

INFLUENCE OF APICAL PATENCY ON ROOT CANAL TREATMENT OUTCOME: A CONTEMPORARY OVERVIEW

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ABSTRACT

Determining the apical limit of root canal preparation has proved to be a matter of continuous debate. During root canal instrumentation, soft tissue or debris get impacted in the apical region causing canal blockage. This can be avoided if apical patency is maintained. A major concern over apical patency is extrusion causing periapical tissue irritation and delaying or hindering periapical healing. The aim of this review was to evaluate the literature regarding the influence of apical patency on success of root canal treatment. A search of the literature was conducted via PubMed using the terms “apical patency” OR “patency file”. Inclusion criteria were: articles published in English, between the years 2000 and 2020, and were neither case reports nor reviews. A total of 32 articles were selected. Clinical studies directly investigating the influence of apical patency on root canal treatment outcome are limited. *In-vitro* and *in-vivo* studies were found evaluating amount of extrusion, canal cleanliness, and shaping associated with apical patency 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 root canal treatment outcome. However, more evidence of high quality is required to confirm this.

KEY WORDS: apical patency, patency, file patency.

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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

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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].

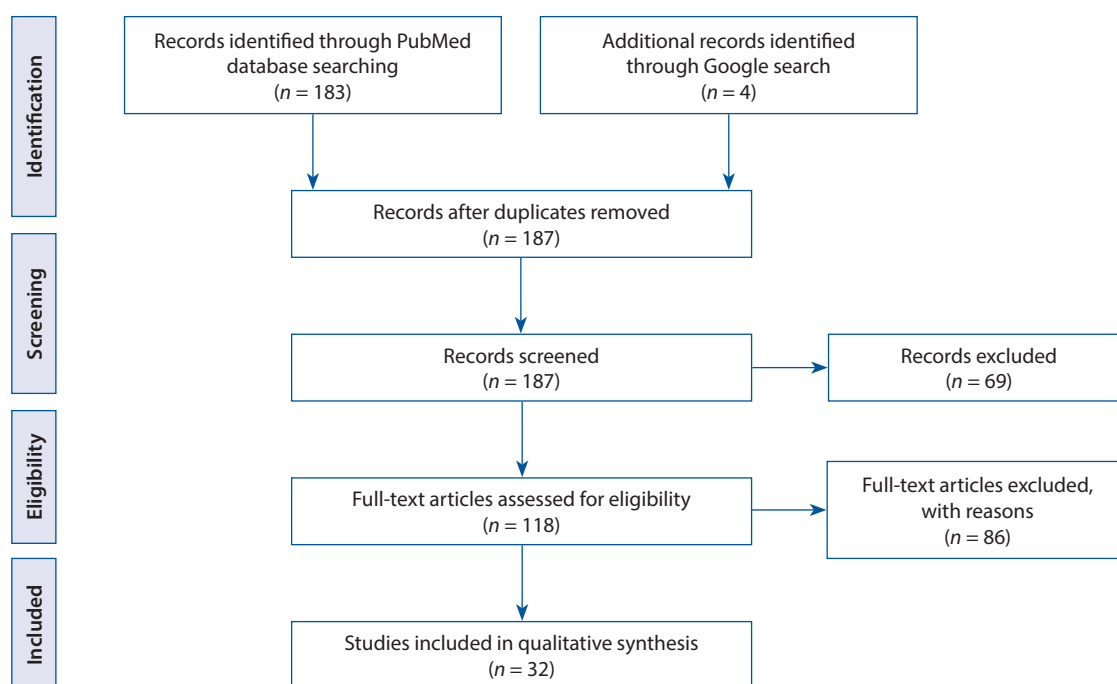


FIGURE 1. PRISMA flowchart on study selection and inclusion

TABLE 1. A summary of the included studies

No.	Study	Year	Study design	Sample size	Topic of influence	Findings
1.	Camões <i>et al.</i> [5]	2009	<i>In-vitro</i>	17 teeth	Extrusion of NaOCl with and without patency	Irrespective of maintaining irrigant extrusion occurred with and without maintaining apical patency
2.	Holland <i>et al.</i> [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 <i>et al.</i> [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 <i>et al.</i> [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 <i>et al.</i> [11]	2016	Randomized clinical trials	68 necrotic teeth with apical periodontitis	Postoperative pain	Apical patency had no significant influence on postoperative pain
6.	Arias <i>et al.</i> [12]	2009	Randomized clinical trials	300 necrotic teeth with apical periodontitis	Postoperative pain	Apical patency was associated with significantly less postoperative pain
7.	Yaylali <i>et al.</i> [13]	2018	Randomized clinical trials	320 necrotic teeth with apical periodontitis	Postoperative pain	Apical patency was associated with significantly less postoperative pain
8.	Arslan <i>et al.</i> [14]	2019	Randomized clinical trials	50 necrotic teeth with apical periodontitis	Postoperative pain Periapical healing	Apical patency did not increase the incidence of postoperative pain or flare-up rate in teeth with vital/nonvital pulp Apical patency did not affect endodontic treatment outcomes
9.	Garg <i>et al.</i> [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 <i>et al.</i> [17]	2018	Meta-analysis	4 Studies	Postoperative pain	Apical patency did not increase the incidence of postoperative pain
12.	Yaylali <i>et al.</i> [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 <i>et al.</i> [20]	2014	<i>In-vitro</i>	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	<i>In-vitro</i>	30 human maxillary lateral incisors	Canal transportation	Apical patency did not increase canal transportation in the apical 4 mm
15.	Gonzalez Sanchez <i>et al.</i> [22]	2010	<i>In-vitro</i>	102 human molars	Canal transportation	No transportation was found when size 10 stainless steel reamers were used for apical patency
16.	Tsisis <i>et al.</i> [23]	2008	<i>Ex-vivo</i>	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 <i>et al.</i> [24]	2013	<i>Ex-vivo</i>	70 mandibular first molars	Canal transportation	Patency files significantly decreased both apical transportation and canal straightening

TABLE 1. Cont.

No.	Study	Year	Study design	Sample size	Topic of influence	Findings
18.	Hasheminia and Ardestani [25]	2004	<i>In-vitro</i>	70 mandibular first molars	Canal transportation	Patency file in conjunction with passive step back techniques significantly reduced apical transportation
19.	Trierweiler Paiva <i>et al.</i> [26]	2018	<i>In-vitro</i>	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 <i>et al.</i> [27]	2005	<i>In-vivo</i>	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 periradicular lesion
21.	Abdelsalam and Hashem [28]	2020	<i>In-vitro</i>	43 mandibular molars	Working length	Apical patency is essential for proper working length determination with apex locators
22.	Lambrianidis <i>et al.</i> [29]	2006	<i>In-vitro</i>	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 <i>et al.</i> [30]	2011	<i>In-vivo</i>	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 <i>et al.</i> [31]	2012	<i>In-vivo</i>	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 <i>et al.</i> [32]	2012	<i>In-vivo</i>	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 <i>et al.</i> [35]	2001	<i>In-vitro</i>	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 <i>et al.</i> [37]	2015	<i>In-vitro</i>	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 NAOCL was sufficient to kill microorganisms on the file
28.	Izu <i>et al.</i> [38]	2004	<i>In-vitro</i>	28 teeth	Inoculation of periapical tissue with contaminated patency file	NaOCl in the canals prevented the inoculation of periapical tissue with bacteria contaminated patency files NAOCL was sufficient to kill microorganisms on the file
29.	Deonizio <i>et al.</i> [41]	2013	<i>In-vitro</i>	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 <i>et al.</i> [42]	2005	<i>In-vitro</i>	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 It increased however, as the diameter of the apical patency increases
31.	De-Deus <i>et al.</i> [43]	2019	<i>In-vitro</i>	10 teeth	Regaining apical patency using reciprocating files during retreatment	No significant difference was found between M-Wire Reciproc and Reciproc Blue files in removing filling materials Both files reestablished apical patency in all specimens
32.	Carpenter <i>et al.</i> [44]	2014	<i>In-vitro</i>	86 teeth	Regaining apical patency during retreatment of MTA containing sealer and gutta percha	Gutta percha solvents allowed regaining apical patency when retreating canals filled with MTA containing sealer and gutta percha

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 $\times 100$ 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]. Tsesis *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 indispensable 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-vitro* 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 pulpal 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, Lambrianidis *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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