Review Article

Minimal Invasive Approach in Deep Caries – A Systematic Review

Sidharth Menon[1]*, Zarana Sanghvi[2], Prateek Pachore[1]

[1]Department of Conservative Dentistry and Endodontics, Narsinhbhai Patel Dental College and Hospital, Visnagar, Gujarat, India.
[2]Department of Conservative Dentistry and Endodontics, Ahmedabad Dental College and Hospital, Ahmedabad, Gujarat, India.

Abstract

The best possible materials and methods for deep cavity excavation were studied. The review included various aspects of the procedure, including the effects of cariogenic bacteria, preparation of soft dentin, and the likelihood of producing tertiary dentin. The review included randomized control trials that investigated the effects of pulp exposure on deep caries in permanent teeth. It was not restricted to the treatment of primary teeth. Sources: A comprehensive electronic search was conducted in 2009–2021. The search was performed in the databases of PUBMED/MEDLINE. Total number of 225 papers retrieved all in English. The inclusion and exclusion criteria were also applied to the documents containing mainly three studies. Our research shows that minimal invasive techniques can help preserve the pulp of deep caries without the usual symptoms of irreversible pulpitis. Calcium silicate cements is used to reduce bacteria and promote remineralization of the carious dentin. Further studies should be conducted to identify the most advantageous methods of removing carious dentin through clinical trials.

Keywords: Minimal invasive, Deep caries, Pulp.

Introduction

As the biological understanding of caries has advanced, so have the management philosophies with paradigm shift in approaches to treat it. Instead of using traditional destructive preparations, we have shifted to conservative approaches that are more non-operative and less traumatic. Public health measures and initiatives have been proposed to address the various oral health inequalities, including the risk of caries. These measures aim to reduce the need for intervention and delay the onset of restorative intervention.[1]

In 2016, the guiding principles for the removal and management of different types of caries lesions were presented in a consensus. It was also stated that in shallow lesions, the goal should be to provide a cavity that can support a final restoration. There are various approaches to remove caries, such as selective removal (SR). This procedure involves leaving soft carious tissue over the pulp to avoid its exposure. Although SR is the preferred method, SWR may be performed if the need for a re-entry is not significant. Non-SR is no longer considered. Despite the cost-effectiveness of some of the less invasive options, many practitioners still have strong opinions on the required extent of tooth removal.[2]

Many clinical questions need to be considered before performing the stepwise excavation technique on permanent teeth with deep caries. What is the best way to remove soft dentin to promote remineralization? This review aims to provide a comprehensive analysis of the various steps involved in the stepwise excavation of deep cavities in permanent teeth. The goal is to reduce cariogenic bacteria in the dentin by hardening it. This procedure can take a long time to complete and is usually triggered by the development of tertiary dentin.[3]

Access this article online

Website: www.jrad.co.in

DOI: https://doi.org/10.53064/jrad.2022.13.3.180

Materials and Methods

The goal of the Cochrane Collaboration guidelines is to carry out systematic reviews that are aimed at assessing the effectiveness of interventions. This review tried to adopt the Cochrane principles in assessing the minimal invasive techniques for deep caries in permanent teeth (Cochrane Handbook).

Selection criteria

The inclusion and exclusion criteria were established for the review of papers. The criteria were based on published studies. Randomized control trials (RCTs) and controlled clinical trials

Address for correspondence: Sidharth Menon, Department of Conservative Dentistry and Endodontics, Narsinhbhai Patel Dental College and Hospital, Visnagar, Gujarat, India.
E-mail: sidharthmenon93@gmail.com

Received: Feb. 12, 2022; **Accepted:** Mar. 05, 2022; **Published:** Apr. 03, 2022

How to cite this article: Menon S, Sanghvi Z, Pachore P. Minimal Invasive Approach in Deep Caries – A Systematic Review. J Res Adv Dent 2022;13(3):174-178.

are usually conducted for the treatment of deep caries. The objective of these is to find out if the treatment of the deep cavities can result in pulp exposure. Studies involving the treatment of primary teeth were not included as well as case reports and laboratory studies.

Search strategy

The journal search, consisting of both electronic and manual searching, was undertaken to identify all relevant studies written in English.

Electronic databases

An electronic search was conducted and included the following databases from 2009 to 2021: MEDLINE. The subject search used a combination of controlled vocabulary and free text based on the search strategy for MEDLINE, which is shown as follows:

DENTAL CARIES

(TEETH + TOOTH + DENTAL) AND (CARIES + CARIOUS + DECAY + LESIONS)

(DEEP + EXTENSIVE + ASYMPTOMATIC) AND (CARIES + CARIOUS + DECAY + LESIONS)

DENTAL PULP

(DENTAL + TOOTH + TEETH) AND PULP) EXPOSE

DENTAL PULP CAVITY

DENTAL PULP DISEASE

(CARIOUS PULP) OR (CARIES PULP)

PULP DEVITALIZATION

PULP PROTECTION$

PULP MANAGEMENT

PULP (TREAT + THERAPY + EXTIRPATE + REMOVE+ EXPOSE + EXTRACT + CAP)

STEPWISE EXCAVATION

DT = (CLINICAL TRIALS + RANDOMIZED CONTROLLED TRIAL) + (STUDY + TRIAL + RANDOMIZED CONTROLLED TRIAL)

AND PY > 2009

Manual searching

The reference lists of all the relevant studies, existing reviews, and personal reprint collections of authors were screened for additional relevant publications.

Selection of relevant publications

Each publication was initially assessed for relevance by the authors using the information presented in the abstract. When an abstract was not available or failed to provide sufficient information, a reprint of the full paper was obtained. When papers or abstracts reported different stages of clinical trials, only the long-term study was included in the review.

Evaluation of clinical effectiveness

Study selection

To evaluate the clinical effectiveness of minimal invasive techniques, RCTs, in which complete caries removal was used as a control group or in which the effects of different pulp capping agents were compared, were selected independently. Because small numbers of RCTs were found. The study design of each of the selected papers was assessed independently in the review process. If a trial was excluded from evaluation, the reasons for exclusion were described.

Data extraction and synthesis

The following information was extracted from the papers selected for the evaluation of the clinical effectiveness of minimal invasive techniques for extremely deep caries in permanent teeth: Date of the study, year of publication, setting and funding source of the trials, sample size, age and gender of the patients, types of teeth and cavities restored, methods of removing caries, materials for lining, time to re-entry, and duration of study. Information on adverse events or effects was also recorded.

The outcomes were evaluated in terms of pulp exposure, pulp breakdown, post-operative pain or discomfort, amounts of cariogenic bacteria in a cavity, color and hardness of carious dentin, remineralization of softened dentin, regeneration of tertiary dentin, and retention of sealing material. Teeth with minimal invasive treatments were considered to have failed when post-operative pain or discomfort continued or pulp breakdown occurred. On the other hand, the clinical success was that pulp kept its vitality without any adverse symptoms after treatment.

Data were extracted by independently using specially designed data extraction forms. These forms were piloted on several papers and modified as required before use. Data that could be presented in graphs and figures were extracted whenever possible.

Statistical analysis

The statistical guideline in The Cochrane Handbook[4] was followed for evaluating the clinical effectiveness of minimal invasive techniques.

Results

Results of the literature search

Electronic and manual searches of journals retrieved a total of 266 papers. These studies were selected according to the inclusion and exclusion criteria as described previously. Three English studies, which are full papers, were finally identified (Hashem *et al*., Labib *et al*., and Mathur *et al*.). The summary of these clinical studies is presented in Table 1. In terms of study designs, all the three were RCTs.

Clinical methods of minimal invasive excavation

The expressions of removing carious dentin with stepwise excavation were different among the studies identified. The

Table 1: Clinical studies of minimal invasive approaches for deep caries in permanent teeth (2009)

Study	Design	Patients	Tooth type	Intervention	Control	Time t final restoration	Outcome	Setting
Hashem *et al*., 2015	Controlled clinical trials	18–76 years (median, 28 years)	Eighty-five percent of restorations were placed in molars Seventy-two restorations (36 Biodentine and 36 Fuji IX) were placed in 53 patients (21 [39.6%] women and 32 [60.4%] men) with a limit of two restorations per patient	MI protocol Biodentine placement	MI protocol Fuji IX placement	1 month	Clinical assessment + PA radiographs and CBCT immediate and 1-year follow-up	King's College Dental Institute at Guy's Hospital, London
Labib *et al*., 2019	RCT	18–47 years *n*=132	Premolars/molars with occlusal/ occlusal-proximal deep lesions (radiographically >2/3 dentine), sensible pulps, without spontaneous pain, were included	Peripheral carious tissue removal to hard dentine was performed. Pulpo-proximally, soft dentin was left. A glass ionomer (GI) restoration was placed. After 3–4 months, teeth were randomly allocated to SE (*n*=66), with reduction of the GI into a base and no further tissue removal, followed by a composite resin restoration, or SW (*n*=66), with full removal of the GI, additional excavation until firm dentine pulpo-proximally, followed by a GI-based composite restoration	NA	Immediate	Primary outcome was success (absence of endodontic/ restorative complications). Secondary outcomes were tooth survival and initial and total treatment costs. After 1 year	Outpatient clinic of a private university in Cairo, Egypt
Mathur *et al*., 2016	RCT	7–12 years *n*=109	52 permanent first molar	After satisfactory caries excavation, one of the test materials was applied at the base of the cavity according to manufacturer's instructions	NA	Immediate	An immediate post-operative CBCT scan was performed the same day. At follow-up examination, detailed clinical and radiographic examination was performed after 8 weeks, 6 months, and at 1 year	Outpatient department of the Division of Pedodontics and Preventive Dentistry, CDER, AIIMS, New Delhi

types of carious dentin removed were variously described as "superficial, soft, infected dentine," "cavitated enamel," and "active deep caries."[5-7] In all of these studies, the authors did not clearly state either how much carious dentin was removed or how much infected dentin remained in the cavities. It was clear, however, that in all the studies clinicians intended to avoid visible pulp exposure.

Amongst the three studies identified, GIC (GC Fuji IX, Fuji, and Tokyo, Japan) was used as a lining material in two studies. In the remaining studies, setting type calcium hydroxide (Dycal® Ivory, Dentsply Caulk, Dentsply, L.D. Caulk, Milford, DE, USA); Biodentine™; and MTA (ProRoot MTA; Dentsply Tulsa Dental Specialties, Dentsply International, Inc., USA) were used. The time to re-entry varied from 0 to 4 months.

Clinical findings

Clinical success rates were reported between 83.3% and 100% in the two studies (Table 2).[5,8] There were no significant differences in the success rates among the cases using different lining materials. When caries were removed by stepwise excavation without pulp exposure, pulp in most of the cases was symptomless. The conditions of dentin on re-entry were reported in five studies[8-12] and all of these studies stated that the remaining softened dentin in the cavities became darker, harder, and drier after 2–12 months following stepwise excavation.

Radiographic findings

Radiographic examinations was reported in two studies (Table 2)[5,7] and one from them reported increasing

Table 2: Clinical and radiographic assessment of minimal invasive approaches for deep caries in permanent teeth (2009)

Study	Patients	Intervention	Time re-entry	Clinical observation	Radiographic finding
Hashem *et al*., 2015	53	IPC 2 step	1 month	The clinical success rates for both Biodentine and Fuji IX were equal (83.3%). Twelve teeth lost vitality by T12 (6 Biodentine/6 Fuji IX). Among 53 patients, five patients with six restorations dropped out of the trial by failing to attend subsequent appointments. The total number of teeth analyzed excluded the dropouts (n=66)	A significant difference (P=0.02) was observed between teeth with healing/healed lesions identified using CBCT receiving Biodentine (71%) and those with new/progressed lesions receiving Fuji IX (88%)
Labib *et al*., 2019	115	SE versus SW	3–4 months	During the first 3 months (T1-T2), 8 teeth (6%) in eight patients showed signs of failure (three pulp necrosis, four irreversible pulpitis, and one patient had post-operative pain and had her tooth extracted at another dental clinic). Ten patients with 11 teeth (8.3%) were lost to follow-up At T2, five pulp exposures (8.9%) occurred in SW, and none in SE In the following 9 months (T2-T3), four further teeth (three in SE and one in SW) experienced pulpal complications. Moreover, a total of 15 teeth (11.3%) in 13 patients were lost to follow-up between T2 and T3	
Mathur *et al*., 2016	94	IPC 1 step	0 months	A total of 95 teeth (calcium hydroxide (setting)-31, GIC Type II-33, and MTA-31) could be followed up at the end of 1 year. There were no treatment failures reported in any case at 8-week and 6-month follow-up. One patient reported with abscess in mandibular primary second molar at 8 months which was treated with GIC as IPT material. Two more patients presented with pain in teeth treated with calcium hydroxide (setting) at 11 months postoperatively. Therefore, the clinical and radiographic success at 12 months was found to be 93.6% (29/31) with calcium hydroxide (setting), 97% (32/33) in GIC (Type VII), and 100% (31/31) in MTA with no significant differences in success rates	The radiodensity of the dentin barrier (HU) was found to increase at 6-month follow-up in three groups, respectively, signifying a more calcified bridge at dentin pulp junction The findings suggest more gain in radiodensity of the barrier formed in MTA and GIC group than calcium hydroxide though the differences were not significant (ANOVA)

radiodensity or radiopacity, suggesting an encouraging process of remineralization of the remaining carious dentin after stepwise excavation.[6] However, it was difficult to identify exactly when the remineralization started or when the remineralization became sufficient for re-entry, since the observational periods were different in each of the studies. One study reported the generation of tertiary dentin, the radiodensity of the dentin barrier (in Hounsfield units) was found to increase at 6-month follow-up in three groups, respectively, signifying a more calcified bridge at dentin pulp junction. The findings suggest more gain in radiodensity of the barrier formed in MTA and GIC group than calcium hydroxide though the differences were not significant (ANOVA).

Discussion

Results of the electronic and manual searches showed that there were small numbers of RCTs that fulfilled the inclusion criteria in this research field. Because limited numbers of RCTs and used the same clinical methods and materials were available, we could not undertake data synthesis followed by the selected statistical analyses. Instead, we summarized the outcome of the minimal invasive techniques pertaining to the clinical and radiographic findings (Table 2). This approach seemed appropriate to evaluate the clinical effectiveness of the minimal invasive techniques.

In this systematic review, as previously reported, minimal invasive was considered effective for the preservation of pulp that might be exposed during removal of extremely deep caries in permanent teeth when there were no clinical symptoms showing irreversible pulpitis. The collective results indicate that cariogenic bacteria are effectively reduced, and remaining softened dentin becomes harder as a consequence of remineralization. Paddick *et al*.[13] reported details of changes in cariogenic bacteria on stepwise excavation.

During the interval between sealing a cavity and re-entry, the available nutrient, primarily serum proteins, or the relative simplicity and homogeneity of the nutrient supply significantly affected the surviving bacteria. The surviving bacteria were less complex, based on compositional, phenotypic, and genotypic analyses, than those isolated from carious lesions which were also exposed to salivary secretions and pH perturbations. In addition, not only calcium hydroxide but also other materials such as Biodentine™; Fuji IX GIC and MTA are suitable as lining materials, since all these materials were found to have superior marginal seal and to promote remineralization as effectively as calcium hydroxide.

The methods and extent of removing carious dentin during minimal invasive procedures were not sufficiently clear when comparing the expressions in the various selected papers (Table 1).

Studies have shown that after leaving carious dentin in deep cavities, patients could restore their damaged cavities without re-entry.[14-16] However, the amount or extent of dentin that can be left in the cavities has again not been discussed in those studies. The consensus on this issue is to remove peripheral caries dentin completely, to remove as much of the caries

adjacent to the pulp as possible, and to avoid pulp exposure with maximum caution. In addition, when comparing the bonding capabilities of carious dentin to sound dentin, it has been observed that the former exhibits inferior adhesion.[17,18] Therefore, removing peripheral carious dentin and achieving firm marginal adhesion are a minimum mandatory requirement for protecting vital pulp from the invasion of bacteria and any other potentially invasive stimuli. For long-lasting restorations, after removing deep caries, marginal sound dentin is critically important since it can produce more reliable adhesion to restorative materials. However, we could not confirm when remineralization became sufficient for re-entry or how quickly it occurred. Again, the onset and speed of remineralization may be affected by the quality and quantity of the remaining carious dentin in the cavities following minimal invasive procedures. To the best of our knowledge, there has not been a clinical study in which the speed and amount of remineralization have been investigated longitudinally. Lack of such information limits the determination of an ideal time for re-entry.

Only one study reported the generation of tertiary dentin found on radiographic examination, but the results were not significant.[7] It should be noted that evaluating the generation of tertiary dentin is not easy, since only precisely standardized longitudinal radiographic or histological examinations make such an assessment possible. Generation of tertiary dentin has usually been considered to relate to lesion activity. When a lesion progresses rapidly, it can be either atubular or no tertiary dentin. The difference between the two is that the former has tubules and the latter has normal dentin.[19,20] From the results of this systematic review, the likelihood of tertiary dentin generation is not so frequent.

This finding suggests that removal of carious dentin at reentry must be carried out cautiously to avoid pulp exposure, since the thickness of the remaining dentin may be unchanged after minimal invasive procedure even though remaining carious dentin may have become harder.

Further clinical trials with high levels of study design in this research field are needed to clarify the best possible methods and materials for minimal invasive protocols. Specifically, clinical studies must devise recommendations for how much and how far to remove carious dentin during stepwise excavation. Conducting such studies and subsequently more clearly understanding the changes in carious dentin after minimal invasive excavation will facilitate the elucidation of the best possible clinical methods that can enhance the preservation of pulp in deep cavities.

Conclusions

This review emphasizes the usage of the minimal invasive techniques that can be used for the preservation of pulp in deep caries. Further studies are needed to best identify the methods to safely and effectively remove carious dentine during caries excavation.

References

1. Edwards D, Stone S, Bailey O, Tomson P. Preserving pulp vitality: Part one-strategies for managing deep caries in permanent teeth. Br Dent J 2021;230:77-82.
2. Chai B, Tay B, Chow C, Fuss J, Krishnan U. Treatment preferences for deep caries lesions among Australian dentists. Aust Dent J 2019;65:12740.
3. Hayashi M, Fujitani M, Yamaki C, Momoi Y. Ways of enhancing pulp preservation by stepwise excavation: A systematic review. J Dent 2011;39:95-107.
4. Cochrane Handbook for Systematic Reviews of Interventions. Available from: http://www.cochrane-handbook.org. [Last accessed on 2022 Dec 22].
5. Hashem D, Mannocci F, Patel S, Manoharan A, Brown JE, Watson TF, *et al*. Clinical and radiographic assessment of the efficacy of calcium silicate indirect pulp capping: A randomized controlled clinical trial. J Dent Res 2015;94:562-8.
6. Labib ME, Hassanein OE, Moussa M, Yassen A, Schwendicke F. Selective versus stepwise removal of deep carious lesions in permanent teeth: A randomised controlled trial from Egypt-an interim analysis. BMJ Open 2019;9:e030957.
7. Mathur VP, Dhillon JK, Logani A, Kalra G. Evaluation of indirect pulp capping using three different materials: A randomized control trial using cone-beam computed tomography. Indian J Dent Res 2016;27:623-9.
8. Maltz M, Oliveira EF, Fontabella V, Carminatti G. Deep caries lesions after incomplete dentin caries removal: 40-month follow-up study. Caries Res 2007;41:493-6.
9. Bjørndal L, Larsen T. Changes in the cultivable flora in deep carious lesions following a stepwise excavation procedure. Caries Res 2000;34:502-8.
10. Bjørndal L, Thylstrup A. A practice-based study on stepwise excavation of deep carious lesions in permanent teeth: A 1-year follow-up study. Community Dent Oral Epidemiol 1998;26:122-8.
11. Bjørndal L, Larsen T, Thylstrup A. A clinical and microbiological study of deep carious lesions during stepwise excavation using long treatment intervals. Caries Res 1997;31:411-7.
12. Ogawa F, Machida Y. Clinical observation of indirect pulp capping on deep carious lesions. Shikwa Gakuho 1984;84:43-50.
13. Paddick JS, Brailsford SR, Kidd EA, Beighton D. Phenotypic and genotypic selection of microbiota surviving under dental restorations. Appl Environ Microbiol 2005;71:2467-72.
14. Bjørndal L, Simon S, Tomson PL, Duncan HF. Management of deep caries and the exposed pulp. Int Endod J 2019;52:949-73.
15. Neelakantan P, Rao CV, Indramohan J. Bacteriology of deep carious lesions underneath amalgam restorations with different pulp-capping materials-an *in vivo* analysis. J Appl Oral Sci 2012;20:139-45.
16. Nakajima M, Kunawarote S, Prasansuttiporn T, Tagami T. Bonding to caries-affected dentin. Jpn Dent Sci Rev 2011;47:102-14.
17. Cardoso MV, de Almeida Neves A, Mine A, Coutinho E, Van Landuyt K, De Munck J, *et al*. Current aspects on bonding effectiveness and stability in adhesive dentistry. Aust Dent J 2011;56:31-44.
18. Goldberg M, Kulkarni AB, Young M, Boskey A. Dentin: Structure, composition and mineralization. Front Biosci (Elite Ed) 2011;3:711-35.
19. Liang T, Hu Y, Zhang H, *et al.* Mouse *Dspp* frameshift model of human dentinogenesis imperfecta. Sci Rep 2021;11:20653.
20. Reparative Dentin. Vol. 1. Science Direct Topics; 2019 Available from: https://www.sciencedirect.com/topics/engineering/reparative-dentine [Last accessed on 2022 Jan 12].