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Effectiveness of Retreatment of Oval-Shaped Canals Filled With Warm Gutta-Percha: A Systematic Review

Emilia Karova[1], Sherihan Zongova-Adem[2*]

[1]Associate Professor, Department of Conservative Dentistry, Faculty of Dental Medicine, Medical University, Sofia, Bulgaria
[2]Doctor of Dental Medicine, Center of Integrated Dental Medicine, Faculty of Dental Medicine, Medical University, Sofia, Bulgaria

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***Corresponding author**: Sherihan Zongova-Adem
Doctor of Dental Medicine, Center of Integrated Dental Medicine, Faculty of Dental Medicine, Medical University, Sofia, Bulgaria

Abstract **Original Research Article**

Oval-shaped canals with their isthmuses and inter-canal communications represent a challenge for secondary endodontic treatment. Different techniques have been proposed to enhance the filling removal during retreatment procedures of oval canals filled with warm gutta-percha techniques. The aim of this review article is to systematically summarize and analyze published in vitro studies over a ten-year period of time (2012-2022), evaluating the effectiveness of retreatment of oval-shaped canals filled with warm vertical compaction technique and/or carrier-based gutta-percha. A thorough search in PubMed - MEDLINE, The Cochrane Library and Science Direct databases and manual web search was performed. After the investigations were assessed by two reviewers. A total number of eleven articles out of 145 titles covered all eligibility criteria and were selected for further synthesis. All articles investigated the effectiveness of retreatment techniques in oval-shaped root canals filled with warm vertical compaction or/and carrier-based gutta-percha. According to the present review none of the currently described retreatment techniques resulted in completely clean of remnants root canal walls. Secondary endodontic treatment is still a difficult procedure and due to the complex anatomy of oval-shaped root canals, their retreatment represents even a bigger challenge and often requires additional cleaning procedures.

Keywords: retreatment, oval-shaped canals, warm vertical compaction, carrier-based gutta-percha.

INTRODUCTION

The long term prognosis of primary endodontic treatment depends on thorough cleaning, disinfection, shaping and three-dimensional sealing of the complex root canal space followed by a hermetic restoration of the tooth (Nasiri K *et al*., 2020). Its success rate at a follow-up of at least 1 year has been reported to be over 90% (82.0% - 92.6%) (Burns LE *et al*., 2022). Despite the rapid improvement of endodontic instruments and treatment protocols and techniques, it is still not possible to fully debride the root canals with more complex anatomy. Isthmuses, intercanal communications, irregularities in the canal space facilitate the accumulation of debris and microorganisms while at the same time access to them, their cleaning and filling become more complicated, and sometimes impossible (Velozo C *et al.*, 2021). The percentage of untouched areas for oval-shaped canals during their shaping ranges from 10% to 80% (Siqueira Junior JF *et al.*, 2018).

The three-dimensional sealing of the root canal space with a biocompatible material is the final goal of the endodontic treatment, thus preventing the passage of microorganisms, toxins and fluids to periradicular tissues (Tsenova-Ilieva I *et al*., 2018). The most commonly used material for obturation is gutta-percha combined with a sealer. The ideal obturation is considered to consist of a maximum volume of core material and a minimum thickness of sealer used (Ozawa T *et al.*, 2009). Obturation of root canals with oval shape represent a challenge. Among known obturation techniques, those using thermoplastic gutta-percha have been reported to provide better filling rates, especially in oval-shaped root canals, when compared to lateral condensation (Mohammadi Z *et al*., 2015).

Despite the high positive outcome of primary endodontic therapy, failures may occur in some case. Numerous factors lead to such failures, including presence of pre-operative periapical radiolucency, complex root canal anatomy, inefficient shaping and disinfection of the root canal space, inappropriate canal

filling, damaged coronal seal etc. (Bhujbal D *et al.*, 2020) Secondary root canal treatment is considered the safest and most successful first-choice option for managing such cases. The primary goal of the orthograde retreatment is to perform complete root canal filling removal and thorough cleaning, shaping, disinfection and obturation of the root canal space (Karova E *et al.*, 2021; Rao LN *et al.*, 2016). Several retreatment techniques have been proposed for removal of filling materials from the root canal space including hand stainless-steel files, engine-driven nickel-titanium (NiTi) systems, heat, sonic and ultrasonic devices, solvents, lasers and combinations between them (Karova E *et al.*, 2022). According to the literature, NiTi instruments are reported to be more effective and less time consuming for removal of the bulk of canal obturation compared to manual instrumentation (Karova E *et al.*, 2021; Tsenova-Ilieva I *et al.*, 2022). Although most of the techniques can successfully remove the bulk of canal obturation, none of them result in root canal walls 100% clean of filling remnants. Removing filling materials in oval-shaped canals becomes even more challenging due to their complex anatomy (De-Deus G *et al.*, 2019).

The aim of this systematic review is to summarize the articles determining the effectiveness of nickel-titanium instruments for the removal of thermoplastic gutta-percha from oval-shaped root canals.

MATERIAL AND METHODS

Eligibility Criteria

Articles selected for inclusion in this review fulfilled the following criteria:

1. Articles describing in vitro studies carried out on extracted fully formed permanent human teeth with oval-shaped canals without any root canal caries, cracks, fractures or other defects.
2. Articles evaluating the effectiveness of nickel-titanium files in the removal of filling materials from teeth filled with warm vertical compaction and/or carrier-based gutta-percha (Thermafil and/or Guttacore).

Exclusion Criteria

Studies investigating only the amount of debris extrusion, transportation of the root canals, time required for removal of the filling material, changes in the microbial microflora, removal of canal medications, registration of cracks/fractures initiation, studies focusing on the use of solvents, case reports, letters, review articles, thesis, articles not in English were not included in the present systematic review. Studies using human teeth with severely curved root canals or samples with unknown root cross-sectional shape were also excluded.

Search strategy and data extraction

A thorough search of literature on PubMed – MEDLINE, The Cochrane Library, Science Direct database and manual search on the web was performed. The following keywords in different combinations were used: retreatment, endodontic retreatment, warm vertically-compacted gutta-percha, thermafil, guttacore. The search was applied for in vitro studies published in the period from 2012 to 2022. The language was restricted to English.

Screening and selection

Two independent reviewers examined each paper based on its title and/or abstract. Disagreements were resolved in between the two. The full-text of an article was accessed when it was not possible to judge the study by the title and/or the abstract. Later the full texts were obtained and those papers that fulfilled all of the eligibility criteria were processed for later data extraction. Information about authors and year of publication, teeth type, instrumentation protocol, obturation, retreatment protocol, supplemental steps used during the retreatment and the observation method was extracted and summarized in tables.

RESULTS

The number of articles retrieved with the keyword combination for the different databases is as follows: in PubMed – MEDLINE 40 articles, in The Cochrane Library 9 articles, in Science Direct database and manual search 31 and 65 articles, respectively. A total number of 145 were selected after initial analysis.

A number of 21 duplicate studies were excluded. Further analysis of the titles and abstracts resulted in exclusion of another 76 articles, thus leaving 48 articles for detailed reading. Figure 1 illustrates a PRISMA flow chart of the search strategy.

Thus, 11 articles were selected for the systematic review. All the data collected are summarized in Table 1.

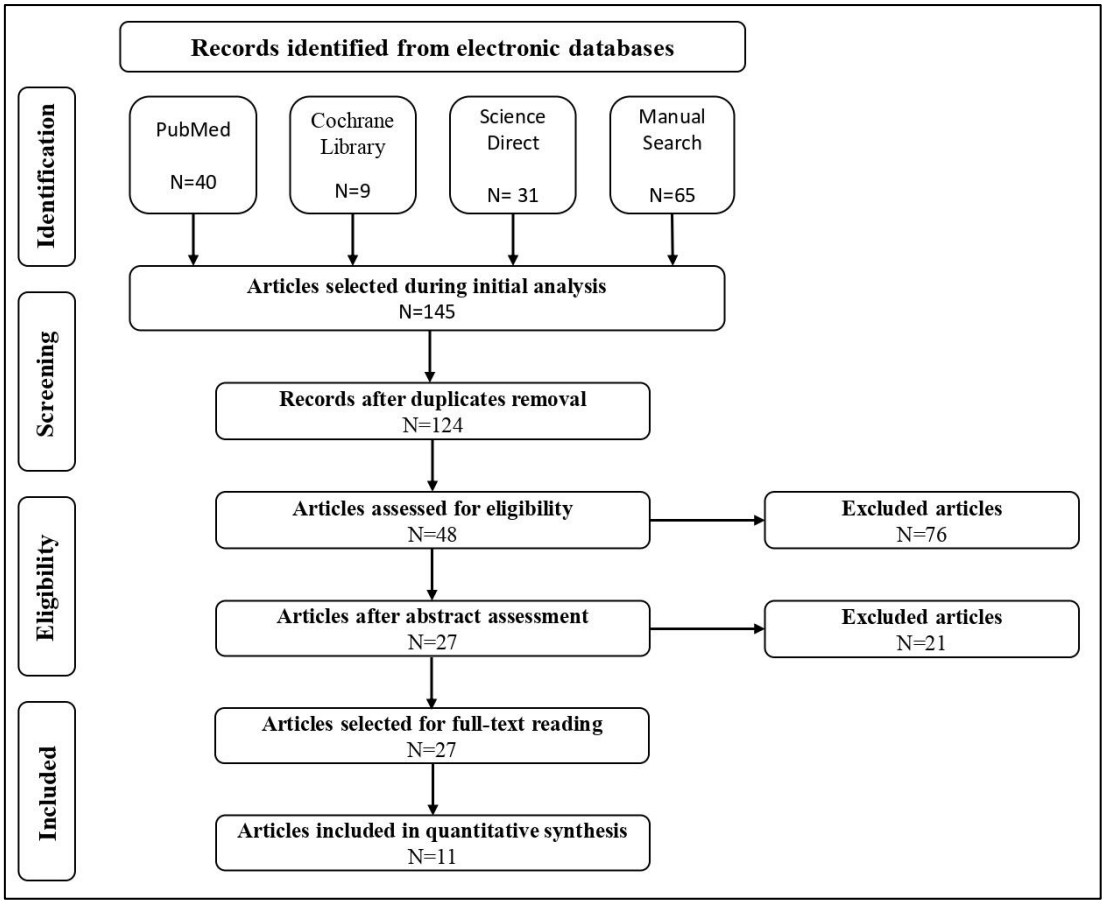

Fig 1: Prisma flow diagram of the literature search and included articles

Table 1: General information concerning the selected articles reviewing the effectiveness of NiTi instruments used for the removal of filling material from oval-shaped root canals filled with warm vertical compaction or carrier-based gutta-percha

Author/Year	Sample Type	Preparation	Obturation	Retreatment	Supplementary methods	Solvents used	Observation method
1. Keleş A *et al*., 2014, May	20 maxillary premolars single oval-shaped canal	Revo-S SC1 25/.06 SC2 25/.04 SU 25/.06 AS (30/.06; 35/.06; 40/.06) SS K-file 45/.02	CLC VC AH Plus	R-endo Re 25/.12 R1 25/.08 R2 25/.06 R3 25/.04	2.0-mm SAF	none	Micro - CT
2. Keleş A *et al*., 2014	32 maxillary premolars single oval-shaped canal	Revo-S SC1 25/.06 SC2 25/.04 SU 25/.06 AS (30/.06; 35/.06; 40/.06) SS K-file 45/.02	WVC AH Plus	R-endo Re 25/.12 R1 25/.08 R2 25/.06 R3 25/.04	2.0-mm SAF	none	Split longitudinaly SEM
3. Keleş A *et al*., 2015	42 mandibular canines Single oval-shaped canal	Revo-S SC1 25/.06 SC2 25/.04 SU 25/.06 AS (30/.06; 35/.06; 40/.06) SS K-file 45/.02	WVC AH Plus	R-endo Re 25/.12 R1 25/.08 R2 25/.06 R3 25/.04 45/.02 SS K-file	1. Er:YAG laser 2. Er:YAG PIPS 3. Nd:YAG laser	none	Micro - CT
4. Özyürek T. *et al*., 2016	100 mandibular canines	PTN X1 17/.04 X2 25/.06	WVC AH Plus	D-Race DR1 (30/.10) DR2 (25/.04)	1. CI 2. XP-F 3. EA	none	Split longitudinaly Stereomicroscope Digital images +

Author/Year	Sample Type	Preparation	Obturation	Retreatment	Supplementary methods	Solvents used	Observation method
	Single oval-shaped canal	X3 30/.07 X4 40/.06			4. IrriSafe		AutoCAD
5. Azim AA. *et al.*, 2018	60 mandibular incisors Single oval canal	VB 30/.04	WVC AH Plus	1.WOG Primary 25.07 2. HyFlex EDM 25.08 3. XP-S 27.01	none	none	Micro - CT
6. Crozeta BM *et al.*, 2020	20 distal roots of mandibular molars Single oval-shaped canal	R40 40.06	WVC AH Plus	R50 50.05	1. PUI 2. GentleWave System	none	Micro – CT SEM
7. Faus-Llácer V *et al*., 2021	20 upper canines Slightly oval canal	PTG F2 25.08	1. Thermafil 2. GuttaCore	D-Race DR1 30.10 XP-S XP-FR	EA	none	Micro - CT
8. Zhang W *et al*., 2022	40 single-rooted premolars Single oval-shaped canal	R25 25.08	1. SCO 2. WVC HiFlow sealer	PTUR D1, D2, D3 R40 40.06	XP-FR	none	Micro - CT
9. Spinelli A *et al*., 2022	64 single rooted teeth Single oval canal	RB25 25.08	SCO 2. Guttafusion AH Plus sealer	Gated Gliddens # 2/3 RB 25.08 RB 40.06	None	none	X-Rays Micro – CT Split teeth + ESEM + EDX
10. Karova E *et al*., 2022	12 mandibular incisors Single oval canal	XP-S	WVC AH Plus	D-race DR1 30/.10 DR2 25/.04	XP-FR	none	Micro - CT
11. Hassan *et al*., 2022	75 single-rooted lower premolars; Single oval-shaped canal	HyFlex EDM 40/.04	WVC TotalFill HiFlow BC sealer	D-race DR1 (30/.10) DR2 (25/.04) HyFlex EDM (40/.04)	Conventional syringe technique XP-F XP-FR E1 Irrisonic tip	none	Split teeth SEM

Legend: PTN – ProTaper Next; VB – Vortex Blue; R – Reciproc; PTG – ProTaper Gold; RB – Reciproc Blue; XP-S – XP Endo Shaper; XP-FR – XP Endo Finisher R; XP-F – XP Endo Finisher; WOG – WaveOne Gold; PTUR – ProTaper Universal Retreatment; SAF – Self-Adjusting file; EA – EndoActivator; WVC – Warm vertical compaction; VC – vertical compaction; CLC – cold lateral condensation; CI – Conventional Needle Irrigation; PIPS - Photoinduced Photoacoustic Streaming; PUI – Passive Ultrasonic Irrigation; Micro – CT - Microcomputed tomography;; SEM – Scanning Electron Microscope;; ESEM – Environmental Scanning Electron Microscopy; EDX – Energy dispersive X-ray Spectroscopy;

DISCUSSION

A high incidence of oval root canals, especially in mandibular incisors, has been reported (Papic M *et al.*, 2022). This type of complex anatomy must always be taken into account since it significantly affects the quality of shaping (Mohammadi Z *et al.*, 2015) and filling procedures. Since one of the main goals of root filling is to prevent microbial recolonization, thorough obturation of the root canal space is of great importance for the treatment outcome and its long-term prognosis. According to *De-Deus et al.*, thermoplastic techniques fill the irregularities of oval-shaped root canals better than the lateral condensation technique and thus are considered more suitable for obturation of these types of canals (De-Deus G *et al.*, 2008).

The bacterial infection plays a major role in the formation of periapical inflammation and leads to endodontic treatment failures. (Siqueira JF Jr *et al.*, 2004). Thus, the removal of as much of the root content as possible, is considered essential for the eradication of persistent infection. (Al-Zaka IM *et al.*, 2022; Keleş A *et al.*, 2015). Nowadays, greater attention is paid to the engine-driven nickel-titanium instruments and their ability to remove gutta-percha and sealer, as they appear to be superiorly effective to manual instrumentation and more time consuming. (Madani ZS *et al.*, 2015; Patil A *et al.*, 2018). According to the literature, various NiTi systems and techniques have been investigated, but conflicting results have been registered regarding their effectiveness for removing root canal filling materials. (Rossi-Fedele G *et al.*, 2017). None of them were able to completely clean the canal walls of filling residues, despite files' design or kinematics. (Madarati AA *et al.*, 2018; Alakabani TF *et al.*, 2020; Bhujbal D *et al.*, 2021). The retreatment of oval-shaped root canals still represents a challenge (Rechenberg DK *et al.*, 2013) as standard endodontic instruments rotate in the center of the root canal thus leaving a big portion of untouched surface (Versiani *et al.*, 2013). Supplementary procedures, like additional

shaping, irrigation, etc. should be applied. (Karova E *et al.*, 2022).

As a summary of the selected articles, it is worth mentioning that the instruments used in the initial retreatment procedures included NiTi systems with multiple files of different numbers and design, manufactured from different types of NiTi alloy, moved with continuous or reciprocating motion. NiTi systems designed for primary root canal space shaping have also been reported as effective tools in the retreatment process. (Martins MP *et al.*, 2017; Crozeta BM *et al.*, 2016).

In nine of the selected articles (Keleş A *et al.*, 2014 May; Keleş A *et al.*, 2014; Keleş A *et al.*, 2015; Özyürek T *et al.*, 2016; Azim AA *et al.*, 2018; Crozeta BM *et al.*, 2020; Zhang W *et al.*, 2022; Karova E *et al* 2022; Hassan E *et al.*, 2022) the samples were filled with warm vertical compaction while in the remaining two articles carrier-based gutta-percha was used (Faus-Llácer V *et al.*, 2021; Spinelli A *et al.*, 2022). Both obturation techniques resulted in fewer voids in the root canal filling compared to lateral condensation or single cone technique, making them preferred for obturation of oval-shaped canals (Li GH *et al.*, 2014; Schäfer E *et al.*, 2016; Zhang W *et al.*, 2022).

All studies included in this review demonstrated by the presence of residual material after the initial retreatment procedures, regardless of the type of instrumentation, obturation technique or examinational method. [Keleş A *et al.*, 2014 May; Keleş A *et al.*, 2014; Keleş A *et al.*, 2015; Özyürek T *et al.*, 2016; Azim AA *et al.*, 2018; Crozeta BM *et al.*, 2020; Zhang W *et al.*, 2022; Karova E *et al.*, 2022; Hassan E *et al.*, 2022; Faus-Llácer V *et al.*, 2021; Spinelli A *et al.*, 2022).

According to *Azim et al.,* the ideal endodontic instrument should be able to remove root canal fillings effectively in short time, without any debris extrusion or root canal transportation, and without any complications, including root canal perforations or file separation. In an *in vitro* study they evaluated the performance of three single-file systems for secondary endodontic treatment of oval-shaped canals filled by warm vertical compaction and found a significant difference in their performance. The reciprocating instrument leaves the most residue after use, making the authors to conclude that continuous rotation appears to be more appropriate in retreatment cases (Azim AA *et al.,* 2018), which is consistent with a previous study (Jorgensen B *et al.,* 2017). Furthermore, the authors used XP-Endo Shaper (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland) in higher speed (3000 rpm), resulting in greater efficiency and less time needed for the retreatment. It was the XP-Endo Shaper that showed superior performance over the other instruments tested when used at a higher than the recommended speed (Azim AA *et al.,* 2018). In another study, the authors concluded that the reciprocating Reciproc Blue may be the system of choice for removing debris and filling material from the apical third of the oval canals (Spinelli A *et al.,* 2022). These contradictory statements could be explained with the different study design and the characteristics of instruments. However, in the second study, the cleanliness of the apical portion of the root canal may be due to the increased diameter of the apical preparation from RB25 to RB40. Further enlargement of the apical portion of the canal should be undertaken carefully, because it may lead to complications such as root cracks or fractures (Kunert GG *et al.,* 2010).

Supplementary methods have been advocated to enhance the cleaning procedure after the use of NiTi rotary instruments. Innovative XP-Endo system, ultrasonic and sonic devices and lasers have shown sophisticated results.

XP Endo Finisher and XP Endo Finisher R (FKG, La Chauxde-Fonds, Switzerland) were used as a supplementary instruments in five of the inspected investigations. *Özyürek T. et al.* and *Hassan E. et al.* used XP Endo Finisher in their studies and came to similar conclusions. In both studies XP Endo Finisher demonstrates superior cleaning ability compared to sonic and ultrasonic irrigation (Özyürek T *et al.*, 2016; Hassan E *et al.*, 2022). In four of the included studies XP Endo Finisher R was used as a supplementary instrument, as it was specifically designed for the purpose of orthograde endodontic retreatment. The file showed significant cleaning ability when used after the initial retreatment procedures (Faus-Llácer V *et al.*, 2021; Zhang W *et al.*, 2022; Karova E *et al.*, 2022; Hassan E *et al.*, 2022 Mar).

It appears to be equally effective in removing canal contents from teeth obturated with various filling techniques, (Faus-Llácer V *et al.*, 2021; Karova E *et al.*, 2022; Tavares SJO *et al.*, 2021; Silva EJNL *et al.*, 2021) regardless of the canal portions (Tsenova-Ilieva I *et al.*, 2022) or the time for samples storage. (Zhang W *et al.*, 2022). It seems that retreatment of newly filled root canals appears to be less effective than old filled canals, and the efficiency of retreatment is more related to sample storage time than filling technique (Zhang W *et al.*, 2022). XP Endo Finisher retreatment instrument is considered an instrument of choice when retreating oval-shaped canals. Due to its metallurgy and mechanical action it shows greater effectiveness in dislodgment root filling material when compared to Passive ultrasonic irrigation (Shaheen NA *et al.*, 2021; De-Deus G *et al.*, 2019).

Although PUI and sonic irrigation may not facilitate removal of filling material as much as XP Endo files, their use still improves retreatment procedures and is superior to needle irrigation alone as

noted in the selected studies, (Özyürek T *et al.*, 2016; Crozeta BM *et al.*, 2020) and in other studies as well (Grischke J *et al.*, 2014; Volponi A *et al.*, 2020).

The Self-Adjusting file system (ReDent, Ra'anana, Israel) resulted in better cleaning of the root canal walls from the filling material after the use of R-Endo retreatment system in oval-shaped canals (Keleş A *et al.*, 2014 May; Keleş A *et al.*, 2014). Same results were stated when SAF was used after ProTaper Universal Retreatment (Abramovitz I *et al.*, 2012).

The epoxy resin-based endodontic sealer AH Plus (Dentsply De Trey, Konstanz, Germany) was used in combination with gutta-percha as a filling material in almost all observed studies. Due to its biocompatibility, excellent physiochemical properties and higher bond strength with dentin, it is considered a "gold standard" sealer (Silva EJNL *et al.*, 2019). However, all these qualities interfere with its displacement from the dentinal wall during orthograde retreatment (Crozeta BM *et al.*, 2021; Keleş A *et al.*, 2015).

Evaluation of the remaining root canal filling material has been accomplished by several methods such as specimen sectioning (Purba R *et al.*, 2020; Colaco AS *et al.*, 2015), radiography (Dhaimy S *et al.*, 2021; Mollo A *et al.*, 2012), digital images (Özyürek T *et al.*, 2016; Joseph M *et al.*, 2016), stereomicroscope images (Özyürek T *et al.*, 2016; Nasiri K *et al.*, 2020), scanning electron microscopy (SEM) analysis (Keleş A *et al.*, 2014; Vidal FT *et al.*, 2016), Micro-CT (Bago I *et al.*, 2020; Delai, D *et al.*, 2019; Karova E *et al.*, 2022), Environmental scanning electron microscopy (ESEM) (Gomes NN *et al.*, 2017) and energy dispersive X-ray spectroscopy (EDX) (Spinelli A *et al.*, 2022). According to literature Micro-CT is assumed to be the most accurate, non-destructive and non-invasive tool for qualitative and quantitative analysis of the endodontic retreatment procedures, overcoming the limitations of other methods (Alakabani TF *et al.*, 2020; Keleş A *et al.*, 2014 May). It allows prolonged 3D-evaluation of the tooth tissues as well as the remaining filling materials, (Tsenova-Ilieva I *et al.*, 2022; Robinson JP *et al.*, 2012), due to its high sensitivity and ability to detect the correct location of remnants on the root canal walls (Spinelli A *et al.*, 2022).

LIMITATION

A potential limitation of this systematic review is that the literature search was performed in large electronic databases, therefore some additional relevant studies may be missed. The present study is an overview of articles written in English that may cause omission of related articles written in other languages.

CONCLUSION

Secondary endodontic treatment is a difficult procedure, especially in cases with oval-shaped canals. Cleaning and shaping their more complex anatomy is a real challenge and often requires additional cleaning procedures. Nonetheless, none of the currently described retreatment techniques resulted in completely free of filling residue root canal walls.

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