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Original Article

Dentistry Section

Sealing Ability of Root Canal Sealers in Warm Obturation Techniques Compared to Cold Obturation Techniques: A Systematic Review

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ABSTRACT

Introduction: Obturation is a critical step in root canal treatment of the teeth that significantly contributes to its success. Various techniques are used for obturation of root canals.

Aim: To compare the sealing efficiency of sealers under warm and cold obturation techniques across parameters such as Microleakage (ML), Push-out Bond Strength (PBS), and dentinal tubule penetration, which help evaluate the sealer-dentin interface in root canal systems.

Materials and Methods: The research question was designed in the Population, Intervention, Comparison, Outcome (PICO) format, and the databases searched were Medical Literature Analysis and Retrieval System Online (MEDLINE), Cochrane, and Scopus following Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines. Inclusion criteria included in-vitro studies between January 2011 and June 2021 in the English language, comparing the influence of both cold and warm obturation techniques on root canal sealers. Key parameters considered for evaluating the sealing ability of endodontic sealers were marginal adaptation, ML, and Dentinal Tubule Penetration (DTP). Two independent reviewers assessed studies for eligibility against the inclusion and exclusion criteria and conducted data extraction. Risk of bias assessment was performed using the Cochrane risk of bias assessment tool, Review Manager (v5.4).

Results: A total of 19 articles were finalised for review, and methodological assessment for all parameters involved in the study was conducted using the Cochrane risk of bias assessment tool. Out of the total, five studies showed a moderate risk of bias, while the remaining 14 studies showed a low risk of bias.

Conclusion: Warm and cold obturation techniques perform similarly in producing a good apical seal when used in root canal treatment with different endodontic sealer materials. Warm obturation techniques perform better than cold obturation techniques in producing homogeneous root canal fillings, while cold obturation techniques enhance push-out bond strength at the sealer-dentin interface.

Keywords: Bond strength, Microleakage, Sealing, Thermoplasticised

INTRODUCTION

Endodontic sealers play a crucial role in determining the outcome of endodontic treatment by working alongside core obturating materials or independently to create a strong seal within the root canal system. This seal helps block the entry of microorganisms and toxins from both the oral environment and periradicular region [1]. The apical sealing ability of sealers depends on their adaptation and interaction with the root canal anatomy, which can be assessed through properties such as DTP, marginal adaptation, microleakage, and Push-out Bond Strength (PBS) [2-6]. Various factors, such as the type of irrigants used, activation protocols, obturation materials, and techniques employed, can impact the properties of sealers and consequently affect their ability to create a strong apical seal [6]. Endodontic sealers aid in maintaining the integrity of the sealer-dentin interface by forming a strong bond with the root canal dentin. This bond is crucial during tooth flexure and procedures like preparing post-space for tooth rehabilitation post-endodontic treatment [7]. Failure to use the appropriate sealer and follow proper obturation protocols can lead to complications like microleakage, sealer extrusion, inadequate filling of lateral canals, ultimately compromising the overall success of root canal treatment. Inconsistencies in sealer consistency and application can result in voids in the obturation systems, increasing the risk of endodontic failure [8].

There are various techniques for root canal obturation in endodontics, broadly categorised as cold and warm obturation techniques based on the heat application method to the gutta-percha during obturation. Examples of cold obturation techniques include cold lateral condensation and the single cone technique, while warm obturation techniques encompass the continuous wave technique, thermoplasticised injectable obturation technique, and carrier-based obturation technique. The ongoing debate regarding the efficacy of cold versus warm obturation techniques in achieving a strong apical seal remains inconclusive due to variations in the physical and chemical properties of sealers used in root canal treatments under different temperature conditions [9]. The application of heat during obturation in root canal treatments reduces the water content in the environment and sealer, impacting parameters such as sealer flow and humidity, which in turn modify the properties of the sealers. The difference can be primarily appreciated when bioceramic sealers are used, as their properties are highly dependent on the water content in the environment and the flow of the sealer [10]. Warm obturation techniques have rapidly gained popularity and are purported to seal the root canal better without voids and irregularities, allowing the plasticised gutta-percha to adapt to the canal wall. Bhandi S et al., conducted a systematic review evaluating the success of cold and warm obturation techniques using micro Computed Tomography (CT) studies and have reported that thermoplastic obturation techniques show better outcomes over cold obturation techniques [11]. The observation of gutta-percha and the obturation system under micro CT presents itself with artifacts, which makes it difficult to determine the overall success of root canal treatment. Peng L et al., conducted a systematic review evaluating the outcome of both

warm and cold obturation techniques with different sealers and reported that both techniques perform similarly [12].

However, there is not much clarity over the influence of warm obturation techniques on the sealing ability of the sealer at the apical third. The present review aimed to compare the sealing efficiency of the sealers under warm and cold obturation techniques across parameters like microleakage, PBS, and DTP, which help in the evaluation of the sealer-dentin interface in root canal systems.

MATERIALS AND METHODS

Protocol and Registration

The present review was designed based on the requirements listed in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Statement for reporting systematic reviews. The study design and protocol for the systematic review were registered at the Prospective Register of Systematic Reviews {International Prospective Register of Systematic Reviews (PROSPERO) ID CRD42021261473} in 2021.

Research Question

The study's research question was designed in the PICOS format (Population, Intervention, Comparison, Outcomes, and Study design) based on the PRISMA guidelines: "What is the influence of warm obturation techniques (I) when compared to cold obturation techniques (C) on the quality of the apical seal (O) produced by root canal sealers in the root canal treatment of permanent teeth (P) in in-vitro studies?".

Literature Search Strategy

The present review included the studies obtained through a thorough search in the following databases: PUBMED (MEDLINE), Cochrane Central, and Scopus, from January 2010 to June 2021 (30th June). The search terms for the review were adapted based on the PICOS question and designed as per the syntax rules. New keywords such as ((root canal sealer) OR (endodontic sealer) OR (root canal sealers) OR (endodontic sealers)), (tubule penetration) OR (marginal adaptation) OR (microleakage) OR (push-out) OR (bond strength), (warm obturation) OR (thermoplasticised) OR (thermal) OR (heat) OR (warm) OR (cold obturation) OR (single cone) OR (lateral compaction) were added using Boolean operators (OR, AND) to combine the search terms [Table/Fig-1]. A complementary hand search was also conducted by reviewing the references of selected articles.

S. No.	Search terms
1.	((root canal sealer) OR (endodontic sealer)) OR (root canal sealers)) OR (endodontic sealers))
2.	((((tubule penetration) OR (marginal adaptation)) OR (microleakage)) OR (push-out)) OR (bond strength)
3.	(((((((warm obturation) OR (thermoplasticised)) OR (thermal)) OR (heat)) OR (warm)) OR (Cold obturation)) OR (single cone)) OR (Lateral compaction)
4.	#1 (AND) #2 (AND) #3
5.	#1 (AND) #2 (AND) #3 from January 2010 to June 2021

[Table/Fig-1]: Search strategy for systematic review.

Eligibility criteria: The requirements for in-vitro studies as specified by the PICOS question to be included in the present review are provided below.

Population (P): Studies on root canal treatment of permanent human teeth only.

Intervention (I): Warm obturation techniques.

Comparison (C): Cold obturation techniques.

Outcome (O): Apical sealing ability, PBS, microleakage, dentinal tubule penetration.

Study design (S): In-vitro studies.

Inclusion criteria:

- Studies comparing both warm and cold obturation techniques.
- Studies using conventional gutta-percha obturation material only.
- Studies evaluating properties in the root canal treatment of permanent teeth only in-vitro studies.

Exclusion criteria:

- Studies on primary teeth, bovine teeth, and artificial teeth.
- Studies not in the English Language.

Data Screening and Data Extraction

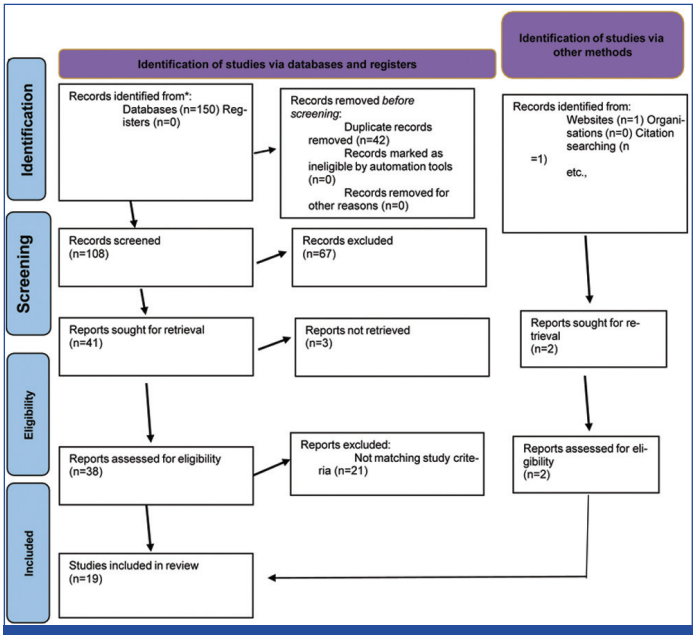
The titles and abstracts of retrieved studies were individually assessed by two reviewers (AK and RS) during the initial screening process, after which the full text of the articles was reviewed to identify articles based on the predetermined inclusion criteria. Data extraction was conducted after defining the included articles, and any confusion or lack of clarity in the data was clarified by contacting the authors of the articles via electronic message. In cases of disagreement between the two authors (RS and AK), a third author's opinion (NM) was considered.

Quality Assessment

The Cochrane Risk of Bias tool was used for Risk of Bias Assessment after modifications to suit the needs of this study [13]. Cochrane's Risk of Bias Tool was the third most commonly used tool among 13 tools for assessing the quality of in-vitro studies [14]. Selection bias was evaluated based on criteria such as teeth free of caries and fractures, sample size calculation, uniform sample selection, randomisation of teeth, use of materials following manufacturer's instructions, irrigation protocol, use of control samples in study groupings, and thermocycling were considered under performance bias. Detection bias was assessed through blinding, and reporting bias was evaluated for selective reporting and incomplete data criteria.

RESULTS

The process is illustrated in the flowchart shown in [Table/Fig-2]. The initial search was conducted with specific criteria, and 150 potential articles were retrieved. A manual search of the references of the articles added two more articles, resulting in a total of 152 articles. Duplicates in the articles were removed, leaving 108 articles for scanning of titles and abstracts. After scanning, 67 articles that did not meet the study's objective were removed. A total of 19 articles were finalised based on the eligibility criteria. Full-text scanning of the articles was conducted by the two reviewers [4,15-32]. There



[Table/Fig-2]: PRISMA flow chart.

was a fair agreement between the two reviewers, with a Kappa Coefficient percentage of 85%.

Study Characteristics

Information regarding the various characteristics of the selected studies is compiled in [Table/Fig-3] [4,15-32]. The 19 studies included in the review were published between the years 2010 to 2021 and were sourced from countries such as India [4,16,21,30], Malaysia [32], Turkey [19], Jordan [20], Indonesia [22], USA [25,28], China [27], and Kosovo [24].

The review involved studies with a variety of sealers like resin-based sealers, eugenol-based sealers, bioceramic sealers, etc., used with warm and cold obturation techniques to compare and evaluate the influence of obturation techniques on the root canal sealers' sealing ability in the apical third. The parameters used to evaluate the sealing ability are PBS, dentinal tubule penetration, and ML. There are nine articles evaluating PBS [4,15-22], seven articles evaluating DTP [22-28], and three articles [30-32] about microleakage of the sealers.

The PBS studies included in the present review comprise different types of sealers like Resin sealers (AH plus-8 studies, Epiphany SE-1 study), Bioceramic sealers (Bioroot ™ - 1 study, Endosequence BC- 3 studies, BC sealers- 1 study, Totalfill BC- 1 study), Silicone sealer (Roeko Sealer- 1 study), and ZOE-based sealers (Endomethasone- 1 study), etc., evaluated using Universal Testing Machine (UTM) and modern diagnostic tools such as a stereomicroscope, optical microscope, Scanning Electron Microscope (SEM), etc. Seven studies [15,16,18-22] report better PBS with cold obturation techniques, while two studies [4,17] report better PBS with warm obturation techniques.

The DTP studies include various types of sealers: Resin-based sealers (AH Plus- 2 studies, AH 26- 1 study, 2 Easy seal mix- 1 study); Bioceramic sealers (I Root SP -1 study, Endosequence BC- 1 study, Endosequence BC Hiflow- 1 study, Bio C sealer- 1 study, Neo MTA- 1 study, MTA Fillapex- 1 study, Smart paste bio sealer- 1 study) under different obturation techniques compared under a confocal laser scanning microscope analysing the root canal sealer penetration depth into the dentinal tubules and the influence of obturation techniques on the same. Four studies [23,26-28] report no significant difference across both obturation techniques, while the rest three studies [24,25,29] report improved DTP with warm obturation techniques, especially when used with bioceramic sealers.

The ML studies were based on the techniques used to measure the ML observed in the root canal filled teeth obturated by different obturation techniques [30-32]. The different techniques included in the study to measure ML were Methylene blue dye leakage test, bacterial leakage test, glucose test, and electrochemical test. The studies report no significant difference across both obturation techniques in all ML tests except for the bacterial fluid infiltration test conducted by Mathur R et al., which reports that warm obturation techniques produce less ML than cold obturation tests [30].

Risk of Bias Assessment

Methodological assessment of all the parameters involved in the study was done using the Cochrane risk of bias assessment tool RevMan 5.4. Twelve studies [4,16,19-25,28,30,32] exhibited high risk in three domains of selection bias, performance bias, and detection bias. Seven studies [15,17,18,26,27,29,31] showed high risk in two domains, and none of the studies presented a risk of bias in the reporting bias domain [Table/Fig-4].

DISCUSSION

The apical sealing ability of a sealer and obturation material is influenced by the ability of the sealer to penetrate dentinal tubules, PBS, and whether it results in ML at the apex [33-35]. The effect of heat application during warm obturation on the physical and chemical properties of the sealers plays a significant part in determining the apical sealing ability of the sealer and the overall prognosis of the treatment. Resin sealers have gained popularity since their advent due to the ability to produce excellent apical seal and dimensional stability, which has been proved by various studies [36-38].

Dentinal Tubule Penetration (DTP)

Resin-based sealers have good DTP with cold and warm obturation techniques, with comparatively better penetration under cold obturation techniques [35,36,39]. DTP is marginally reduced under warm obturation techniques due to the compromised flow of the resin sealers.

The DTP of bioceramic sealers is found to be enhanced with warm obturation techniques when compared with SC (Single cone) [40,41]. Eid D et al., compared bioceramic sealers treated with SC and Warm Vertical Compaction (WVC) techniques to report improved DTP with WVC techniques. The main difference between the techniques is associated with the improved ability of warm obturation techniques to fill the irregularities in root canals when compared to the SC technique [29].

Push-out Bond Strength (PBS)

Resin sealers fare better under cold obturation techniques, especially cold lateral condensation techniques, than warm obturation techniques as demonstrated in most studies [15,42-44]. AH Plus shows significantly better bond strength under the cold lateral compaction technique due to the formation of a strong polymer network between the amine groups in the collagen and opening of the epoxide ring of the sealer, which culminates in increased PBS [45]. Resin sealers do not perform well in PBS evaluations with warm obturation techniques as observed in various studies where AH Plus is treated with warm obturation techniques [46-48]. Lower bond strength of AH Plus when used with warm obturation techniques could be due to the accelerated setting reaction, shrinkage of GP while setting, and compromised flow of the sealer into the dentinal tubules and canal irregularities [49].

It has been reported in some studies that AH Plus reaches intermediate bond strength when used with warm obturation techniques displaying heat tolerance of the sealer [50]. This implies that the use of resin sealers with warm obturation techniques could produce satisfactory levels of PBS at the sealer-dentin interface.

The PBS of bioceramic root canal sealers has been found to produce variable results with either obturation techniques in most studies. The self-adhesive property of the bioceramic sealer to the root dentin by alkaline etching leads to the formation of a mineral infiltration zone at the dentin-sealer interface resulting in lower gap formation compared to AH Plus [51,52].

Bioceramic sealers are primarily composed of Calcium silicates, calcium phosphates, and radiopacifiers and secondary components such as accelerators, thickening agents to optimise its properties such as solubility, working time, setting time, etc., [53]. Bioceramic sealers, when used with warm obturation techniques, show bond strengths similar to or weaker than cold obturation techniques. The decrease in the PBS of bioceramic sealers has been attributed to variation in the physical properties of the sealers on the application of heat as reported by Camilleri J [46].

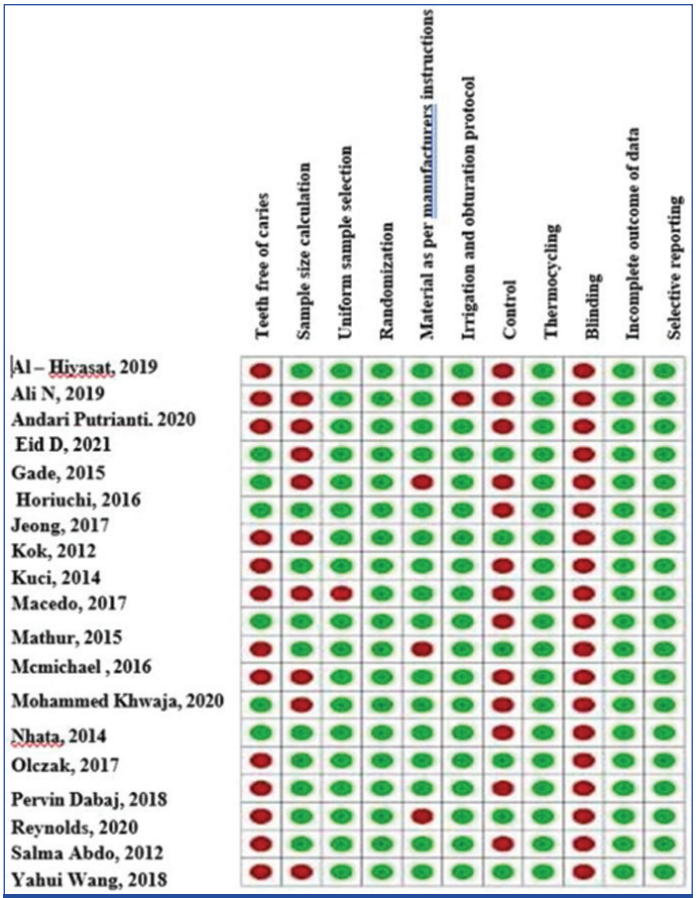
Application of heat to the sealer accelerates hydration with the release of smog resulting in rapid setting reaction and hydroxyapatite formation, as reported with iRoot SP bioceramic sealer [26]. The flow of the sealers is also found to be less than the standards of ISO and ADA specifications on the application of heat carriers and warm obturation techniques. The decrease in the flow of the sealers is attributed to the decrease in the water content in the sealers on the application of heat [46,54,55].

Push-out Bond Strengths (PBS)																
		Root canal sealers				Obturation technique										
						Cold obturation techniques			Warm obturation techniques							
	Author/Country/ Year	Resin-based	Bioceramic	Silicon-based	ZOE-based	Lateral	Single Cone	C point	Warm vertical	Thermo plasti-cised systems	Carrier based	Combination of warm vertical and lateral condensation	Hybrosonic obturation	Property studied	Methodology	Comments
1	Nhata J et al., 2014, Sao Paol o (PBS 1) [15]	AH Plus	-	-	-	Y	-	-	Y	Y	-	-	-	Push-out bound strength	UTM	LC and THT have better bond strength when compared to CWC. LC reports maximum number of voids in obturation.
2	Gade et al., 2015, India (PBS 2) [16]	AH Plus	Endo sequence BC	-	Endomethsone	Y	-	-	-	Y	-	-		Push-out bond strength	UTM and Stereomicroscope	CLC has better overall PBS. AH plus better with CLC than other techniques. Endosequence better with thermoplastic technique.
3	Horiuchi ZH et al., 2016 Sao Paolo (PBS 3) [17]	AH Plus, Epiphany SE	-	-	-	Y	-	-	-	Y	-	-	-	Push-out bond strength	UTM and Stereomicroscope	Microseal and Obtura produce better bond strength when compared to lateral condensation.
4	Macedo LMD et al., 2017 Brazil (PBS 4) [18]	AH Plus	-	-	-	Y	Y	-	Y	Y	-	-	-	Push-out bond strength and Dentinal Tubule penetration	Universal testing machine and SEM, CLSM	Single cone technique reported least dentinal penetration among all techniques LC and VC had better bond strengths when compared to THT and SC techniques.
5	Dabaj P et al., 2018, Turkey (PBS 5) [19]	AH Plus	Endo sequence BC	-	-	Y	-	-	Y		-	-		Push-out bond strength	Universal testing machine and SEM	CLC best over-all PBS with AH plus. No significant differences observed in Endo sequence between both techniques.
6	Al-Hiyasat AS et al., 2019-Jordan (PBS 6) [20]	AH Plus	Total FIll BC	-	-	Y	Y	-	Y			-	-	Push-out bond strength	Universal testing machine and optical microscope	CLC with total fill BC best overall PBS. CLC significantly better than WV for all sealers.
7	Ali N et al., 201 9, India (PBS 7) [21]	AH Plus	Endo sequence BC	Roeko Seal	-	Y	-	-	-	Y	-	-		Push-out bond strength	UTM	CLC with AH plus best overall PBS. AH plus best PBS with Cold obturation techniques. Endo sequence best PBS with warm obturation technique.
8	Putrianti A et al., 2020, Indonesia (PBS 8) [22]	-	Bioroot TM	-	-	Y	-	-	Y		-	-		Push-out bond strength	Universal testing machine and stereo microsco pecamera	Combination of CLC and SC better PBS than warm obturation techniques. Fracture analysis: CLC-cohesive failure WV-Mixed cohesive failure.
9	Moinuddin MK et al., 2020, India (PBS 9) [4]	AH Plus	BC sealer	-	-	Y	-	Y	-	Y	-	-		Push-out bond strength	UTM and Stere omic rosc ope	CLC with AH plus and GP least PBS overall.
	Dentinal Tubule Penetration (DTP)															

10	Kok D et al., 2012 (DTP) [23]	AH Plus	-	-	-	Y	Y	-	-	-	Y	-	-	Sealing ability-Penetration	CLSM	Dentinal Tubule Penetration (DTP) is independent of obturation technique, Thermafil produces least sealer thickness in apical third.
11	Kuci A et al., 2014, Kosovo (DTP 2) [24]	AH 26	MTA fillapex	-	-	Y	-	-	Y		-	-		Dentinal tubule penetration	CLSM	Overall best TP observed with AH Plus and WV MTA fillapex best TP observed with CLC technique.
12	McMichael GE et al., 2016, USA (DTP 3) [25]	-	Endo sequence BC, MTA Fillapex, Neo MTA plus, Quickset 2	-	-	-	Y	-	Y		-	-		Dentinal tubule penetration	CLSM	CW and SC perform similarly in BC sealer, Quickset2, Neo MTA plus. CW significantly better TP than SC for MTA Fillapex.
13	Jeong JW et al., 2017, Texas (DTP 4) [26]	-	Smart paste biosealer	-	-	-	Y	Y	Y		-	-		Dentinal tubule penetration	CLSM	No significant differences between the penetration produced by sealers.
14	Wang Y et al., 2018, China (DTP 5) [27]	AH Plus	i Root SP	-	-	-	Y	-	Y		-	-		Dentinal tubule penetration	CLSM	The DTP of the sealers is not affected significantly by the nature of obturation technique. I Root SP performs better than AH plus with both techniques.
15	Reynolds JZ et al., 2020, USA (DTP 6) [28]	2 Easy seal mix	BC Sealer, Endo sequence BC Hi Flow	-	-	-	Y	-	Y		-	-		Dentinal tubule penetration	CLSM	No significant difference in the depth and percentage of tubule penetration with both obturation techniques.
16	Eid D et al., 2021, Lebanon (DTP 7) [29]	-	Bio Csealer and Endo sequence BC Hi Flow	-	-	-	Y	-	Y	-	-	-		Sealing ability-penetration	CLS M	WV produces significantly better penetration than SC technique at 1 mm and 5 mm levels from the apex.
Microleakage (ML) of sealers																
17	Mathur R et al., 2015, Indi a (ML 1) [30]	-	-	-	Tubliseal	Y	-	-	Y		Y- the rm afil	Y		Coronal microlea kage	Methylene blue dye test	**Bacterial leakage test:** CLC shows the most ML. Combination of WV and CLC reports the least ML. **Dye penetration test:** No statistically significant differences between different obturation techniques. CLC shows maximum leakage among groups at different levels of RCS.
18	Olczak K et al., 2017 Poland (ML2) [31]	AH Plus	-	-	-	Y	-	-	Y		Y-Protaper obturators	-		Sealing ability	Glucose test	Both obturation techniques perform similarly in producing a good apical seal.
19	Abdo SB et al., 2012, Malaysia (ML 3) [32]	Resilon Epiphany, Nano HA	-	-	-	Y	-	-	Y	-	-	-	Y	Sealing ability	Electrochemical model	No significant difference between the three obturation techniques on ML produced with GP and Nano HA sealer.

[Table/Fig-3]: Studies under the scope of the review under parameters of push-out Bond Strength (PBS), Dentinal Tubule Penetration (DTP) and Microleakage (ML) [4,15-32].

DTP: Dentinal tubule penetration; ML: Microleakage; UTM: Universal testing machine; PBS: Pushout bond strength; SEM: Scanning electron microscope; THT: Thermomechanical hybrid technique; CLC: Cold lateral condensation; WVC: Warm vertical compaction; CLSM: Confocal laser scanning microscope; SC: Single cone; ZOE: Zinc oxide eugenol; MTA: Mineral trioxide aggregate



[Table/Fig-4]: Risk of bias summary.

Microleakage (ML)

The integrity of the sealer at the apical third, when evaluated in various studies, seems to be consistent, though the number of voids in the middle and apical third of the root canal system was high with cold techniques compared to warm obturation techniques [56,57]. Warm obturation techniques produce a uniform filling of the root canal system, ensuring three-dimensional filling of the canals. A high GP to sealer ratio obtained with warm obturation techniques reduces the concentration of resin sealers used in the root canals, thus reducing the possibility of shrinkage of resin sealers, ensuring reduced ML of the obturated canals [58]. Warm compaction applies pressure on the obturation materials to flow into the apical ramifications, producing a good seal in the apical region [46]. Bioceramic sealers have reduced ML under the influence of both techniques than other endodontic sealers, as has been proved by various studies [34,59]. Modern bioceramic sealers like Endosequence BC Hi Flow and Total Fill BC Hi flow used in conjunction with Bioceramic particle-coated GP points have improved the quality of obturation with warm obturation techniques [47,60].

ZOE-based Sealers

The ZOE-based sealers have been used in the field of endodontics extensively to date and have produced good results with respect to the apical sealing ability of obturation. Warm obturation techniques have a positive mild incremental on their properties as the setting time and flow of the sealers are improved with a significant decrease in the number of voids produced during obturation [61]. Multiple studies have reported that the effect of heat applied during the obturation does not permeate to the apical third to affect the physical or chemical properties of the sealers, thus preventing any compromise of the activity of the sealers [61-63]. A combination of warm and cold obturation techniques, as attempted by Mathur R et al., would result in an ideal clinical scenario where the benefits of both obturation techniques can be obtained, improving the success of the treatment, despite requiring a little more time than the usual obturative protocol [30].

Limitation(s)

The present review was conducted with a search limit for studies in the English language over a period of ten years and the search was performed in only three databases. Evidence from in vitro studies should be extrapolated with caution. The studies do not include the scope of clinical outcomes of obturation techniques in different pathological conditions and their impact on root canal treatment. Future studies should also incorporate the effect of these obturation techniques on recent endodontic sealers that have been reported to have enhanced success using warm obturation techniques.

CONCLUSION(S)

Cold and warm techniques of obturation are comparable in their ability to produce apical seals with different endodontic sealers. A proper understanding of the physical and chemical properties of the sealers and the influence of heat applied during warm obturation techniques can help clinicians choose the appropriate sealer and obturation technique. Further studies with standardised protocols will help shed light on how the results obtained from laboratory-based investigations will translate to a clinical setting.

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