Review Article

Evaluation of coronal microleakage of intra-orifice barrier materials in endodontically treated teeth: A systematic review

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Abstract

Background: Endodontic success depends on complete sealing of the root canal orifice to prevent re-infection and re-Contamination of the treated teeth through microleakage. Intra-orifice barrier material provides a seal against micro-organisms, its by-products thus, preventing microleakage and subsequent endodontic failure. Several studies have been done to evaluate microleakage after placing various materials as IOB, but still there is no standardization for the same. Thus, this systematic review was conducted to evaluate the microleakage associated with mineral trioxide aggregate (MTA), composite, and glass ionomer cement (GIC) when used as IOB material.

Materials and Methods: Protocol was formulated in accordance with PRISMA checklist 2020 and registered on PROSPERO (CRD42021226225). Electronic search from databases such as Medline/PubMed, Scopus, EBSCOhost, Embase, Google Scholar, and Cochrane were performed from the year 2000–2020. *In vitro* and *ex vivo* studies evaluating coronal microleakage after placing IOB material using methylene blue dye penetration test under a stereomicroscope were included. A total of 5 studies were included in the systematic review. After assessing the risk of bias using customized criteria referred from JBI critical appraisal tool, characteristics of the included studies, reason for exclusion of the studies, and data extraction sheet were prepared.

Results: All studies included in this systematic review reported that placement of an IOB material significantly reduces microleakage as compared to control groups. MTA used as an IOB showed less microleakage than composite and GIC.

Conclusion: MTA as IOB material demonstrated the least microleakage *in vitro* studies. However, in this systematic review, only *in vitro* studies were included. Thus, more studies in the form of randomized control trials are required to give a conclusive and definitive result.

Keywords: Composite; dye penetration test; glass ionomer cement; intra-orifice barrier; methylene blue; microleakage; mineral trioxide aggregate; systematic review

INTRODUCTION

The anatomical irregularities of the root canal system have always posed a challenge in achieving a three-dimensional coronal and apical seal. Despite the various advances in obturation materials and techniques, failure is still evident in some cases, primarily due to bacterial microleakage.[1-3] According to earlier literature, achieving a proper apical

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seal was the most important factor for the success of endodontic treatment. Microleakage investigations later revealed a substantial link between inadequate coronal seal and endodontic failure, leading to the conclusion that the coronal seal was more critical than the apical seal.[4-7]

In 1996, Roghanizad and Jones proposed the concept of the intra-orifice barrier (IOB) technique to seal root canal orifices with the objective of reducing coronal microleakage by creating a dual seal at the root canal orifice.[4] This technique, is also known as "double-seal technique," which entails inserting a barrier material after removing 2–4 mm of gutta-percha from the orifice of the canal. The goal of IOB is to provide a seal against microorganisms and their by-products in order to prevent microleakage and subsequent endodontic failure. The positive effects of IOB on microleakage, periapical healing, fracture resistance, and push-out bond strength are widely documented in the literature.[8-11]

Various materials have been used as an IOB to prevent microleakage, such as amalgam,[10,11] conventional glass ionomer cement (GIC),[12,13] light-cured GIC (resin-modified GIC [RMGIC]), composite,[10,12] Zirconomer,[14] gray and white mineral trioxide aggregate (MTA),[10,13,15] Biodentine,[12] and calcium-enriched mixture cement.[10] With microleakage being the leading cause of endodontic failure, the literature demonstrates insufficient data regarding the evidence of "Which IOB material shows the least microleakage?." On this background, a systematic review was planned to comparatively evaluate the coronal microleakage associated with MTA, composite, and GIC placed as an IOB material using methylene blue dye penetration test under a stereomicroscope.

MATERIALS AND METHODS

Protocol and registration

The PRISMA guidelines 2020[16] were referred for writing the protocol and the systematic review was registered on PROSPERO, reference number CRD42021226225.[17]

Research question

Which IOB material shows the least microleakage when evaluated with methylene blue dye penetration test under stereomicroscope?

i. P (Population): Permanent single-rooted endodontically treated anterior and premolar teeth
ii. I (Intervention): 2–4 mm of gutta-percha was removed, followed by the placement of IOB material. Microleakage evaluated using methylene blue dye penetration test under a stereomicroscope
iii. C (Comparison): Microleakage associated with MTA, composite, and GIC placement as IOB was compared
iv. O (Outcome): Microleakage associated with MTA, composite, and GIC
v. S (Study design): *In vitro* and *ex vivo* studies.

Search strategy

From the year 2000–2020, electronic databases such as Medline, PubMed, EBSCOhost, Scopus, Embase, Google Scholar, and Cochrane were searched. The MESH term "Dental Microleakage" with keywords "Intra-orifice barrier," "Intracanal barrier," "Intra-orifice plug," "Coronal Microleakage," "Mineral trioxide aggregate," "Glass ionomer cement," "Composite," "Dye penetration test," and "Methylene blue test" were used with Boolean operators for data identification and screening. Search strategy is provided in Supplementary Table 1.

Eligibility

Inclusion criteria

1. *In vitro* and ex vivo studies evaluating coronal microleakage after placing MTA and/or composite and/or GIC IOB materials using methylene blue dye penetration test under a stereomicroscope.
2. Studies carried out on single-rooted teeth with a mature apex.
3. Studies used gutta-percha as an obturating material.
4. Articles published in English only.

Exclusion criteria

1. Studies carried out on the placement of IOB material after the bleaching procedure.
2. Studies carried out on single-rooted, multiple-canal, and multi-rooted teeth.
3. Microleakage evaluated using other methods or dyes.

Data identification and screening

Data screening is mentioned in Flowchart 1.

Total 5 articles were selected for this systematic review.

Reason for exclusion of articles is mentioned in Supplementary Table 2.

Data collection

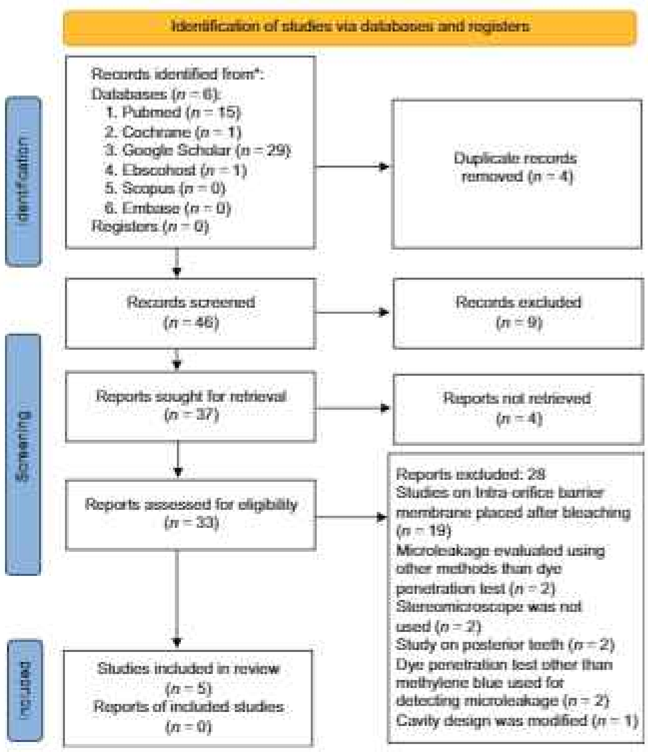
After applying eligibility criteria, two independent reviewers scrutinized the articles. The first reviewer screened the records, and the second cross-checked the records obtained by the first reviewer and vice versa. In the case of divergence, the decision was taken through mutual consensus. After going through all the included articles, an Excel sheet was formulated for data entry as a master chart.

Risk of bias

Due to the unavailability of standard quality assessment tools for *in vitro* studies, and no prior systematic review published on this topic, the following customized criteria were developed according to need of the study with reference from JBI critical appraisal tool.[26] The criteria were modified for the studies pertaining to IOB materials and the requirement of data for evaluation of quality of the study. Both reviewers selected and scored the selected paper on the basis of these criteria, and the overall risk of bias was calculated. Two reviewers independently scored the selected papers for these criteria. The criteria shown in Table 1 were used to assess the risk of bias.

Based on the data, the risk of bias was calculated. When this score was <3, it was considered unclear or had a high risk of bias. If an article fulfilled 4 or more domains, then it was considered to have a low risk of bias. If an article had four or more unmentioned domains, then it was considered either unclear or high risk of bias.

After assessing the quality of studies, a robvis tool[32] was used to create a traffic light plot [Figure 1] and weighted bar plot [Figure 2].



Flowchart 1: PRISMA flowchart. From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, *et al*. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

RESULTS

In this systematic review, all studies reported that placement of IOB material significantly reduces microleakage as compared to positive and negative control groups in which placement of IOB was not performed. All studies also reported that MTA is better as an intra-orifice material than comparison groups in terms of microleakage. The data extraction sheet for this systematic review is described in Table 2.

Characteristics of included studies

Out of the 5 studies included in this systematic review, 2 were from PubMed database[27,28] and 3 were from Google Scholar.[29-31] Studies by Ghulman *et al.*[27] and Salim *et al.* [30] showed variations in the depth of placement of IOB. Ghulman *et al.*[27] and Yavari *et al.*[28] used AH sealers in the study, whereas Salim *et al.*[30] used zinc oxide eugenol sealer. Malik *et al.*[29] reported the use of two different sealers, i.e., zinc oxide eugenol and AcroSeal, while the sealer was not mentioned by Tapashetti *et al.*[31] Variation in methodology was found among the studies, regarding the time duration for which the specimen teeth were immersed in methylene blue. Two studies reported immersion in methylene blue dye for 5 min[27,30] and one each for 48 h,[31] 5 days,[29] and 2 weeks,[28] respectively.

DISCUSSION

Successful endodontic treatment depends on thorough disinfection and three-dimensional obturation of the

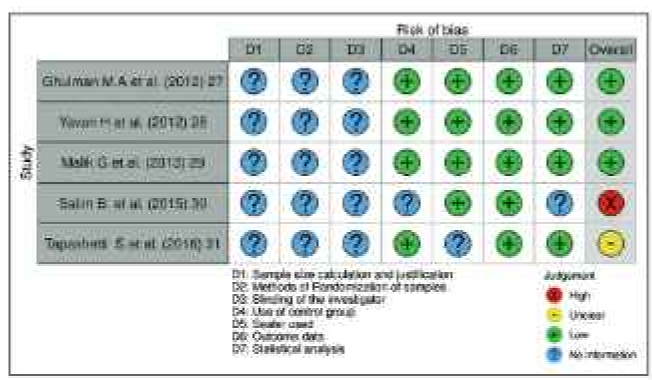


Figure 1: Visual representation of risk of bias (traffic light plot)

Table 1: Risk of bias

Study	Sample selection and size calculation and justification (D1)	Method of randomization of samples (D2)	Blinding of the investigator (D3)	Use of control group (D4)	Sealer used (D5)	Outcome data (D6)	Statistical analysis (D7)	Overall risk of bias
Ghulman *et al.*[27]	Not reported	Not reported	Not reported	Reported	Reported	Reported	Reported	Low
Yavari *et al.*[28]	Not reported	Not reported	Not reported	Reported	Reported	Reported	Reported	Low
Malik *et al.*[29]	Not reported	Not reported	Not reported	Reported	Reported	Reported	Reported	Low
Salim *et al.*[30]	Not reported	Not reported	Not reported	Not reported	Reported	Reported	Not reported	High
Tapashetti *et al.*[31]	Not reported	Not reported	Not reported	Reported	Not Reported	Reported	Reported	Unclear

Table 2: Data extraction sheet

Author	Year	Sample size (comparison)	Comparison group	Sample size (control)	Control	Methodology	Summary of study
Ghulman *et al.*[27]	2012	Group A: Depth of placement - 2 mm Group A1: 10 teeth Group A2: 10 teeth Group A3: 10 teeth Group A4: 10 teeth Group B: Depth of placement - 3 mm Group B1: 10 teeth Group B2: 10 teeth Group B3: 10 teeth Group B4: 10 teeth Total sample size: 80	Group A1, B1: Flowable composite (Fusio Liquid Dentin, Pentron Clinical Technologies, LLC) Group A2, B2: Gray ProRoot MTA (Dentsply Tulsa Dental, Tulsa, OK) Group A3, B3: Light cure GIC Type II (GC Corporation, Tokyo, Japan) Group A4, B4: GIC Type IX (GC Corporation, America)	Group C: 6 teeth (positive control) Group D: 6 teeth (negative control) Total sample size: 12	Group C: No obturation Group D: Obturation was done but no intra-orifice barrier material	i. Endodontically treated teeth, obturated with GP and AH Plus sealer were decoronated. ii. 2 mm and 3 mm of GP was removed and intra orifice barrier materials were placed in the respective groups. iii. The root apex of all samples were blocked with sticky wax and coated with nail polish except for an area of 1 mm around the orifice barrier for Group A, B, and C. Group D were completely coated. iv. Samples were submerged in 2% methylene blue dye solution and centrifuged for 5 min. v. Samples were rinsed under running tap water. vi. Microleakage was examined under stereomicroscope. (Olympus)	Least microleakage was seen with gray MTA followed by Flowable composite, GIC type IX, and GIC type II Mean Group A1=1.549 Group B1=2.86 Group A2=0.551 Group B2=0.308 Group A3=2.138 B3=2.568 Group A4=2.007 Group B4=2.968 SD Group A1=0.071 Group B1=0.004 Group A2=0.08 Group B2=0.077 Group A3=0.036 Group B3=0.041 Group A4=0.108 Group B4=0.085 At 3 mm, all the material showed statistically significant values At 2 mm, significant difference was only found between GIC type IX and GIC type II Microleakage was found more at 3 mm except for MTA which showed less leakage at 3 mm
Yavari *et al.*[28]	2012	Group A: 56 teeth Group B: 56 teeth Group C: 56 teeth Total sample size: 148	Group A: Composite resin (Flow-It Alc Pentron Clinical, Dentsply, USA) Group B: Light-cured GIC (GC-Gold Label, Japan) Group C: White ProRoot MTA (Dentsply Tulsa Dental, Tulsa, Oklahoma, USA)	Group D: 20 teeth (positive control) Group E: 20 teeth (negative control) Total sample size: 40	Group D: Obturation was done but no intra-orifice barrier material Group E: Obturation was done but no intra-orifice barrier material and crowns and roots covered completely with nail varnish and sticky wax	i. Endodontically treated teeth, obturated with GP and AH Plus sealer were decoronated. ii. 3 mm of GP was removed and intra orifice barrier materials were placed in the respective groups. iii. All the samples were coated sticky wax and later coated with nail varnish except for 1 mm around the tooth-restoration interface. iv. Samples were submerged in 2% methylene blue dye solution and centrifuged for 2 weeks. v. Samples were rinsed under running tap water. vi. Microleakage was examined under stereomicroscope (Olympus).	Least microleakage was seen with white MTA which was statistically significant as compared to flowable composite and light cured GIC Mean Group A=5.00 Group B=5.02 Group C=4.09 SD Group A=1.36 Group B=1.15 Group C=0.85 No statistical difference was seen in the microleakage of composite and light cured GIC

Contd...

Table 2: Contd...

Author	Year	Sample size (comparison)	Comparison group	Sample size (control)	Control	Methodology	Summary of study
Malik *et al.*[29]	2013	Group A: GP + ZOE sealer Group A1: 15 teeth Group A2: 15 teeth Group B: GP + AcroSeal Group B1: 15 teeth Group B2: 15 teeth Total sample size: 60	Group A1, B1: White MTA (White ProRoot, Dentsply Maillefer, Ballaigues, Switzerland) Group A2, B2: GIC (Fuji II, GC Corporation, Tokyo, Japan)	Group C: 5 teeth (positive control) Group D: 5 teeth (negative control) Total sample size: 10	Group C: Obturation was done but no intra-orifice barrier material Group D: Canal was coated with two coats of dental varnish and was restored with amalgam restoration	i. Endodontically treated teeth obturated with GP and ZOE sealer or AcroSeal respectively were decoronated. ii. 3 mm of GP was removed and Intra orifice material was placed. iii. Group A, B and C were coated with sticky wax except the orifice. Group D were completely coated. iv. All teeth were immersed in methylene blue for 5 days and then decalcified in 5% nitric and for 72 hours with fresh solution used daily. v. Teeth were then washed for 4 hours under running water and were dehydrated gradually in ascending percentages of ethanol. vi. Microleakage was examined under stereomicroscope. C DS Model, Nikon) under 15×magnification.	White MTA showed least microleakage irrespective of the sealer and the data was statistically insignificant Mean Group A1=12.34 Group B1=6.995 Group A2=6.790 Group B2=2.737 SD Group A1=1.263 Group B1=1.575 Group A2=4.771 Group B2=2.384
Salim *et al.*[30]	2015	Group A: Depth of placement - 1 mm Group A1: 15 teeth Group A2: 15 teeth Group A3: 15 teeth Group B: Depth of placement - 2 mm Group B1: 15 teeth Group B2: 15 teeth Group B3: 15 teeth Total sample size: 90	Group A1, B1: MTA gray material (Dentsply DeTrey, GmbH, Konstanz, Germany) Group A2, B2: Composite material Tetric® N-Ceram (Ivoclar, Vivadent) Group A3, B3: Glass ionomer cement (Promedica, Neumunster, Germany)	None	NA	i. Endodontically treated teeth, obturated with GP and ZOE sealer were decoronated. ii. 1 mm and 2 mm GP was removed and intra orifice material was placed in respective groups. iii. All the samples were coated sticky wax and later coated with nail varnish except for 1 mm around the orifice. iv. The teeth were immersed in 2% methylene blue dye for 5 min, later rinsed with copious water to remove the dye. v. Microleakage was examined under stereomicroscope (magnification×20)	Least leakage was seen with gray MTA followed by GIC and composite At 1 mm, all the material showed statistically significant values for microleakage At 2 mm, no statistical significance was seen

Contd...

Table 2: Contd...

Author	Year	Sample size (comparison)	Comparison group	Sample size (control)	Control	Methodology	Summary of study
Tapashetti *et al.*[31]	2016	Group A: 30 teeth Group B: 30 teeth Total sample size: 60	Group A: MTA Group B: GIC	Group C: 5 teeth (positive control) Group D: 5 teeth (negative control) Total sample size: 10	Group C: Obturation was done but no intra-orifice barrier material Group D: Entire access opening was restored with silver amalgam	i. Endodontically treated teeth, obturated with GP (sealer not mentioned) were decoronated. ii. 4 mm of GP was removed from the orifice and intra orifice barrier was placed. iii. Samples from groups A, B, and C were covered on all surfaces with sticky wax except the access openings which were left uncovered and group D, the entire tooth including the access cavity was covered with sticky wax. iv. The teeth were immersed in dye for 48 hours v. Then the teeth were subjected to decalcification. vi. Microleakage was examined under stereomicroscope at a 10X magnification	MTA intra-orifice barrier showed less leakage as compared to GIC and the difference was statistically significant Mean: Group A=1.86 Group B=11.21 SD Group A=0.740 Group B=0.787

GP: Gutta-percha, MTA: Mineral trioxide aggregate, ZOE: Zinc oxide-eugenol, NA: Not available, SD: Standard deviation, GIC: Glass ionomer cement

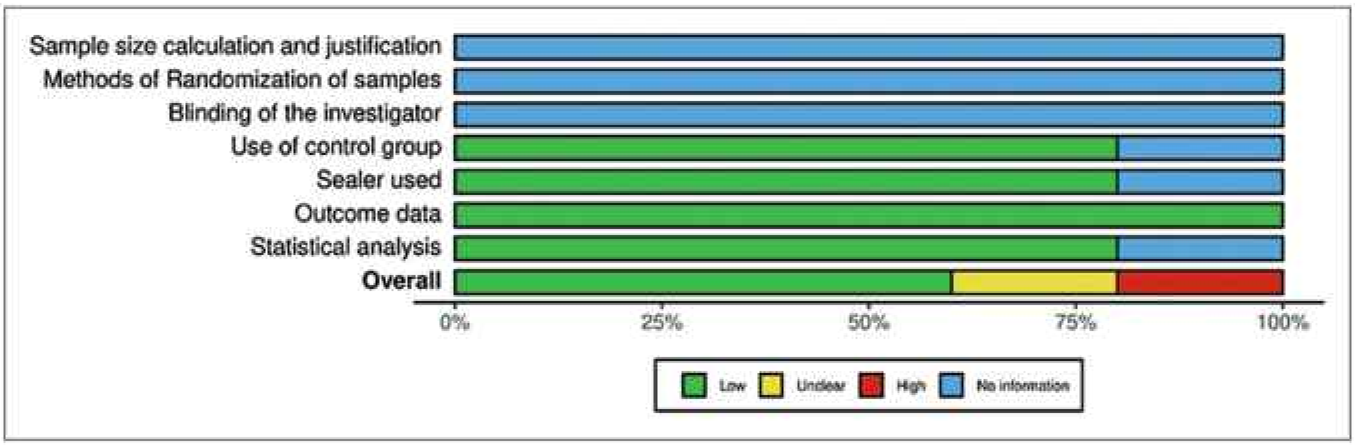


Figure 2: Visual representation of risk of bias (weighted bar plot)

canal spaces. Failures in the long term have been attributed to compromised seal, leading to bacterial re-contamination by dormant microbes of the canals, reactivating the endodontic disease. Most of the scientific studies have focused on improving materials and techniques to enhance the apical seal. Recent studies have demonstrated that an inadequate coronal seal increases the chances of re-infection due to the ingress of microbes from the oral environment.[1-4] The existing protocols for root canal obturation and postendodontic restorations have proven to be ineffective for providing a complete coronal seal.[32-35]

Placement of an IOB material has certainly proved better than the conventional methods of restoring the tooth directly over obturating material in terms of microleakage, fracture resistance, and push out bond strength.[8-11] IOB material reduces microleakage[4,25,28-30] and subsequently periapical re-infection.[9]

In this systematic review, all articles concluded that MTA showed less microleakage as compared to other groups, which is consistent with previous studies.[39-42] This can be attributed to the hydrophilic nature of MTA, which leads to setting expansion in the presence of fluid, thus creating a better seal.[22,26-28] Gray MTA showed more expansion as compared to white MTA,[15,44,45] thus less microleakage.[46] Jenkins *et al*. found that MTA demonstrated higher microleakage than flowable composite.[47] This was attributed to prolonged setting, difficulty in placement, delayed final setting, difficult and time-consuming placement of MTA. The hunt for an optimal IOB material persisted as a result of these drawbacks.

Composites have been employed as IOB materials because of their ability to bond to the tooth structure and ease of application.[30] Because of its low viscosity, the flowable composite adapts better to the wall, thus decreasing microleakage.[40,48] When employed as an intra orifice barrier material, Ghulman *et al.*[27] and Yavari *et al.*[28] found that flowable composite showed decreased microleakage. Flowable composites, on the other hand, have a high polymerization shrinkage because of the decreased filler concentration. To address this, packable composites with higher filler content were used. Packable composites have increased filler loading, but it does not completely eliminate polymerization shrinkage. The actions of root canal irrigants and gutta-percha further interfere with the bonding of the composite.[50]

GIC and its modifications have been popular in dentistry due to their fluoride-releasing properties, biocompatibility, and ability to chemically bond to the tooth structure.[51-54] In this review, Salim *et al.*[30] reported that GIC showed less leakage compared to composite resin. The disadvantage of GIC accounts for its dissolution under moisture, which jeopardizes the marginal integrity.[31] RMGIC has also been used as an IOB.[28] The resin component of RMGIC leads to polymerization shrinkage however while setting, RMGIC continues to absorb water from dentinal tubules and expands, compensating for the polymerization shrinkage.[7,21] RMGIC does not require any pretreatment and releases fluoride, which exhibits antimicrobial properties. According to the literature, RMGIC exhibits less microleakage than GIC.[27,55] Some studies, on the other hand, have found no significant difference in microleakage between conventional GIC and RMGIC.[56-58]

Microleakage can be tested *in vitro* by various methods such as dye penetration, fluid filtration, dissolution, bacteria and toxin filtration, glucose penetration test, protein microleakage test, and electrochemical microleakage test.[59] A systematic review by Jafari and Jafari on microleakage concluded that with standardization and large sample size, all microleakage tests give significant results.[59] Dye penetration test, although invasive, is the most widely used procedure due to convenience of use and inexpensive operation.[22,60,61] Molecules of methylene blue dye have a low molecular weight which can penetrate into locations where bacteria cannot penetrate.[50] Thus, if the sealing material performs well in a dye penetration test, it is likely to perform even better in clinical situations.[28,30]

All the studies in this systematic review concluded that placing an IOB material resulted in less microleakage as compared to control groups, irrespective of the material studied.[27-31] Thus, giving a conclusive interpretation that placement of IOB material reduces microleakage and improves the long term survival of endodontically treated teeth.

CONCLUSION

Placement of IOB material reduces the microleakage as compared to control groups. MTA material proved to show the least microleakage. The studies in this systematic review were conducted in an *in vitro* setup, thus a concrete statement regarding which material shows the least microleakage as an intra orifice material in clinical situation requires further evidence based studies in the form of randomized control trials and clinical trials.

Limitations

Due to the lack of randomized control trials on IOB materials, this systematic review accounts only for *in vitro* studies, which are merely an analytical type of study. The results of *in vitro* situations may not be properly reflected in clinical situations. Further investigation through randomized control trials and clinical trials is advocated to establish an evidence-based database.

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Conflicts of interest

There are no conflicts of interest.

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Supplementary Table 1: Search strategy

Database	Search strategy	Number
PubMed	(((Intraorifice barrier OR Intraorifice plug OR Intra-orifice barrier OR Intra-orifice plug OR Intracoronal plug OR Intracoronal barrier OR double seal technique) AND (Dental microleakage OR Coronal Microleakage)) AND (Dye penetration test OR Methylene blue)) AND (Mineral trioxide aggregate OR MTA OR Glass ionomer OR GIC OR Composite)	4
EBSCOhost	(((Intraorifice barrier OR Intraorifice plug OR Intra-orifice barrier OR Intra-orifice plug OR Intracoronal plug OR Intracoronal barrier OR double seal technique) AND (Dental microleakage OR Coronal Microleakage)) AND (Dye penetration test OR Methylene blue)) AND (Mineral trioxide aggregate OR MTA OR Glass ionomer OR GIC OR Composite)	1
Cochrane, Scopus, and Embase	(((Intraorifice barrier OR Intraorifice plug OR Intra-orifice barrier OR Intra-orifice plug OR Intracoronal plug OR Intracoronal barrier OR double seal technique) AND (Dental microleakage OR Coronal Microleakage)) AND (Dye penetration test OR Methylene blue)) AND (Mineral trioxide aggregate OR MTA OR Glass ionomer OR GIC OR Composite)	0
Google Scholar	(((Intraorifice barrier OR Intraorifice plug OR Intra-orifice barrier OR Intra-orifice plug OR Intracoronal plug OR Intracoronal barrier OR double seal technique) AND (Dental microleakage OR Coronal Microleakage)) AND (Dye penetration test OR Methylene blue)) AND (Mineral trioxide aggregate OR MTA OR Glass ionomer OR GIC OR Composite)	28

Supplementary Table 2: Reason for exclusion of articles

Author	Year	Reason for exclusion	Database
Shindo *et al.*[illegible]	2004	Stereomicroscope not used; digital microscope was used	PubMed
Yavari *et al.*[illegible]	2012	Variation in method of testing microleakage	PubMed
Bailón-Sánchez *et al.*[illegible]	2011	Variation in method of testing microleakage	PubMed
Lee *et al.*[illegible]	2015	Stereomicroscope not used; digital image used	PubMed
Parekh *et al.*[illegible]	2014	Variation in dye used for testing microleakage	PubMed
Faraj *et al.*[illegible]	2013	Study was done on molar tooth	Google Scholar
Ramezanali *et al.*[illegible]	2017	Variation in dye used for testing microleakage	Google Scholar
Kumar and Dengre[illegible]	2018	Study was done on molar tooth	Google Scholar
Gomaa and Ghulman[illegible]	2013	Cavity design was modified	EBSCOhost