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The Most Effective Obturation Technique in Curved Root Canals: A Systematic Review and Meta-Analysis

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ABSTRACT

Objective: A complete three-dimensional filling of the root canal system is the primary goal of endodontic therapy. In the case of curved canals, obturating the entire root canal space is a concern and adjunctive techniques are required to attain so. This systematic review aims to understand the most effective obturation technique in curved root canals.

Methodology: A systematic literature search was undertaken in the databases MEDLINE Ovid (from 1946), Scopus, and Google Scholar, as well as a hand search of the references of included publications. Ex-vivo and in-vitro studies were also included. The risk of bias was assessed. Meta-analysis was performed comparing lateral condensation and thermoplasticized technique using microleakage as an outcome.

Results: A total of 15 studies were included for systematic review and 6 studies were included for meta-analysis. No significant difference was seen between the main comparison group Of Cold Lateral Condensation and thermoplasticized obturation techniques.

Conclusion: Both Cold lateral condensation and thermoplasticized technique have comparable microleakage and the comparison of void space in the individual studies also showed debatable results.

KEYWORDS: Obturation techniques, Curved Root Canal, Thermoplasticized, Lateral condensation, Gutta-percha.

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INTRODUCTION

The goal of successful endodontic therapy is to completely debride vital or necrotic tissue and then achieve a total three-dimensional filling of the root canal space (1,2). In the long term, success can be measured either clinically with no symptoms or radiographically with the absence of lesions. The clinical success rate is almost 96% once complete obturation of the canal space is attained whereas an inadequate or incomplete filling is the cause of nearly 60 % of endodontic failures (3,4). The leakage of microorganisms and their pathogens through the interface of the obturating material and the dentinal walls initiates the reinfection of the canal space (3,5). The morphology of the root canal is also critical for endodontic success(6). The extent of the root canal curvature has an impact on obturation. Gutta-percha has proven to be an excellent obturation material for both straight and curved roots because it becomes viscous especially when heated and can be condensed to the root canal walls. According to literature, gutta-percha can be used to obturate 95% of the root canal space utilising various filling procedures(7). Although many procedures involving gutta-percha have been devised to provide acceptable three-dimensional obturation, cold lateral condensation(CLC) in conjunction with a root canal sealer remains one of the most popular(8,9).

Single cone, core carrier-based, and thermoplasticized are the other main techniques to fill the root canal space. A single master cone is inserted into a sealer-lined canal in a single cone obturation technique, whereas a master cone is inserted into a canal coated with sealer and condensed by a pre-fitted, tip heated electrical plugger in an injectable thermoplastic obturation technique. The canal is backfilled with thermoplasticized material after the softened point is vertically condensed and the plugger is removed. In a core carrier-based technique, a sealer is coated into the canal and a core carrier covered with gutta-percha or other materials is inserted, which is heated before placement for a thermoplasticized effect. The Cold lateral condensation being the most commonly used method of canal obturation, it serves as a standard against which other techniques can be compared (9). Some studies have also shown the superiority of these techniques over CLC for curved canals obturation (10–12).

Various methods have been used to evaluate the quality of the apical seal established by root canal obturation material, including dye penetration, radioisotope penetration, bacterial leakage, fluorometric and electrochemical techniques, fluid filtration, scanning electron microscopy, and gas chromatography (13). Microleakage tests are commonly used to assess the root canal filling's capacity to seal (14). The dye penetration method was chosen because it is simple, easy to carry out, and does not necessitate the use of specialized materials(15). The amount of void space in canal fillings can also be examined while analysing the adequacy and quality of the obturation. Void space in canal fillings their capacity to create a tight seal, allowing pathogens and fluid to escape through(16,17). When it comes to evaluating void space, any image analysis techniques can be (stereomicroscope (SEM), Cone-beam computed tomography (CBCT), MICRO-CT).

Thus, the aim of this systematic review and meta-analysis is to analyse the most effective obturation technique for curved root canals.

METHODS

This systematic review and meta-analysis were intended to answer the research question, "Which obturation technique is most effective for curved root canals?" and included in-vitro studies and ex-vivo studies. Studies were included if they satisfied the following criteria: (a) root canals with a minimum curvature of 5 degrees; (b) any type of tooth; and (c) only studies written in English. The exclusion criteria were (a) simulated cured root canals for example within acrylic blocks (b) obturation done with any other technique other than lateral condensation, single cone, and thermoplasticized (core carrier-based, injectable).

The intervention group consisted of obturation techniques which included single cone obturation and thermoplasticized technique (both injectable technique and core carrier-based method) and the control group was the conventional CLC method. The outcomes measured were the microleakage for studies that used dye penetration method and void space calculated using any image analysis techniques viz SEM, CBCT, Micro-CT.

The MEDLINE Ovid, Scopus, Google Scholar, and EBSCO databases were searched for relevant articles. There were no constraints on the date or place of publication, but only studies published in English were considered for this systematic review. Additionally, the reference lists of the included studies were examined for additional references, and a hand search of the studies was undertaken. The search strategy used in Medline was: ((obturat*) OR (gutta-percha) OR (obturat* technique*) OR (obturat* method*) OR (root canal fill*)) AND ((curved canal) OR dilacerat* OR (bent root*) OR (curved root*)).

Two authors (SR and RR) independently performed the search management using Covidence software. Duplicate articles were removed and remaining articles were screened by title and abstract. Studies that did not match the criteria for inclusion were eliminated following which full-text of the selected articles were retrieved. They were analyzed further for specific inclusion and exclusion criteria and final articles for the systematic review were included. At all stages, if there were any disagreements, it was adjudicated by a third reviewer (RV). For all of the databases specified, the search was conducted in February 2021. There was no lower time limit specified. For each of the included studies, relevant data was extracted in a Microsoft Excel sheet which included study authors name, country, study design, root canal curvature, sample size, outcome measure, outcome assessment method, post obturation processing technique prior to analysis, type of sealer, intervention, outcomes, and results.

The risk of bias for each included study was assessed independently by two authors (SR and RR). For in-vitro studies, there was no standardized tool for quality assessment. Customized tools have been utilized in previous reviews. This review adapted a tool from a similar review (18) and the following parameters were assessed and graded for calculating the risk of bias (i) presence of control group (ii) Description of sample size calculation (iii) randomization (iv) root canal procedure performed by a single operator (v) use of obturating material according to manufacturer's instructions (vi) time for evaluation of outcome (vii) blinding of outcome assessor. Each article received a Y (yes) for that parameter if the authors reported it; if the information could not be found, the article received an N (no). High risk of bias was assigned to studies that reported 1–2 items, medium risk to studies reporting 3–5, and low risk to studies reporting 6–7 items.

For quantitative synthesis, the outcome studied were microleakage (recorded in mm) and the void space (recorded in mm^3 and percentage). Meta-analysis was performed with RevMan 5.4.1. As the data was continuous in nature, the mean and standard deviation was extracted from the included studies and the summary effect measure used was Mean Difference (MD) reported with a 95% confidence interval. For any missing data, the study was excluded from the review.

We used Cochran's Q statistic, a chi-square test, and a p-value cut-off of less than 0.10 to assess the data's heterogeneity (19). The consistency of the results was assessed visually using forest plots and by the I^2 statistic (20). The I^2 statistic describes the proportion of variation in point estimates attributable to heterogeneity as compared to sampling error.

RESULTS

A total of 518 studies were retrieved based on database and hand searching. After removing duplicates, 286 papers were included for the title and abstract screening. Further, 251 articles were eliminated because they were irrelevant to this review. Full-texts were retrieved and screened for the remaining 35 articles and 15 papers were chosen for qualitative synthesis. Among them, five articles were chosen for quantitative analysis (Figure 1).

Of the 15 included studies, five studies were from Unites States of America(9,21–24), three from Turkey (2,25,26), two from United Kingdom (12,27) and one each from Spain (28), Germany (29), Netherland (10), Wales (30) and Iran (11). All the studies were in-vitro with sample sizes ranging from 20 to 144 and with a minimum of 5^{O} canal curvature. No ex-vivo studies were found. In eleven studies dye penetration was measured (9,10,12,21–25,27,28,30), whereas in four studies void space was calculated (2,11,26,29). Among those eleven studies which measured dye penetration, India Ink was the dye of choice for seven studies (9,12,21,22,24,28,30), methylene blue for three studies (10,25,27), and procion blue for one study (23) (Table 1).

Considering the intervention groups in the included studies, thermoplasticized obturation technique was the only intervention group in eleven studies (9,10,11,12,21–28,30), and one study each was those, that compared thermoplasticized (injectable and core carrier) and single cone technique (2), and both thermoplasticized and single cone technique (29). AH Plus sealer was the commonly used sealer material in five studies (2,9,26,28,29) followed by Tubliseal (12,27,30) in three studies, AH 26 (10,11) and Roth 801 (22,23) in two studies and Topseal (21), Kerr Pulp (24), Zoe sealer (25) in one study each (Table 1).

Among the 20 studies excluded during full-text screening, six studies had the wrong patient population, four were duplicate studies not identified in the initial screening, three each had wrong comparator and wrong intervention, two with wrong study design, one with a wrong indication and one article (full text) was not retrievable.

Quality assessment was done for included studies using a customized tool. It was found that all the studies had the presence of a control group, no study reported a description of sample size estimation, 9 out of 15 studies did not randomize the tooth into intervention groups, 8 out of 15 studies were only carried out by single operators, 10 out of 15 studies performed the procedures following manufactures instructions, 12 out of 15 studies have stated the time for evaluation outcome and 11 out of 15 studies did not perform the blinding of outcome assessor. Within the 15 studies around 11 studies had medium risk (73.3%) and four studies were found to be of high risk (26.7%). (Table 2)

Of the 15 included studies, six were counted in for quantitative analysis which had microleakage assessment using dye penetration as the outcome. Among the nine studies which were not included for quantitative analysis, four studies (2,11,26,29) measured the outcome as void space, which was of a different outcome effect than microleakage, and none of these studies had a common standard measurement value. Among these, two studies (2,26) did not show any significant variations between the method of obturation whereas one study favoured the lateral condensation (29) and one favoured thermoplasticized (11) as a superior method. One study (10) measured the microleakage and radiographic quality assessment of obturation in a different measurement unit (percentage), so was not included, in which thermoplasticized was found to be much superior to CLC in terms of radiographic appearance and stereomicroscopic adaptation, while dye penetration showed no significant difference. Three studies (12,22,30) had reported only the mean values without the standard deviation, hence were not included which one study assessed the microleakage and it favoured thermoplasticized over lateral condensation (22), other two studies assessed the radiographic quality and sealability in which lateral condensation was found superior (12,30). In one study (25) the apical dye penetration seen following obturation by the thermoplasticized and CLC procedures was compared using a spectrophotometric approach, and no significant microleakage variations were discovered.

A total of six studies with were included for quantitative synthesis. The outcome was microleakage (measured in mm). The intervention group in all studies were thermoplasticized technique compared with CLC as the control. It was observed that there was no statistically significant difference in the microleakage between the two obturation techniques [MD: 0.24, 95% Cl: -0.23, 0.70]. The heterogeneity [I^2] was 76% (Figure 2.).

DISCUSSION

Several techniques have been introduced to perform obturation of cleaned and shaped root canals. The obturation of curved canals are a serious concern and the morphology plays a key role in endodontic success. This study aimed to evaluate the most effective obturation technique for curved root canals. In this review, conventionally used CLC was considered as the control group and comparisons were made with thermoplasticized technique which included both ~~of~~ core carrier-based and injectable technique. Microleakage and void space investigations were taken into consideration as these were the two key outcomes.

Radiographs, bioluminescence, histological sections, dye leakage, microleakage models, and cleaning techniques have all been presented as ways to examine the quality of root canal fillings. The use of CT or CBCT is a relatively new technique(31). The fundamental benefit of the clearing procedure is that the dye penetration can be examined in three dimensions, allowing for the measurement of the dye's greatest extent (9,12,32).

Overall metanalysis comparing the CLC and thermoplasticized was performed to evaluate the most effective obturation technique for reducing microleakage in curved root canals, it was suggested that both these techniques have comparable microleakage. When comparing the CLC and thermoplasticized technique, Abarca *et al.*(21) reported that when the curvature was between 20 and 40 degrees, the difference in microleakage was not significant. He also indicated that variance could arise due to differences in specimens, operators, and measuring procedures. Barkins *et al.*(23) suggested that after decalcification and clearing, the metal in the obturators had a natural propensity to revert to a straight form, resulting in curvature reduction when the roots became malleable, and CLC was preferable to thermoplasticized because the latter had more linear leakage. Dummer *et al.* (27) stated that thermafil obturators were equivalent to, if not better than CLC of gutta-percha in terms of radiographic density of fill and apical dye penetration, according to the study. Thermafill obturators with plastic carriers were easy to use and much faster than lateral condensation of gutta-percha, and only a small amount of sealer was required at the canal orifices. This study also had a high weightage in meta-analysis as this study had the maximum sample size and was the only study that clearly preferred thermoplasticized over CLC. Lares *et al.*(24) suggested that sealer was consistently extruded through the apex during obturation with the Thermafil technique, which would increase the rate of postoperative pain after obturation. A probable mass shrinkage of the gutta-percha occurred when it cools down, resulting in a space between the gutta-percha and the canal wall, resulting in greater dye penetration. Thermafil is the only warm gutta-percha technique that did not use condensation in the apical third when the gutta-percha is cooling down, in compared to other warm gutta-percha procedures.

Some studies used fluid filtration to quantify microleakage , which also stated that CLC and thermoplasticized were comparable (33). The most common method of root canal obturation is CLC of gutta-percha (9,34), however to optimise the three-dimensional filling of curved and straight root canals, procedures based on pre-heating the gutta-percha were introduced (35). In terms of void space assessment among the three studies, two studies (2,26) favoured our overall outcome whereas one study (29) stated that thermoplasticized pluggers which were heated using a Bunsen burner flame, took a longer time, it was suggested that LC of greater taper gutta-percha cones is a faster and more efficient method. It was even mentioned that using an electric heat carrier would have resulted in significantly shorter obturation times.

Considering the radiographic quality within the included studies, lateral condensation was superior in two studies (12,30) and the buccolingual view suggested a denser fill than the mesiodistal view because the buccolingual width of teeth is usually greater than the mesiodistal width. But both studies have stated that while comparing the apical sealability thermoplasticized was superior. Comparing other studies which were not in metanalysis with dye penetration, two studies (10,22) also favoured our overall outcome whereas one study (11) suggested herofill system (thermoplasticized) as more effective.

One drawback of CLC is that a homogeneous mass of gutta-percha does not form at any point. A large number of gutta-percha cones are forcefully squeezed together and connected by the frictional grip and cementing substance in the final filling. Schilder claims that warm vertical condensation of gutta-percha provides a higher density of gutta-percha at the apical region of the filling and consistently obturates lateral canals and foramin(36). In the case of an open apex, thermoplasticies obturation may result in obturating material extrusion rather than lateral condensation(37).

Taking canal curvature into account, certain research has concluded that thermoplaticized is a far superior solution than CLC in canals with curvatures higher than 25 degrees(38). Comparing the sealer used, AH Plus is one of the most widely used (39). The chemical composition and setting of AH Plus sealer have been impacted by high temperatures (40). The removal of the smear layer plays a key role, better gutta-percha adaptation is obtained with both obturation techniques when the smear layer is removed (41).

Although results are indicative of similar effectiveness of both techniques, it is also influenced by several factors like degree of canal curvature, use of sealer, and individual clinician's skill in performing the obturation techniques. There were also certain methodological limitations in the included studies especially with respect to the absence of a sample size calculation and randomization which could have impacted the study's validity. The majority of studies also lacked the blinding of outcome assessors, which could have biased the outcome evaluation, and hence the results need to be interpreted with caution.

CONCLUSION

This review suggests that both lateral condensation or thermoplasticized obturation technique do not differ significantly in microleakage. The comparison of void space in the individual studies also showed debatable results, thus it may indicate that both techniques could be indicated in case of curved root canals. Other parameters such as canal curvature, the level of chemo-mechanical preparation, and the particular clinician's experience and knowledge in the specific obturation technique also need to be considered.

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FIGURES

Figure 1: Flow diagram showing the study selection process

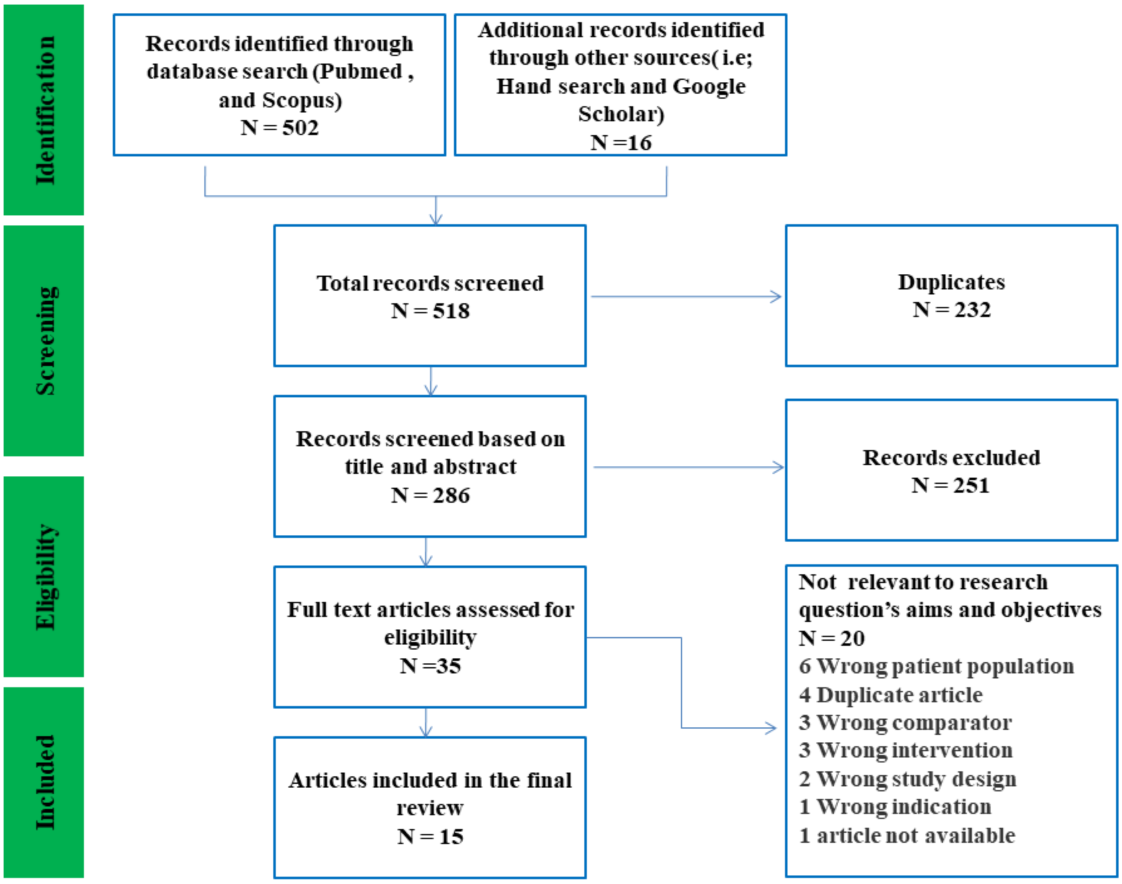
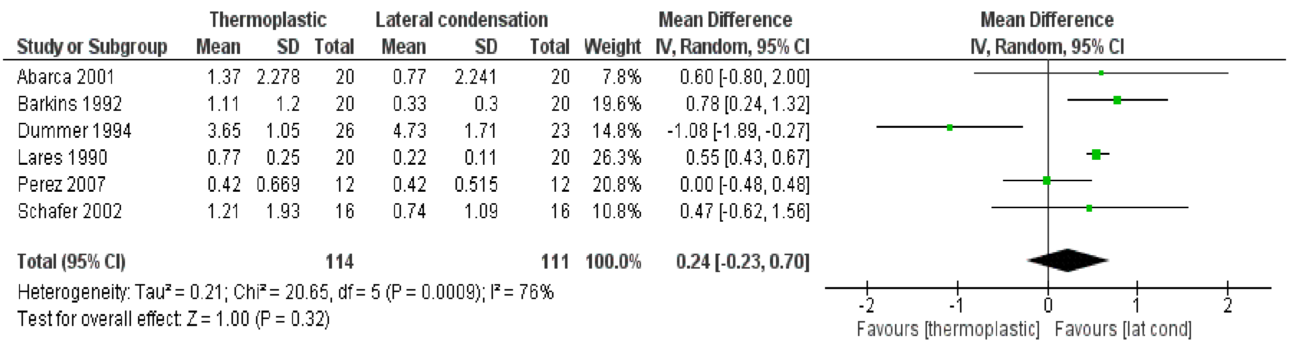


Figure 2: Forest plot of microlekage analysis with dye penetration



TABLES

Table 1: Characteristics of the included studies

Study id	Country	Study design	Canal curvature (c)	Sample size	Outcome measure	Outcome assessment method	Post Obturation Processing technique prior to analysis	Sealer	Intervention	Control
Abarca	United	In vitro	20-40	40	Microleakage	Stereomicroscope	Sealer setting time - 7 days, dye - India ink 2 days, drying - 1 day,5% nitric acid ,100% ethyl alcohol, methyl salicylate	Topseal	Thermoplasticized (core carrier)	LC

2001	States of America									
Barkins 1992	United States of America	In vitro	20-60	46	Microleakage	Stereo microscope	Sealer setting time - 7 days, Procion Blue - 37 C for 5 days, dimethyl sulfoxide - 21 days, ethyl alcohol (70% & 96%)- 1 day each, absolute alcohol- 2hrs, methyl salicylate	Roth 801 sealer	Thermoplasticized (core carrier)	LC
Dummer 1994	United Kingdom	In vitro	Not stated	144	Microleakage/ Radiographic quality	Not Stated	Sealer setting time - 2days, methylene blue - for 2 days	Tubliseal	Thermoplasticized (core carrier)	LC
Lares 1990	United States of America	In vitro	>30	40	Microleakage	Digital Calliper	Sealer setting time - 7 days, India ink -for 14 days, dried - 1 day, 5% nitric acid - 2 days, alcohol (50%,75%,95%, absolute)- 3hrs each, methyl salicylate, alcohol (50%,75%,95%, absolute)- 6hrs each, vaccum - 2days	Kerr Pulp C S	Thermoplasticized (core carrier)	LC
Perez 2007	SPAIN	In vitro	25-40	44	Microleakage	Stereo microscope	Sealer setting time - 3 days, India ink -for 7 days	AH Plus	Thermoplasticized (Injectable Technique)	LC
Schäfer 2002	United States of America	In vitro	20-30	142	Microleakage	Stereo microscope	Sealer setting - 3 days, India ink - 2 days, 5% nitric acid- 3 days, ethanol (80%, 90%, 99%), methyl salicylate	AH Plus	Thermoplasticized (core carrier)	LC
Kersten 1986	NETHERLANDS	In vitro	10-25	112	Microleakage/ Radiographic quality	Stereo microscope	Sealer setting - 7 days, methylene blue - 4 days	AH 26	Thermoplasticized (Injectable Technique)	LC
Gilhooly 2001	WALES	In vitro	Not stated	108	Microleakage/ Radiographic quality	Stereo microscope	Sealer setting time - 3 days, India ink -for 14 days, 11% nitric acid - 3-4 days, 70% ethyl alcohol - 95% alcohol - absolute alcohol (1 day each), methyl salicylate	Tubliseal	Thermoplasticized (Injectable Technique)	LC
McMurtrey 1992	United States of America	In vitro	>30	22	Microleakage	x7 illuminated viewer	Sealer setting time -, India ink - 2 days,5% nitric acid, 100% ethyl alcohol, methyl salicylate.	Roth 801 sealer	Thermoplasticized (core carrier)	LC
Gilhooly 2000	United Kingdom	In vitro	Not stated	108	Microleakage/ Radiographic quality	Stereo microscope	Sealer setting - 3 days, India ink - 14 days, 11% nitric acid - 3–4 days, 70% ethyl alcohol - 95% alcohol - absolute alcohol (1 day each), methyl salicylate	Tubliseal	Thermoplasticized (Injectable Technique)	LC

Zarei 2011	IRAN	In vitro	5-45	80	Void space	CBCT	Not stated	AH 26	Thermoplasticized (core carrier)	LC
Alacam 1994	TURKEY	In vitro	21-30	131	Microleakage	Spectrophotometric	Sealer setting - 2 days, metheleyene blue - 14 days, air dried- 1 day, 5%nitric acid- 1 day	ZOE sealer	Thermoplasticized (core carrier)	LC
Schäfer 2012	GERMANY	In vitro	25 - 35	48	Void space	Stereomicroscope	Sealer setting - 14 days	AH Plus	Thermoplasticized, Single cone	LC
Alim 2020	TURKEY	In vitro	> 25	60	Void space	Micro CT	Not stated	AH Plus	Thermoplasticized (Injectable Technique, core carrier), Single cone	LC
Şımşek 2017	TURKEY	In vitro	17-38	20	Void space	Micro CT	Sealer setting - 7 days	AH Plus	Thermoplasticized (Injectable Technique)	LC

Table 2: Risk of bias assessment

Study ID	Presence of control group	Description of sample size calculation	Randomisation	Root canal procedure performed by a single operator	Use of obturating material according to manufacturer's instructions	Time for evaluation of outcome	Blinding of outcome assessor	Risk
Abarca 2001	YES	NO	NO	YES	YES	YES	NO	Medium risk
Barkins 1992	YES	NO	NO	YES	YES	YES	NO	Medium risk
Dummer 1994	YES	NO	NO	NO	YES	NO	NO	High risk
Lares 1990	YES	NO	NO	NO	YES	YES	NO	Medium risk
Perez 2007	YES	NO	YES	YES	YES	YES	NO	Medium risk
Schäfer 2002	YES	NO	YES	YES	YES	YES	NO	Medium risk
Kersten 1986	YES	NO	NO	NO	NO	YES	YES	Medium risk
Gilhooly 2001	YES	NO	YES	YES	YES	YES	NO	Medium risk
McMurtrey 1992	YES	NO	YES	NO	NO	YES	YES	Medium risk
Gilhooly 2000	YES	NO	YES	YES	YES	YES	NO	Medium risk
Zarei 2011	YES	NO	YES	YES	YES	NO	YES	Medium risk
Alacam 1994	YES	NO	NO	NO	NO	YES	NO	High risk
Schäfer 2012	YES	NO	NO	YES	NO	YES	YES	Medium risk
Alim 2020	YES	NO	NO	NO	YES	NO	NO	High risk
Şımşek 2017	YES	NO	NO	NO	NO	YES	NO	High risk