la preparación químico-mecánica, seguida de la obturación hermética y el sellado coronal. El grado apropiado de ensanchamiento apical y su influencia en la calidad de la obturación endodóntica siguen siendo controvertidos. El propósito de este estudio fue realizar una revisión sistemática para investigar los efectos del ensanchamiento apical en la microfiltración apical después de la obturación del conducto radicular. El diseño del estudio elegible fueron modelos *ex vivo*. Se realizaron búsquedas electrónicas en PubMed/MEDLINE, Scopus, Web of Science, SciELO y Cochrane Library hasta abril de 2022. Se seleccionaron seis estudios que cumplieron con los criterios de inclusión para el análisis cualitativo. La relación entre el ensanchamiento apical y la infiltración apical evaluada en los estudios reveló que cuatro estudios mostraron un valor de $p > 0,05$, lo que indica que no existe diferencia estadística entre el tamaño apical y el aumento de la infiltración, mientras que dos estudios mostraron un valor de $p < 0,05$, lo que indica una diferencia entre los grupos. Según los resultados de los estudios evaluados en esta revisión sistemática, el ensanchamiento apical por sí solo no influye en el aumento de la infiltración apical tras la obturación. Sin embargo, se necesitan más estudios clínicos aleatorizados para corroborar este hallazgo.

Palabras clave: Agrandamiento Apical. Tratamiento Endodóntico. Microfiltración.

1 INTRODUCTION

Endodontic therapy aims at reducing the amount of bacteria and their by-products in the root canal system, in addition to promoting healing of the periapical tissue through chemical-mechanical preparation, followed by hermetic filling and coronal sealing^{1,2,3}. Adequate root canal preparation is an important step towards successful treatment^{1,2,3}. Moreover, the long-term success of endodontic treatment may be influenced by the accuracy of working length determination.

Different working lengths are proposed. While some studies recommend root canal preparation short of the apical foramen^{4,5,6}, others perform instrumentation at the major foramen or beyond^{7,8,9,10}. In addition, the issue of appropriate degree of apical widening, and its influence on the quality of the endodontic obturation remain controversial^{11,12}.

In cases of necrotic teeth with the presence of periapical lesion, tissue remnants and microorganisms may persist on the dentinal walls of the root canal that were untouched by endodontic instruments. Therefore, proper cleaning and debridement to the apical foramen followed by an appropriate root canal filling may have the potential to prevent possible bacterial reinfection and apical leakage, and consequently, reducing the possibility of endodontic failure^{1,2,13,14}. Conversely, larger preparations of the apical region may also favor the extrusion of filling materials, which may impair the proper sealing of the apical foramen and increase microbial infiltration if the filling is exposed to fluids¹⁵.

There is still no consensus in the literature regarding the effects of apical widening on the microbial infiltration in endodontic filling. Although some studies showed no significant influence of foraminal enlargement in the apical sealing^{16,17,18,19}, other studies reported greater apical microleakage in the groups submitted to foraminal enlargement^{20,21}. Therefore, the purpose of this study was to perform a systematic review to investigate the effects of apical widening on apical microleakage after root canal filling.

2 METHODS

The present study is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist, which was registered at the Open Science Framework (OSF) register (osf.io/wg7ba).

Eligibility criteria

The inclusion criterion was *ex vivo* studies that evaluated apical microleakage after root canal filling in teeth submitted to foraminal enlargement. The exclusion criteria were as

follows: (1) studies that did not assess microleakage; (2) absence of a control group without foraminal enlargement; (3) studies whose full text was unavailable for authors. There were no restrictions on the language and date of publication.

The population, intervention, comparison, outcome, and study design (PICOS) strategy was used to address the following question: 'Does apical enlargement influence apical microleakage in teeth after endodontic treatment?' The study population was extracted human or animal teeth submitted to root canal preparation. The intervention was root canal preparation with apical enlargement, while the comparison was root canal preparation without apical enlargement. The outcome was apical microleakage. The eligible study design was *ex vivo* models.

Search Strategy and Information sources

Electronic searches were conducted in PubMed/MEDLINE, Scopus, Web of Science, SciELO, and Cochrane Library up to April 2022. Grey literature was consulted through Google Scholar and manual searches were carried out in the reference list of the included records. The search strategy used a combination of keywords and Medical Subject Heading (MeSH) terms associated with the Boolean operators 'AND' and 'OR' as shown in Table 1.

Study selection

Study selection was performed by 2 independent authors (I.C.F. and G.C.F.) in a two-step procedure. In Step 1, the authors assessed the titles/abstracts of the studies retrieved from the searches. Records were organized alphabetically by title and duplicates were removed manually. Studies with titles and abstracts that met the eligibility criteria were included. For studies with titles and abstracts that provided insufficient information to arrive at a decision, the full texts were downloaded. In Step 2, full text assessment was performed, and studies whose full text fulfilled the eligibility criteria were included. Disagreements were resolved through discussion, and when necessary, a third author (W.L.F.T.) was consulted. Cohen's kappa coefficient for inter-investigator agreement during studies' selection was calculated (Landis & Koch, 1977)²².

Data collection and analyses

Two authors (I.C.F. and G.C.F.) collected the following data: first author's last name, year of publication, experimental model, sample size, instrumentation protocol, root canal filling protocol, and method of analysis. Data of the analyses, such as evaluation methods and the main findings, were also collected. A piloted data extraction form in an excel

spreadsheet was used for data extraction. Subsequently, a third author (W.L.F.T) reviewed the data.

Risk of bias

Two investigators (I.C.F. and G.C.F.) independently assessed the methodological quality of the selected studies according to their levels of evidence, following a modified version of the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Experimental Studies (Yalali et al. 2015, Dos Reis-Prado et al. 2021 e Simões et al. 2022)^{23,24,25}. The items included in the checklist were a clearly stated aim, justification of the sample size, sample randomization, blind treatment allocation, possibility of comparison between controls and treatment groups, baseline equivalence of control and treatment groups, clear root canal preparation protocol, clear root canal filling protocol, measurement method, measurement standardization, and adequate statistical analysis. Each item was scored using a 2-point scale: 0, not reported or reported inadequately; 1, reported and adequate. Doubts and discrepancies between both investigators were discussed to achieve a consensus, and when necessary, a third investigator (W.L.F.T.) was consulted.

Synthesis of results

The included records were evaluated in terms of similarities to determine whether a meta-analysis could be performed. However, quantitative analysis was not performed due to a considerable heterogeneity in the groups as a difference in the type of tooth used, in the instrumentation, in the method and time of evaluation of the infiltration. Thus, a narrative synthesis of the results of included studies was provided instead.

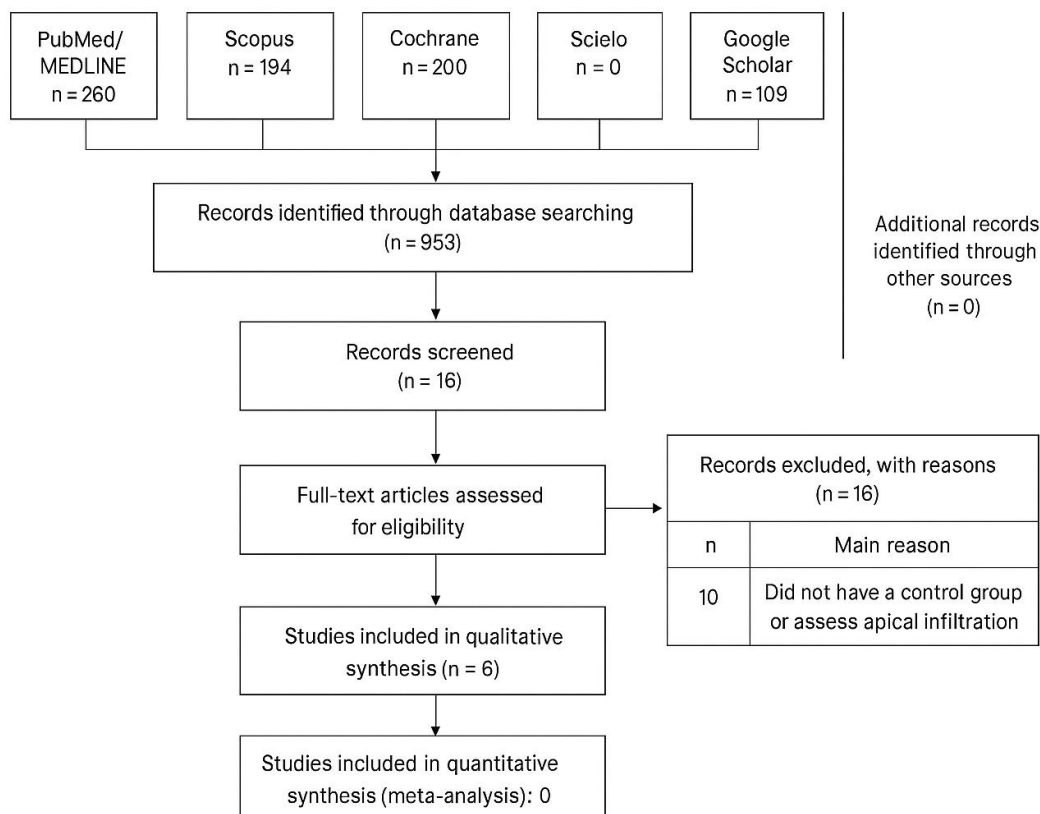
3 RESULTS

Search Results

The selection process of the articles is presented in Figure 1. A total of 953 articles were screened. After the first screening (Step 1), 16 studies were selected for full-text evaluation in which 10 were excluded^{26,27,28,29,30,31,32,33,34,35} by reasons available in Figure 1. Six studies meeting the inclusion criteria^{16,17,18,19,20,21} were selected for qualitative analysis.

Figure 1

The selection process of the articles



Source: The authors.

The assessed Cohen kappa coefficient value for inter-investigator agreement was 0.979 for PubMed, 0.885 for Scopus, 0.960 for the Cochrane Library, 1.000 for the Web of Science and 1.000 for Google Scholar. These values indicated an almost perfect agreement among reviewers according to the scale of Landis and Koch ³⁶.

Characteristics of the included studies

The characteristics of the studies are presented in Table 1. All included studies were *ex vivo*. Four studies were performed on human front tooth^{16,17,20,21}, two on incisors^{18,19}. Four studies used a working length of 1 mm short of the foramen^{17,18,19,20}, while one study¹⁶ kept it 0.5 mm short of the foramen and another carried out two working lengths, 1 mm short and 1 mm beyond the foramen²¹.

Table 1

The characteristics of the studies

| Author/year | Study design | Experimental model | N | Groups | Root canal preparation protocol | Root canal filling protocol | Analysis and Infiltration method | Dye | Analysis period | Statistical difference |
|---------------------------|--------------|--------------------|-------|------------------------|---|--|---------------------------------------|-------------------|--|------------------------|
| Fabra-Campos 1993 | Ex vivo | human front tooth | n= 43 | 0,5 short the foramen | G1 e G2 K25-K50 | G1= Thermanfil, G2= lateral condensation | Infiltration in the apical portion | Ink | 48h | P < 0,4 |
| Yared and Bou Dagher 1994 | Ex vivo | human front tooth | n= 60 | 1 mm short the foramen | G1=K25, G2=K40 | vertical condensation | Fluid infiltration - applied pressure | Fluorescein 0.2% | 1,5 e 6 h, 1 day, 4 days e 1, 2, 4, 8, 12, 16 e 24 weeks | P < 0,005 |
| Gomes et al. 2008 | Ex vivo | human front tooth | n= 27 | | G1=K40, G2=K55, G3=K55 | lateral condensation | Infiltration in the apical portion | Rhodamine B | 7 days | P < 0,05 |
| Souza et al. 2010 | Ex vivo | human front tooth | n= 38 | 1 mm short the foramen | G1=k (1+4), G2=K(1+4) (+3), G3=k(1+4), G4=k (1+4) | lateral condensation | Infiltration in the apical portion | Methylene blue | 72h | P > 0,05 |
| Laslami et al. 2018 | Ex vivo | human incisors | n= 50 | 1 mm short the foramen | G1=#20, G2=#30, G3=#50, G4= CONTR OL+, G5=CONTROL - | lateral condensation | Infiltration in the apical portion | Methylene blue 1% | 48h | P > 0,05 |
| Saluja et al. 2020 | Ex vivo | human incisors | n= 90 | 1 mm short the foramen | G1=#20, G2=#30, G3=#50 | lateral condensation | Infiltration in the apical portion | Methylene blue 1% | 48h | P > 0,05 |

Source: The authors.

Regarding the instrumentation technique used, four studies^{16,17,20,21} performed the technique with hand files, one study used the ProTaper rotary system¹⁸, while another used the Hyflex system¹⁹.

Regarding the obturation technique used, four studies performed lateral condensation^{17,18,19,21}, another study performed vertical condensation²⁰ and one study performed thermafill technique¹⁶.

Immersion time in the infiltration test

The evaluation time of the studies can also be seen in Table 1. Two studies used the infiltration method with 1% methylene blue for a period of 48 hours^{18,19}. One study used methylene blue for a period of 48 hours¹⁷ and other used ink for a period of 72 hours¹⁶. While one study used the Rhodamine B infiltration method for a period of 7 days²¹, another study used the 0.2% fluorescein for a period of 24 weeks²⁰.

Correlation between apical preparation size and infiltration

The relationship between apical widening and apical infiltration evaluated in the studies revealed that four studies^{16,17,18,19} showed $p > 0.05$, showing no statistical difference between apical size and increased infiltration, while two studies^{20,21} showed $p < 0.05$, showing a difference between the groups.

Synthesis of results

Due to variations between studies, mainly in the study methodology, type of tooth used, instrumentation technique, time and method of infiltration assessment, the meta-analysis was not performed. Instead, a qualitative summary was provided.

Risk-of-bias assessment within ex vivo

The critical assessment of the included studies is presented in Table 2 and Figure 2. To assess the risk of bias in ex vivo studies, the JBI tool was used (Table 2, Figure 2). All records showed a clearly stated objective, comparability between control and treatment groups, baseline equivalence between groups, standardization of measures, reliable outcome assessment. Low risk of bias was observed in the clarity of the description of the type of filling used and adequate statistical. However, a high risk of bias was found only for specific items, such as sample randomization and blinded evaluation of results.

Table 2

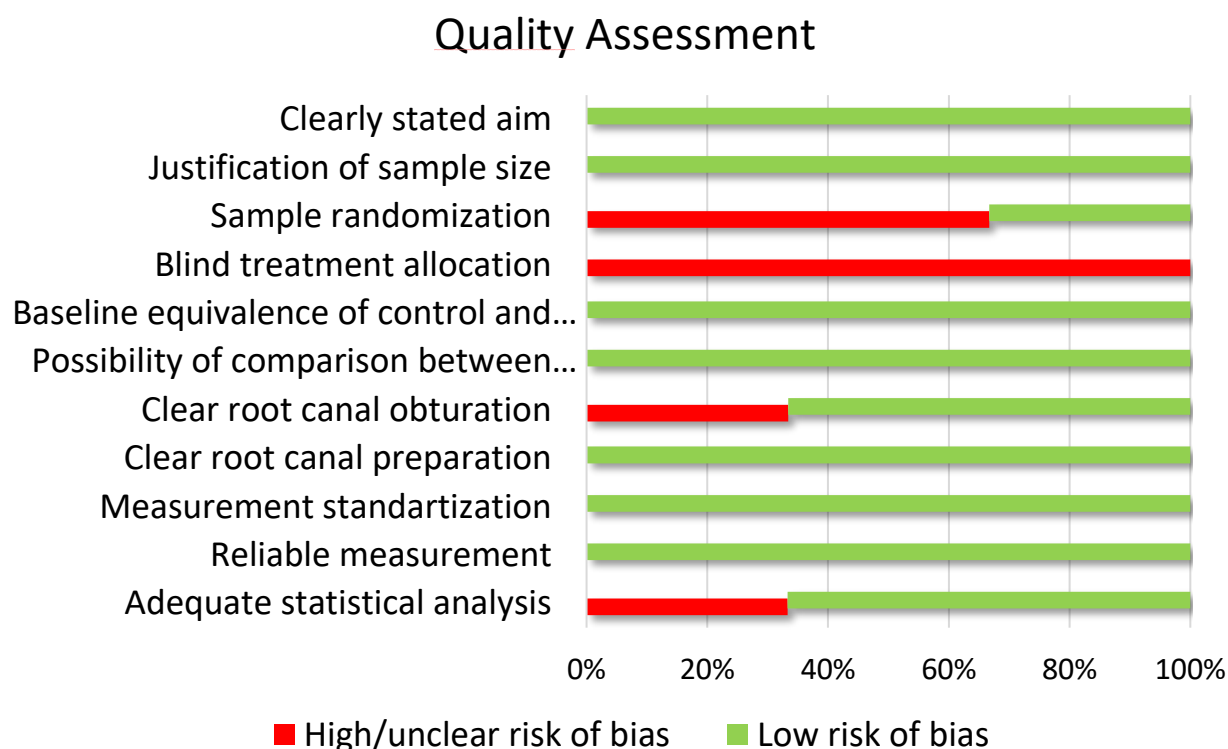
The critical assessment of the included studies

| Quality criteria | Was the aim of the study clearly stated? | Was the sample size justified? | Was the assignment to treatment groups truly random? | Were those assessing the outcomes blind to the treatment allocation? | Were control and treatment groups comparable at entry? | Were groups treated identically other than for the named interventions? | Was root canal preparation clearly described? | Was root canal obturation clearly described? | Were outcomes measured in the same way for all groups? | Were outcomes measured in a reliable way? | Was appropriate statistical analysis used? | Total score |
|-------------------|--|--------------------------------|--|--|--|---|---|--|--|---|--|-------------|
| Fabra-Campos 199 | 1 1 | 1 1 | 0 0 | 0 0 | 1 1 | 1 1 | 1 1 | 1 1 | 1 1 | 1 1 | 1 1 | 9 9 |
| Yared 1994 | 1 1 | 1 1 | 0 0 | 0 0 | 1 1 | 1 1 | 1 1 | 1 1 | 1 1 | 1 1 | 0 0 | 8 8 |
| Gomes et al. 2008 | 1 1 | 1 1 | 0 0 | 0 0 | 1 1 | 1 1 | 1 1 | 1 1 | 1 1 | 1 1 | 1 1 | 9 9 |
| Souza 2010 | 1 1 | 1 1 | 0 0 | 0 0 | 1 1 | 1 1 | 1 1 | 1 1 | 1 1 | 1 1 | 1 1 | 9 9 |
| Laslami 2018 | 1 1 | 1 1 | 1 1 | 0 0 | 1 1 | 1 1 | 1 1 | 0 0 | 1 1 | 1 1 | 0 0 | 8 8 |
| Saluja 2020 | 1 1 | 1 1 | 1 1 | 0 0 | 1 1 | 1 1 | 1 1 | 0 0 | 1 1 | 1 1 | 1 1 | 9 9 |

Source: The authors.

Figure 2

Quality assessment



Source: The authors.

4 DISCUSSION

The causes of endodontic treatment failure are related, among other factors, to the presence of bacteria, inadequate filling and infiltration in the coronary and apical region. It is essential for the absence of infection in the root canals that the filling allows a hermetic sealing of the root canal, both in the apical and in the cervical region, avoiding new infiltrations and possible reinfections^{1,2,13,14}.

Microbial infiltration can occur due to exposure of the filling material to fluids via both the apical and coronary routes. Inadequate sealing of the coronal restoration allows fluid contamination in the root canal system. If the endodontic filling associated to temporary or definitive restoration does not prevent the infiltration of saliva, the microorganisms will penetrate and colonize the root canals, reaching the periapical tissues, and favoring the emergence or perpetuating the apical pathologies^{36,37,38,39,40}.

In this scenario, the quality of sealing provided by obturation has always attracted the attention of endodontists. An adequate filling does not seem to depend only on the materials and techniques used in this phase of endodontic therapy. One of the variables evaluated has been the preparation of the root canal and what influence this can have on the filling^{1,2,3,13,14,36}.

In the context of the chemical-mechanical preparation of the root canal system, the literature states that the enlargement of the canals promotes a better sealing due to the facilities it provides, such a greater contact between the materials used in the filling to the root canal walls. However, this topic still remains controversial in endodontics^{1,2,3,13,14,36,41}.

In addition, the literature states that the size of the canal preparation also significantly influences the effectiveness of irrigation, especially so that it can reach the apical third, which directly influences the cleaning of the root canal and, consequently, the filling. In this manner, it is important to use instruments of great diameters to clean the walls in this region. The studies evaluated in this systematic review performed apical preparations in the experimental groups that ranged from apical sizes of tip 30 to 55^{16,17,18,19,20,21}.

The experiments by Fabra-Campos (1993) and de Souza et al. (2010) included in the results of this review, evaluated 43 and 38 teeth, respectively. The mechanical preparations were performed with hand files of different apical sizes and the statistical analysis did not show a significant difference between the size of the apical preparations and an increasing infiltration of the filling.

Similar results were also demonstrated by the experiments of Laslami et al. (2018) and Saluja et al. (2022) who evaluated 50 and 90 teeth, respectively. The authors performed apical

widening in their experimental groups, and the apical preparation sizes of the samples varied between 20 and 50. Their results did not show a statistical difference regarding an increase in apical infiltration in the widened teeth in relation to the control group.

In contrast, in the experiments by Gomes et al. (2008), the teeth were randomly divided into 3 groups of 9 specimens each. In the group in which a #40 K file was advanced 1 mm beyond the foramen, there was a higher rate of dye infiltration. Their result showed a statistical difference between the groups with $p < 0.05$.

Yared and Bou Dagher's study also reinforces the result presented by Gomes. In their study, the samples were divided into two groups, with apical sizes of 25 and 40. As a result, in the group of file size 40 there was a tendency for microleakage to increase over time. However, in the file size 25 group, there was no significant difference in microleakage in the last 06 weeks of the experiment.

It is noteworthy that the literature shows great concern with the validity and efficacy of the use of dyes as a method of analyzing the quality of root canal fillings. A clinical study by Oliver and Abbott (2001) showed that dye penetration is a poor indicator to assert that the filling technique or material will indicate the long-term success of endodontic therapy^{17,42}.

Dye penetration should be considered only as an indicator of the sealing potential of the root canal space and can be used to compare techniques under the same laboratory test conditions. Currently, there is a wide variety of root canal preparation techniques, including manual, rotary and reciprocating, which may suggest the possibility of different results when using any of them^{17,43}. In addition, infiltration research has been affected by the lack of standardization of variables, leading to great variability in results and negatively interfering with the correlation between studies^{17,43}.

5 CONCLUSION

According to the results of the studies evaluated in this systematic review apical enlargement alone does not influence an increasing in apical infiltration after obturation. However, further randomized clinical trial studies are needed to corroborate this finding.

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