INTRODUCTION

Success of root canal treatment (RCT) depends on neutralizing infection in the entire root canal system through effective root canal preparation [1]. Determining the apical limit of this preparation has proved to be a matter of continuous debate, from which emerged different approaches to managing the apical segment of the root canal [2]. Apical patency as defined by the American Association of Endodontists is a technique intended to maintain the apical part of the root canal free of debris by repeatedly passing a patency file through the apical foramen [3]. Buchanan [4], who was the first to advocate this technique, described the patency file as “a small flexible K-file which passively moves 0.5-1 mm beyond the apical constriction, without widening it”. He went on to describe the patency technique, specifying that the gauge of the patency file should be smaller in diameter than the apical constriction (the narrowest part of the root canal coronal to the foramen) and recommended using an ISO standardized 0.06, 0.08, or 0.10 instrument [4].

The apical plug technique, on the other hand, limits instrumentation within working length of the root canal without using any patency file, and advocates the creation of a dentinal plug at the apical constriction to serve as a biological barrier [2], preventing the extrusion of remnants, irrigating solution, sealers and thermoplastic gutta-percha [5]. Supporters of this technique assume that the apical constriction is the point at
which the periodontium starts and any instrumentation beyond that is an over-extension that violates the biological integrity and healing of the periapical tissue [2]. Many authors have advocated conserving the soft tissue situated in what is considered the cemental part of the canal (between the apical constriction and major foramen) to promote deposition of newly-formed cementum and improve healing [6, 7]. Histologically, Ricucci and Langeland [8] showed that instrumentation limited to the apical constriction or 1 mm short reduced regional tissue damage, and claimed it would be more favorable to healing.

Adequate cleaning and shaping of the apical area of the root canal system has proved particularly challenging [9, 10]. During root canal instrumentation, pulpal tissue or dentin debris get impacted in the apical region causing canal blockage; a common complication which leads to inadequate root canal preparation due to files losing access to the full working length [11]. This scenario can be avoided if apical patency is maintained during canal instrumentation by introducing the patency file in an alternating manner between shaping files and irrigation steps.

**OBJECTIVES**

For long-term favorable prognosis, choices during the process of RCT should be guided by evidence-based decision-making. Thus, the aim of this review was to evaluate what has been discussed in the literature regarding apical patency in RCT and its influence on treatment outcome.

**MATERIAL AND METHODS**

A search of the literature was conducted via PubMed using the terms (apical patency) OR (patency file). The process of identifying and selecting the studies can be seen in (Figure 1). Articles published before the year 2000 and/or not in English were excluded, as well as case reports and reviews, with the exception of systematic reviews. Any difference in opinion regarding study inclusion was resolved between the reviewers (R.A. and R.B.) through discussion.

**RESULTS**

Of the 183 articles yielded by the search, 32 studies satisfied the inclusion criteria. Data from these studies involving the aim and main findings were obtained (Table 1).

**APICAL PATENCY AND PAIN**

Out of the included 32 studies, 8 discussed the association of apical patency with postoperative pain. Two randomized controlled trials each conducted on at least 300 patients with necrotic teeth and apical periodontitis, found that maintaining apical patency was associated with less postoperative pain compared to leaving the canals non-patent. Although no patients suffered from severe pain during the follow-up period, those in the non-patency group experienced more postoperative pain than patients in the patency group during the first 5 postoperative days [12, 13].

![FIGURE 1. PRISMA flowchart on study selection and inclusion](image-url)
### TABLE 1. A summary of the included studies

| No. | Study                        | Year | Study design         | Sample size | Topic of influence                                      | Findings                                                                 |
|-----|------------------------------|------|----------------------|-------------|---------------------------------------------------------|-------------------------------------------------------------------------|
| 1.  | Camões et al. [5]            | 2009 | In-vitro             | 17 teeth    | Extrusion of NaOCl with and without patency             | Irrespective of maintaining irrigant extrusion occurred with and without maintaining apical patency |
| 2.  | Holland et al. [7]           | 2005 | Animal study         | 40 dog teeth | Periapical healing and apical patency                   | Within the proposed experimental conditions, no apical patency had statistically better results than those with patency |
| 3.  | Ng et al. [9]                | 2011 | Randomized clinical trials | 1093 patients | Periapical healing after root canal treatment          | Achievement of apical patency was found to be one of the factors that improve periapical healing |
| 4.  | Ng et al. [10]               | 2011 | Randomized clinical trials | 1093 patients | Tooth survival after root canal treatment              | Achievement of apical patency was found to be one of the factors that reduced tooth loss |
| 5.  | Arora et al. [11]            | 2016 | Randomized clinical trials | 68 necrotic teeth with apical periodontitis | Postoperative pain                                      | Apical patency had no significant influence on postoperative pain |
| 6.  | Arias et al. [12]            | 2009 | Randomized clinical trials | 300 necrotic teeth with apical periodontitis | Postoperative pain                                      | Apical patency was associated with significantly less postoperative pain |
| 7.  | Yaylali et al. [13]          | 2018 | Randomized clinical trials | 320 necrotic teeth with apical periodontitis | Postoperative pain                                      | Apical patency was associated with significantly less postoperative pain |
| 8.  | Arslan et al. [14]           | 2019 | Randomized clinical trials | 50 necrotic teeth with apical periodontitis | Postoperative pain                                      | Apical patency did not increase the incidence of postoperative pain or flare-up rate in teeth with vital/nonvital pulp |
|     |                              |      |                      |             | Periapical                                              | Apical patency did not affect endodontic treatment outcomes            |
| 9.  | Gang et al. [15]             | 2017 | Randomized clinical trials | 80 teeth    | Postoperative pain                                      | Apical patency did not increase the incidence of postoperative pain |
| 10. | Sharaan and Aboul-Enein [16] | 2012 | Randomized clinical trials | 80 teeth    | Postoperative pain                                      | Apical patency did not increase the incidence of postoperative pain |
| 11. | Abdulrab et al. [17]         | 2018 | Meta-analysis        | 4 Studies   | Postoperative pain                                      | Apical patency did not increase the incidence of postoperative pain |
| 12. | Yaylali et al. [18]          | 2018 | Systematic review    | 5 randomized clinical trials Total of 848 patients | Postoperative pain                                      | Low to moderate evidence indicate that apical patency does not increase the incidence of postoperative pain or flare-up rate in teeth with vital/nonvital pulp |
| 13. | Lopreite et al. [20]         | 2014 | In-vitro             | 40 extracted teeth (single canals) | Canal transportation                                   | There was no significant difference between using manual or rotary instruments to achieve apical patency Both produced some apical foramen deformation |
| 14. | Goldberg and Massone [21]   | 2002 | In-vitro             | 30 human maxillary lateral incisors | Canal transportation                                   | Apical patency did not increase canal transportation in the apical 4 mm |
| 15. | Gonzalez Sanchez et al. [22] | 2010 | In-vitro             | 102 human molars | Canal transportation                                   | No transportation was found when size 10 stainless steel reamers were used for apical patency |
| 16. | Tsesis et al. [23]           | 2008 | Ex-vivo              | 40 extracted molars | Canal transportation Working length | Apical patency did not increase canal transportation in the apical 4 mm Apical patency was not associated with loss of working length |
| 17. | Hasheminia et al. [24]       | 2013 | Ex-vivo              | 70 mandibular first molars | Canal transportation                                   | Patency files significantly decreased both apical transportation and canal straightening |
| No. | Study | Year | Study design | Sample size | Topic of influence | Findings |
|-----|-------|------|--------------|-------------|-----------------|----------|
| 18. | Hasheminia and Ardestani [25] | 2004 | In-vitro | 70 mandibular first molars | Canal transportation | Patency file in conjunction with passive step back techniques significantly reduced apical transportation |
| 19. | Trierveiler Paiva et al. [26] | 2018 | In-vitro | 40 teeth | Regaining apical patency using reciprocating files during retreatment | Reciprocating rotary files were more successful in regaining apical patency in single rooted canals |
| 20. | Negishi et al. [27] | 2005 | In-vivo | 57 patients | Endodontic failure and inaccessible apical constriction | Inaccessibility to the apical constriction increases the risk of root canal treatment failure particularly in teeth with preoperative periodical lesion |
| 21. | Abdelsalam and Hashem [28] | 2020 | In-vitro | 43 mandibular molars | Working length | Apical patency is essential for proper working length determination with apex locators |
| 22. | Lambrianidis et al. [29] | 2006 | In-vitro | 64 single-rooted teeth | Canal apical third removal of intra canal medicaments | Apical patency facilitated removal of calcium hydroxide/chlorhexidine medicaments in the apical third |
| 23. | Vera et al. [30] | 2011 | In-vivo | 40 teeth | Irrigant penetration in the apical third using patency and passive ultrasonic irrigation | Maintaining apical patency and then using passive ultrasonic activation improves the delivery of irrigants into the apical third of root canals |
| 24. | Vera et al. [31] | 2012 | In-vivo | 43 teeth | Apical patency and presence of irrigating solution in the apical 2 mm of large root canals | Significantly more canals had irrigant in the apical 2 mm when apical patency was maintained |
| 25. | Vera et al. [32] | 2012 | In-vivo | 71 teeth | Apical patency and gas bubbles during irrigation | Apical patency significantly leads to minimizing the presence of gas bubbles in the middle and cervical thirds during root canal preparation |
| 26. | Lambrianidis et al. [35] | 2001 | In-vitro | 33 maxillary incisors | Periapical extrusion | Without maintaining apical patency, greater extrusion occurred when the apical constriction remained intact compared to after its enlargement |
| 27. | Kini et al. [37] | 2015 | In-vitro | 50 teeth | Inoculation of periapical tissue with contaminated patency file | NaOCl in the canals prevented the inoculation of periapical tissue with bacteria contaminated patency files |
| 28. | Izu et al. [38] | 2004 | In-vitro | 28 teeth | Inoculation of periapical tissue with contaminated patency file | NaOCl was sufficient to kill microorganisms on the file |
| 29. | Deonizio et al. [41] | 2013 | In-vitro | 40 mandibular incisors | Amount of debris extrusion during retreatment | Apical patency did not influence the amount of extruded filling material during retreatment with Protaper Universal System |
| 30. | Tinaz et al. [42] | 2005 | In-vitro | 52 teeth | Periapical extrusion while manual vs. rotary instrumentation | Apical extrusion exists with apical patency technique whether canals are instrumented using K-files or rotary instrumentation with ProFile .04 taper |
| 31. | Carpenter et al. [44] | 2014 | In-vitro | 86 teeth | Regaining apical patency during retreatment of MTA containing sealer and gutta percha | Gutta percha solvents allowed regaining apical patency when retreatting canals filled with MTA containing sealer and gutta percha |

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The majority of the studies, however, found no significant difference, as far as postoperative pain was concerned, concluding that apical patency was not associated with an increase in the incidence of postoperative pain [11, 14-18]. One randomized controlled clinical trial [11] conducted on necrotic mandibular molars with apical periodontitis found that while postoperative pain scores and number of analgesic doses taken to achieve pain relief were less in the patency group, it was not statistically significant. Maintaining apical patency did not increase postoperative pain whether a single-visit or two-visit RCT procedure was used. However, apical patency significantly reduced pain scores that were observed 24 hours postoperatively [11]. These findings could not be generalized to cases of vital teeth without apical periodontitis, as the trial was limited to necrotic teeth with apical periodontitis. In 2018, a meta-analysis and systematic review of randomized clinical trials exploring the influence of apical patency on pain associated with RCT [17, 18] concluded that the evidence – although of low to moderate quality – suggested that apical patency does not increase the incidence of postoperative pain associated with RCT or flare-up rate in cases of both vital or necrotic teeth.

APICAL PATENCY AND FORAMEN TRANSPORTATION

Transportation of the apical foramen during root canal instrumentation may result in incomplete removal of debris and jeopardize the outcome of the RCT [19]. Lopreite et al. [20] conducted an in-vitro study in 2014 on sound teeth recently extracted for orthodontic reasons, to evaluate preservation of the original shape of the apical foramen when patency is performed using either manual or nickel-titanium rotary instrumentation. The roots were examined at ×100 magnification, photographed, and mapped using image managing software. Using both rotary and manual instrumentation to establish apical patency in single straight canals showed foramen deformation in some, but not the majority of cases [20].

In regards to transportation in the apical 4 mm of curved canals, other in-vitro studies concluded that apical patency was not associated with transportation [21-23] specifically, when a size 08 stainless steel K-Flex file or a size 10 reamer were used. Furthermore, a couple of studies even reported that apical patency reduced the degree of apical transportation and curve straightening [24, 25].

APICAL PATENCY AND ACCURACY OF WORKING LENGTH

It has been reported that a short root canal preparation increases the risk of RCT failure by 5.3 folds, especially in teeth having a periapical lesion [26, 27]. Tsless et al. [23] found that maintaining apical patency did not influence loss of working length in curved canals. Recently, however, a study in 2020, examining the influence of apical patency on the accuracy of two different kinds of apex locators concluded that it is essential for reliable working length determination using apex locators to maintain a patent apex [28].

APICAL PATENCY AND CANAL CLEANLINESS

The primary purpose of apical patency is to ensure that the patent canal is clean apically [22]. As a result of the anatomical complexity of the root canal system, it is not possible to clean the whole surface of the root canal using shaping files alone, which establishes the indispensible role of irrigation in root canal preparation. Using radiopaque solution, an in-vivo study determined whether the use of patency was associated with more irrigating solution in the canal apical third after using passive ultrasonic activation [29]. Canals were irrigated with a radiopaque contrast and apical patency was achieved using a size 10 K-file, extended 1 mm beyond the working length. The digital images revealed there were significantly more patent canals with irrigant in the apical third compared to the non-patent canals. The study concluded that apical patency combined with passive ultrasonic activation enhances the transmission of irrigants into the apical third of root canals [30]. A similar study arrived at the same conclusion in regards to irrigant delivery to the apical area of large root canals [31]. Vera et al. [32] also examined the effect of apical patency on the gas bubbles located within the canal coronal and middle thirds which restrict irrigant flow during canal preparation. Irrigation using sodium hypochlorite (NaOCl) with a contrast medium revealed that maintaining apical patency significantly minimized the gas bubbles in large canals.

The incomplete removal of intracanal medications, such as calcium hydroxide, can adversely affect the properties of some root canal filling materials thus influencing RCT outcome [33]. In-vivo studies reported a statistically significant association between the efficient removal of calcium hydroxide or chlorohexidine and the combined use of patency file and irrigation [29].

APICAL PATENCY AND BIOLOGICAL CONSIDERATIONS

Apical patency creates an open passage to the apical foramen, clear from infection-containing debris (dentin chips or pulp tissue). There are those who view this with concern due to the possibility of bacterial extrusion [34, 35], and its subsequent influence on treatment outcome in the light of studies – although rare – that have reported root canal failure due to bacteria found in the periapical area [36]. Two in-vitro studies explored this possibility and reported that when using a patency file in canals filled with NaOCl, this prevented the inoculation of periapical tissue with bacteria [37, 38]. How-
ever, in these studies, the files were contaminated with only *Streptococcus sanguis* which does not reflect the diverse bacterial population found in root canals undergoing endodontic treatment, and which may include more resistant bacterial strains [36].

**APICAL PATENCY AND EXTRUSION**

Extrusion of debris and irrigant solutions beyond the foramen is associated with periapical inflammation and delayed healing of apical periodontitis [39, 40]. One in-vitro study examining apical extrusion found no statistical difference in the amount of extrusion beyond both intact and small-sized apical foramina whether patency files of different sizes were used or not [5]. Deonizio et al. [41] arrived at a similar conclusion, showing that apical patency does not impact the amount of extruded filling material during root canal retreatment. Paradoxically, Lambriniidis et al. [35] reported that more extrusion occurred with an intact apical constriction compared to when it was enlarged. They related these findings to the probable creation of an apical plug due to not performing apical patency in their study. While Tinaz et al. [42] showed that apical extrusion of material increased using larger diameter patency files.

**APICAL PATENCY AND OVERALL TREATMENT SUCCESS**

Two randomized controlled clinical studies exploring factors associated with tooth survival and periapical healing following RCT [9, 10] reported that maintaining apical patency is one of the important factors positively impacting periapical healing and tooth survival after RCT. Negishi et al. [27] reported an increase in failure risk with an inaccessible apical constriction especially in teeth with periapical lesions. On the other hand, a recently published randomized clinical trial evaluating the effect of maintaining apical patency on healing of periapical lesions associated with necrotic teeth, demonstrated that success was similar in both patency and non-patency groups [14].

Only an animal model study examining periapical healing after RCT with or without apical patency in dogs [7], found significant healing in the non-patency group. It was argued that there was an absence of pathogenic bacteria in that study, which explained the decreased outcome being associated with patency, due to mechanical irritation of the periapical tissues.

Achieving apical patency was also cited as a criterion of efficacy in root canal retreatment procedures [26, 43, 44].

**CONCLUSIONS**

Clinical studies directly investigating the influence of apical patency on RCT outcome are limited. In-vitro and in-vivo studies evaluating amount of extrusion, canal cleanliness, and shaping examined this influence indirectly. According to the available literature, there is little evidence to contraindicate the use of apical patency or suggest it has a negative effect on RCT outcome. However, more evidence of high quality is required to confirm this.

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**CONFLICT OF INTEREST**

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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