Management of the deep carious lesion: a literature review

Abstract

Statement of the problem: The management of the deep carious lesion is a topic of keen interest to the dental profession with many and varied treatment modalities advocated in the scientific literature.

Purpose of the study: This literature review proposes to summarise current consensus approaches and scientific thinking in this area. Some new treatment advances have been advocated in recent years and their efficacy is also examined. Topics and areas of interest are proposed for future research.

Methods: The studies examined in this review were based on searches online in the PubMed, Embase, and Google Scholar search engines, and Cochrane reviews, and include systematic reviews and consensus papers, as well as observational studies, randomised controlled trials and meta-analyses.

Conclusion: Problems exist in this area regarding precise definitions and measurement of deep carious lesions in practice, and standardisations of measurement do not currently exist. This is an area where further study and research would be welcome.

Journal of the Irish Dental Association 2020; 67 (1): 36-42

Introduction: dental caries, its sequalae and appropriate caries management

Dental caries is a disease process affecting dental hard tissues, caused by a shift in the normal oral microbiological biofilm balance to a more acidophilic, aciduric and cariogenic, biofilm consisting mainly but not exclusively of *Streptococci mutans* and lactobacilli. Frequent ingestion of fermentable carbohydrates encourages an environment of low pH within the biofilm, which favours the selective growth of cariogenic bacteria.[1]

A cumulative demineralisation pattern over time leads to dissolution of dental hard tissues and the formation of a carious lesion. Other factors such as fluoride ion concentration and salivary flow rate modify the caries process and are intimately involved in determining the likelihood of overall mineral loss and the rate at which this occurs. The operative treatment of the deep carious lesion (DCL) should:

- aid biofilm control on a tooth surface;
- protect the pulp-dentine complex and arrest the lesion activity by sealing the coronal part; and,
- restore the function, form and aesthetics of the tooth.[2]

Dr Brenda Barrett
BDentSc MClinDent
General practitioner
Pembroke Dental
Carlow

Dr Michael O'Sullivan
Senior Lecturer/Consultant in Restorative Dentistry (Special Needs)
Department of Restorative Dentistry and Periodontology
Dublin Dental University Hospital
Lincoln Place, Dublin 2

Corresponding author: Dr Brenda Barrett, Pembroke Dental, Pembroke, Carlow Town, Co. Carlow.
T: 059-913 1667 E: bbarrett@pembrokedental.ie

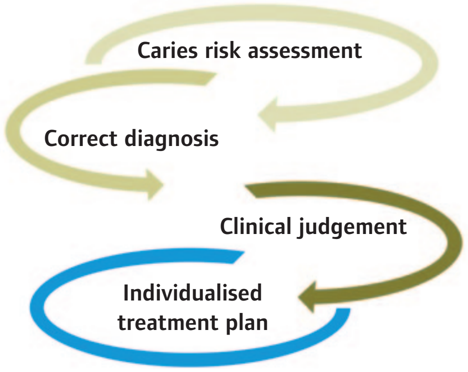

FIGURE 1: Sequential gathering of information leading to individualised patient treatment plan during caries management.

Maintaining pulpal vitality has a great impact on the lifetime prognosis of a tooth and also reduces the overall lifetime cost of retaining that tooth.[3]

Many studies have shown that sealing of carious lesions can lead to caries arrest so this is accepted as one of the guiding principles when restoring a DCL.[4]

Evidence-based research has encouraged a minimally invasive (MI) approach to the management of caries in the post-fluoride caries generation.[2] This approach stresses a preventive philosophy, individualised risk assessments for patients, early detection of lesions, and efforts to remineralise non-cavitated lesions, with the provision of preventive care to minimise the need for operative intervention (**Figure 1**). When operative intervention is unequivocally required, the procedure used should be as minimally invasive as possible.[5]

With the above treatment principles in mind, the DCL should be treated with an MI treatment strategy, with the primary aim of preserving pulp vitality if possible and restoring the tooth to its original form so that normal biofilm control can be re-established.[6]

Precise terminology used in relation to the operative management of the deep carious lesion

In 2015, the International Caries Consensus Collaboration, comprising worldwide cariology experts, decided on consensus recommendations for terminology in relation to managing carious lesions.[7] This terminology is used throughout this review.

A carious lesion is a consequence of a disease process and its management involves intervention to arrest its progression by conversion of the lesion to a cleansable form. The size and depth of a carious lesion can be assessed clinically or radiographically, but there is currently no standard definition or measurement of the term DCL.

According to this Consensus Collaboration, "deep lesions are defined as those radiographically involving the inner pulpal third or quarter of dentine or with clinically assessed risk of pulpal exposure" (**Figure 2**).

The hardness of dentine is an indicator of the extent of caries in dentinal tissue. The International Caries Consensus Collaboration has defined the different clinical presentations of affected carious dentine.

Soft dentine

Soft dentine will deform or deflect when a hard instrument is pressed onto it and can be easily scooped up (e.g., with a hand excavator), with little force being required.

Leathery dentine

Leathery dentine does not deform when an instrument is pressed onto it and can still be easily lifted without much force being required. There may be little difference between leathery and firm dentine, with leathery being a transition on the spectrum between soft and firm dentine.

Firm dentine

Firm dentine is physically resistant to hand excavation, and some pressure needs to be exerted through an instrument to lift it.

Hard dentine

For hard dentine, a pushing force needs to be used with a hard instrument to engage the dentine, and only a sharp cutting edge or a bur will lift it. A scratchy sound or 'cri dentinaire' can be heard when a straight probe is taken across the dentine.

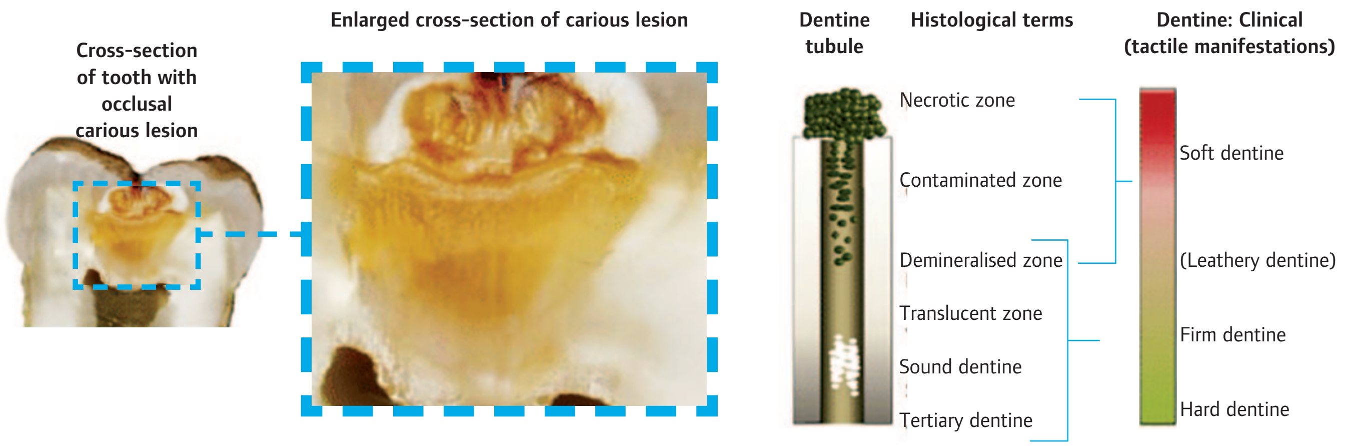

FIGURE 2: Diagrammatic representation of the carious lesion.[8]

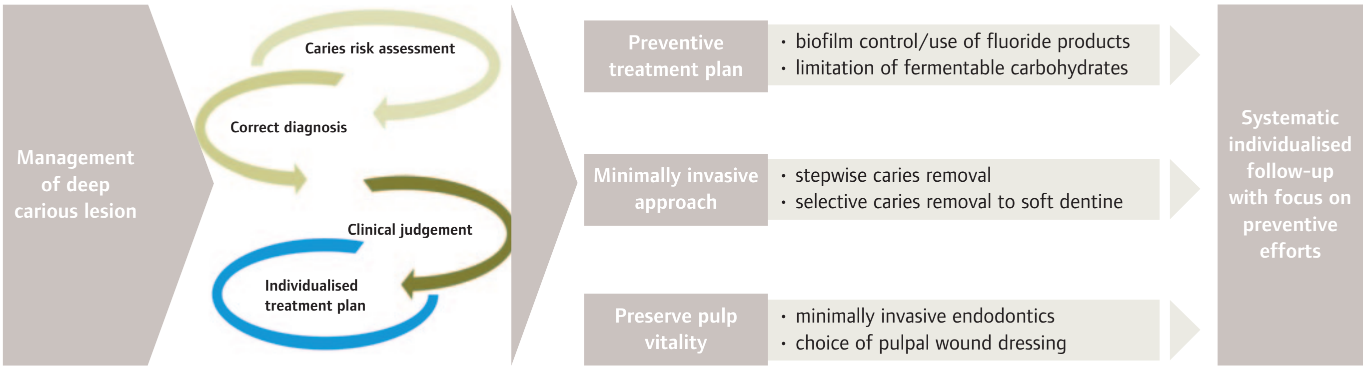

FIGURE 3: Sequential, evidence-based management approach to DCLs.

The classical approach to caries removal: non-selective removal to firm/hard dentine or complete caries removal

Conventional or classical management of caries involves*:*

- removal of all carious tissue (non-selective removal to hard dentine) even at the risk of pulpal exposure;
- remaining dentine must be hard and firm, often tested by means of a tactile approach with a sharp excavator; and,
- looking for the 'chattering' sound or cri dentinaire.

The rationale for this extensive tissue removal is:

- removal of all infected dentine and bacterial removal so that caries could be stopped from progressing further;
- providing a firm base to the lesion so that restorative materials could be placed and retained adequately; and,
- removing demineralised discoloured dentine.

There is no evidence-based scientific rationale behind this approach, although it is practised worldwide and in some countries remains the overwhelming treatment of choice for DCLs.[9]

Inherent risks

There are a number of risks to this approach, including:

- high risk of pulpal exposure during complete caries removal;
- can also be very destructive of tooth tissue, pushing the affected tooth further along the restorative cycle; and,
- unnecessary reduction of residual dentine floor thickness above the pulpal tissue, which is critical to pulpal health.

Non-selective removal to hard dentine or complete caries removal is now considered overtreatment and this approach is no longer recommended. Several recent systematic reviews agree with this consensus opinion.[10-12]

Stepwise management approach

This technique was introduced to manage DCLs with no signs or symptoms of irreversible pulpitis, but where pulpal exposure could be expected if complete caries removal was attempted (**Figure 3**).[13] The outline operative procedure involves:

- the outermost necrotic carious dentine is partially removed, leaving a soft layer of carious dentine over the pulpal floor;
- the peripheries of the lesion are cleaned to hard dentine;
- the tooth is then sealed with a provisional restoration to entomb any remaining bacteria in the carious dentine for several weeks to months, to allow remineralisation of the carious dentine and the formation of tertiary dentine within the pulpal chamber; and,
- when the tooth is definitively restored, the amount of carious dentine that requires removal is often lessened due to remineralisation and re-hardening of dentine.

Upon re-entering the lesion, the remaining dentine is drier and harder, making it easier to remove without exposing pulpal tissue, indicating reduced lesion activity.

The cultivable microflora in the lesion change before and after stepwise caries removal.[13,14] At the first stage of caries removal, a mixed microbiota is found containing mainly lactobacilli, gram-positive and gram-negative rods, and streptococci. Lactobacilli and gram-positive rods dominate the colony-forming units.

After re-entry, the overall colony numbers fall markedly, and the overall proportion of lactobacilli and gram-negative rods substantially reduces. The flora is dominated by *Actinomyces naeslundii* and *Streptococci orallis*, not typical of the cariogenic microbiota of DCLs.[15]

Stepwise caries removal involves sealing off residual caries from their source of fermentable dietary carbohydrates, thus encouraging arrest of the caries process. The provision of an adequate seal by the provisional restoration provided is integral to the success of this treatment. If an adequate peripheral seal is provided, the need for the re-entry second stage has been questioned.[16] Several studies show higher success rates in terms of retaining pulp vitality long term when the stepwise technique is used in comparison to complete caries removal.[17-19]

Ultraconservative management approach: selective removal of carious dentine

Selective removal of caries is a similar approach to stepwise caries removal but is more conservative in nature. Its aim is to avoid pulpal exposure by restricting caries removal comfortably away from the pulp chamber. The operative plan is to clean carious dentine from the peripheral walls of the carious lesion but to leave caries *in situ* over the pulpal floor and place a definite restoration that seals the carious dentine. This takes place in one visit and no re-entry visit is envisaged.

Selective removal of dentine can be further classified into two subsections:

1. **Selective removal to firm dentine**

   This involves removing peripheral dentine around the cavity margins to firm dentine but only excavating to leathery dentine over the pulpal floor. There is resistance to a hand excavator on the pulpal floor, but the peripheral margins are left hard (cri dentinaire) after removal of dentine is complete. This is the treatment of choice in shallow or moderately deep cavitated dentine lesions according to the International Caries Consensus Committee.

2. **Selective removal to soft dentine**
   This is advocated as the treatment of choice in DCLs as it lessens the risk of physiological stress or exposure of pulpal tissue. Soft carious tissue is left over the pulpal tissues to avoid exposure, encouraging pulp health, while peripheral enamel and dentine are prepared to hard dentine, to allow an effective adhesive seal to be achieved by restoration placement. Selective removal to soft dentine reduces the risk of pulp exposure in deep lesions significantly compared with non-selective removal to hard dentine or selective removal to firm dentine.[7]
   Postulated concerns in relation to selective caries removal include the risk of residual caries progression, reduced fracture resistance, and possible higher incidence of long-term clinical restoration failure.
   In a Cochrane review by Ricketts *et al.*, exposure rates were shown to be significantly lower using a stepwise approach as opposed to complete caries removal. Complete caries removal involves a much higher risk of pulpal exposure in comparison to selective removal of carious dentine.[20]
   Assuming that these pulpal exposures are treated mainly by direct pulp capping, which has a poorer success rate in cases of carious exposure, then it must be inferred that selective removal of dentine should be used routinely as it does not have any disadvantages compared to complete caries removal.[21]

Vital pulp therapies – minimally invasive endodontics?

Vital pulp therapy is the umbrella term for three types of procedure that are performed on vital carious exposures: direct pulp capping; partial/complete pulpotomy; and, full/partial pulpectomy.

Direct pulp capping involves the placing of a medicament or wound dressing, commonly calcium hydroxide, over the pulp exposure.

The success rate of direct pulp capping procedures using setting calcium hydroxide as measured by maintenance of pulpal vitality was 37% after five years and 13% after 10 years. Most failures happened slowly and asymptomatically over time, with the pulp becoming necrotic or calcifying.[22]

The low success rates of direct pulp capping using calcium hydroxide in cariously exposed teeth have led to controversy about the use of this technique. The introduction of newer biocompatible materials, such as mineral trioxide aggregate (MTA) and Biodentine (Septodont; Lancaster, PA, USA, and France), has sparked renewed interest with their promise of comparatively higher success rates.

Full/partial pulpotomy is a well-established technique in primary teeth and has shown some success in permanent young molars using calcium hydroxide materials. In light of studies showing much higher success rates following partial pulpotomy techniques in carious teeth using MTA,[23,24] the advent of MI endodontics may be approaching.

Overall, in keeping with the philosophy of MI techniques, the maintenance of a vital pulp, even partially, has many advantages over full pulpectomy. The management of the inflamed pulp is trending to a more conservative approach and techniques such as direct pulp capping, full or partial pulpotomy in vital DCLs using newer materials such as MTA or similar are being revisited with some success.[25]

Table 1: Properties of commonly used restorative materials.

Amalgam	Composite	Glass ionomer
Historical significance – long track record	In use over 50 years	In use over 50 years
Unaesthetic; patient concerns re appearance and safety	Aesthetic demand by patients	Main use in permanent teeth is as provisional/ interim restoration
Minamata signals end of era in Europe		
Ease of use, placement and finishing	Technically more demanding	Usage mainly limited to primary teeth
Proven longevity	Longevity nearing equivalence of amalgam	Poor longevity and wear resistance
Good seal; corrosion products	Greater fracture resistance than amalgam in large restorations in some studies	Release of fluoride ions
Lack of adhesive properties	Adhesive restoration	Chemical adhesion properties

Restoring the deep carious lesion

The choice of restorative material used depends on many factors, such as:

- extent of lesion;
- overall carious risk;
- carious lesion activity; and,
- individual patient conditions, e.g., dental crowding, saliva rate (**Table 1**).

Increasingly, amalgam is becoming unacceptable to dental patients from an aesthetic viewpoint. Environmental concerns are also an issue, and the Minamata Treaty proposes the eventual phase out of amalgam in Europe by 2030 with increasing phase down of its use currently being introduced.[26]

Improvements in the composition of composite resin and bonding agents are leading to increased longevity of restorations.[27] Most studies show dental amalgam to have superior longevity as a restoration in comparison to resin composite. However, some studies have shown that composite is now reaching near equivalence.[28] Large amalgam restorations may show a higher fracture failure rate than the comparable composite resin restoration.[29]

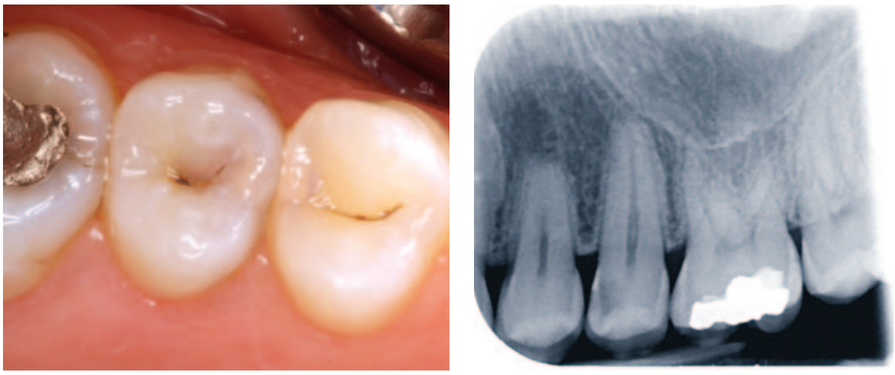

FIGURE 4: Clinical and radiographic appearance of a carious lesion – can we accurately describe how deep this lesion is?

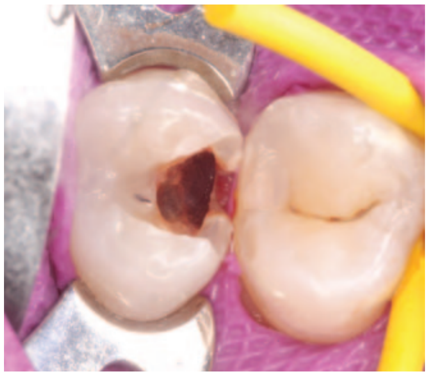

FIGURE 5: Clinical decisions made during caries removal have a direct bearing on the long-term outcome for this tooth, such as the caries management approach undertaken, pulpal treatment considerations and choice of restorative material.

The guiding principles of minimal intervention dentistry should still be practised when deciding to replace an existing restoration or re-intervene when defects are found in current restorations. Similarly, once the decision to re-intervene has been made, sound tooth tissues should be preserved during replacement to preserve pulpal health, reduce costs, and limit the subjective burden to the patient. Thus, resealing, refurbishing, repolishing, and repairing restorations should be performed whenever possible, and complete restoration replacement avoided.[30] Repaired restorations have a clinically equivalent survival rate to those restorations that are completely replaced.[31]

Pulpal wound dressings

The purpose of pulp capping materials is to produce and maintain a bacterially impervious seal and physical barrier over the direct pulpal complex, thus reducing bacterial insult following pulpal exposure. Ideally, hard tissue barrier formation is also induced, resulting from pulpal activity. Ideally, these dressings should:

- be non-toxic, biocompatible, antibacterial, and provide a long-term impervious seal over the wound; and,
- provide an environment that encourages regeneration of the pulp-dentinal complex so that the self-reparative capacity of the pulp is optimised.[32]

Calcium hydroxide cement has been the gold standard material for many years. Its mode of action involves the production of hydroxyl ions in a high pH environment, inducing a superficial pulpal necrosis. This mild cytotoxicity stimulates pulpal cells to proliferate and differentiate, producing reparatory tertiary dentine.[33] This tertiary dentine forms a calcific dentinal bridge and acts as a physical barrier to stop ingress of bacteria into the pulpal tissues. Unfortunately, there are some issues with calcium hydroxide, including:

- it does not bond directly to and does not adequately seal the pulpal tissue exposure area;
- it is soluble and degrades over time leaving voids or dead space, with microleakage under restorations;
- the tertiary dentine produced has numerous tunnel defects and is irregular in production; and,
- the current hypothesis is that bacterial ingress could occur through porous tertiary dentine and induce pulpal irritation, dystrophic calcification and potentially degenerative changes in the pulp.[34]

Some calcium silicate-based bioceramic materials, such as MTA, calcium-enriched mixture (CEM) and Biodentine, have been introduced as alternatives in recent years. All are capable of inducing osteogenesis, dentinogenesis and cementogenesis, inducing hard tissue formation.[35] MTA and Biodentine have been shown *in vivo* to produce thicker, more homogenous and complete reparative dentine bridges in comparison to calcium hydroxide.

The main active compounds in these products are calcium hydroxide and a calcium silicate hydrate gel, which solidifies and forms an effective seal and barrier. Advantages of MTA include:

- excellent sealing ability;
- non-absorbable due to its low solubility; and,
- high compressive strength.

Problems exist and include:

- long setting time;
- difficult handling properties; and,
- staining and discolouration of the treated tooth.[36,37]

Biodentine is a tri-calcium silicate-based material used as a bioactive material and pulp-capping agent. It has:

- a much shorter setting time than MTA (approximately 12 minutes);
- when set, similar mechanical properties to dentine itself; and,
- handling characteristics that are easier than MTA.

Research on the biocompatibility and dentinogenic capacity of Biodentine as compared to MTA is currently scarce but one recent study[38] showed similar results between the two products. Its long-term efficacy needs further investigation.

Discussion

Figures 4 and **5** show general visual examples of the deep carious lesion. The treatment of the DCL is one of the most common scenarios in dentistry, but

some basic key definitions are still a matter of debate, such as:
- the precise definition of a DCL;
- the precise definition of the depth and size of a DCL; and,
- as a rule, is a DCL cavitated?

These fundamental features of a DCL should be agreed and precisely defined so that future scientific studies can be undertaken with agreed definition parameters in place. Any results and conclusions from these studies would have a uniform scientific basis and their results and conclusions would be more universally accepted. This could translate more simply and quickly into true evidence-based dental operative practices.

This literature review has shown that it is a period of great change but also great innovation in the management approach for DCLs. The dental profession is in a time of flux with evidence-based research and best practice not always in line with what happens in daily general dental practice. More wide-ranging, evidence-based research should ideally be undertaken to support these changes in the best interests of science and patients.

References

1. **Marsh, P.D.** Microbiology of dental plaque biofilms and their role in oral health and caries. *Dent Clin North Am* 2010; 54 (3): 441-454.
2. **Kidd, E.A.M., Fejerskov, O.** What constitutes dental caries? Histopathology of carious enamel and dentin related to the action of cariogenic biofilms. *Journal of Dental Research* 2004; 83.
3. **Fejerskov, O.** Concepts of dental caries and their consequences for understanding the disease. *Community Dent Oral Epidemiol* 1997; 25: 5-12.
4. **Oong, E.M., Griffin, S.O., Kohn, W.G., Gooch, B.F., Caufield, P.W.** The effect of dental sealants on bacteria levels in caries lesions. *J Am Dent Assoc* 2008; 139 (3): 271-278.
5. **Pitts, N.B., Longbottom, C., Fontana, M., Young, D.A., Wolff, M.S., Pitts, N.B., *et al.*** Defining dental caries for 2010 and beyond. *Dent Clin North Am* 2010; 54 (3): 423-440.
6. **Tyas, M.J., Anusavice, K.J., Frencken, J.E., Mount, G.J.** Minimal intervention dentistry – a review. FDI Commission Project 1-97. *Int Dent J* 2000; 50 (1): 1-12.
7. **Innes, N.P.T., Frencken, J.E., Bjørndal, L., Maltz, M., Manton, D.J., Ricketts, D., *et al.*** Managing carious lesions: consensus recommendations on terminology. *Adv Dent Res* 2016; 28 (2): 49-57.
8. **Ogawa, K., Yamashita, Y., Fusayama, T.** The ultrastructure and hardness of the transparent layer of human carious dentin. *J Dent Res* 1983; 62 (1): 7-10.
9. **Schwendicke, F., Stangvaltaite, L., Holmgren, C., Maltz, M., Finet, M., Elhennawy, K., *et al.*** Dentists' attitudes and behaviour regarding deep carious lesion management: a multi-national survey. *Clin Oral Investig* 2017; 21 (1): 191-198.
10. **Ricketts, D., Lamont, T., Innes, N., Kidd, E., Clarkson, J.** Operative caries management in adults and children (Review). *Cochrane Database Syst Rev* 2013; (3) :1-52.
11. **Thompson, V., Craig, R.G., Curro, F.A., Green, W.S., Ship, J.A.** Treatment of deep carious lesions by complete excavation or partial removal: a critical review. *J Am Dent Assoc* 2008; 139 (6): 705-712.
12. **Schwendicke, F., Meyer-Lueckel, H., Dörfer, C., Paris, S.** Failure of incompletely excavated teeth – a systematic review. *Journal of Dentistry* 2013; 41: 569-580.
13. **Bjorndal, 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 (6): 411-417.
14. **Bjørndal, L.** Indirect pulp therapy and stepwise excavation. *Journal of Endodontics* 2008; 34: S29-S33.
15. **Bjørndal, L., Larsen, T.** Changes in the cultivable flora in deep carious lesions following a stepwise excavation procedure. *Caries Res* 2000; 34 (6): 502-508.
16. **Maltz, M., de Oliveira, E.F., Fontanella, V., Bianchi, R.** A clinical, microbiologic, and radiographic study of deep caries lesions after incomplete caries removal. *Quintessence Int* 2002; 33 (2): 151-159.
17. **Leksell, E., Ridell, K., Cvek, M., Mejare, I.** Pulp exposure after stepwise versus direct complete excavation of deep carious lesions in young posterior permanent teeth. *Endod Dent Traumatol* 1996; 12 (4): 192-196.
18. **Schwendicke, F., Frencken, J.E., Bjørndal, L., Maltz, M., Manton, D.J., Ricketts, D., *et al.*** Managing carious lesions: consensus recommendations on carious tissue removal. *Adv Dent Res* 2016; 28 (2): 58-67.
19. **Hoefler, V., Nagaoka, H., Miller, C.S.** Long-term survival and vitality outcomes of permanent teeth following deep caries treatment with step-wise and partial-caries-removal: a systematic review. *J Dent* 2016; 54: 25-32.
20. **Ricketts, D., Lamont, T., Innes, N.P.T., Kidd, E., Clarkson, J.E.** Operative caries management in adults and children. *Cochrane Database Syst Rev* 2013; (3): CD003808.
21. **Schwendicke, F., Dörfer, C.E., Paris, S.** Incomplete caries removal: a systematic review and meta-analysis. *J Dent Res* 2013; 92 (4): 306-314.
22. **Asgary, S., Fazlyab, M., Sabbagh, S., Eghbal, M.J.** Outcomes of different vital pulp therapy techniques on symptomatic permanent teeth: a case series. *Iran Endod J* 2014; 9 (4): 295-300.
23. **Barthel, C.R., Rosenkranz, B., Leuenberg, A., Roulet, J.F.** Pulp capping of carious exposures: treatment outcome after 5 and 10 years: a retrospective study. *J Endod* 2000; 26 (9): 525-8.
24. **Matsuo, T., Nakanishi, T., Shimizu, H., Ebisu, S.** A clinical study of direct pulp capping applied to carious-exposed pulps. *J Endod* 1996; 22 (10): 551-556.
25. **Nowicka, A., Lipski, M., Parafiniuk, M., Sporniak-Tutak, K., Lichota, D., Kosierkiewicz, A., *et al.*** Response of human dental pulp capped with biodentine and mineral trioxide aggregate. *J Endod* 2013; 39 (6): 743-747.
26. **United Nations Environmental Programme.** Conference of Plenipotentiaries on the Minamata Convention on Mercury. Kumamoto, Japan. In: *Text of the Minamata Convention on Mercury for Adoption by the Conference of Plenipotentiaries* 2013: 5-8.
27. **Opdam, N.J.M., Bronkhorst, E.M., Loomans, B.A.C., Huysmans, M.C.D.N.J.M.** 12-year survival of composite vs. amalgam restorations. *J Dent Res* 2010; 89 (10): 1063-1067.
28. **Kovarik, R.E.** Restoration of posterior teeth in clinical practice: evidence base for choosing amalgam versus composite. *Dental Clinics of North America* 2009; 3: 71-76.
29. **Opdam, N.J.M., Bronkhorst, E.M., Roeters, J.M., Loomans, B.A.C.** A retrospective clinical study on longevity of posterior composite and amalgam restorations. *Dent Mater* 2007; 23 (1): 2-8
30. **Green, D., Mackenzie, L., Banerjee, A.** Minimally invasive long-term management of direct restorations: the "5 Rs". *Dent Update* 2015; 42 (5): 413-416, 419-421, 423-426.
31. **Frencken, J.E., Peters, M.C., Manton, D.J., Leal, S.C., Gordan, V.V., Eden, E.** Minimal intervention dentistry for managing dental caries – a review: report of a FDI task group. *International Dental Journal* 2012; 62: 223-243.
32. **Komabayashi, T., Zhu, Q., Eberhart, R., Imai, Y.** Current status of direct pulp-capping materials for permanent teeth. *Dent Mater J* 2016; 35 (1): 1-12.

33. **Cox, C.F., Suzuki, S.** Re-evaluating pulp protection: calcium hydroxide liners vs. cohesive hybridization. *Journal of the American Dental Association (1939)* 1994; 125: 823-831.
34. **Cox, C.F., Sübay, R.K., Ostro, E., Suzuki, S., Suzuki, S.H.** Tunnel defects in dentin bridges: their formation following direct pulp capping. *Oper Dent* 1996; 21 (1): 4-11.
35. **Nosrat, A., Peimani, A., Asgary, S.** A preliminary report on histological outcome of pulpotomy with endodontic biomaterials vs calcium hydroxide. *Restor Dent Endod* 2013; 38 (4): 227.
36. **Parirokh, M., Torabinejad, M.** Mineral trioxide aggregate: a comprehensive literature review – part I: chemical, physical, and antibacterial properties. *Journal of Endodontics* 2010; 36: 16-27.
37. **Ioannidis, K., Mistakidis, I., Beltes, P., Karagiannis, V.** Spectrophotometric analysis of coronal discolouration induced by grey and white MTA. *Int Endod J* 2013; 46: 137-144.
38. **Mozynska, J., Metlerski, M., Lipski, M., Nowicka, A.** Tooth discoloration induced by different calcium silicate-based cements: a systematic review of *in vitro* studies. *Journal of Endodontics* 2017; 43: 1593-1601.

CPD questions

To claim CPD points, go to the MEMBERS' SECTION of www.dentist.ie and answer the following questions:

1. According to the International Caries Consensus Committee, the treatment of choice in shallow or moderately deep cavitated dentine lesions is:

- A: Selective dentine removal to soft dentine
- B: Complete caries removal
- C: Selective dentine removal to firm dentine

2. The newer calcium silicate materials such as MTA and Biodentine have significant advantages over the previous gold standard material, calcium hydroxide. These materials:

- A: Induce osteogenesis, dentinogenesis and cementogenesis
- B: Produce thicker, more homogenous and complete reparative dentine bridges in comparison to calcium hydroxide
- C: Consist of calcium hydroxide and a calcium silicate hydrate gel, which solidifies and forms an effective seal and barrier
- D: All of the above

3. Evidence-based research has encouraged a minimally invasive (MI) approach to the management of caries in the post-fluoride caries generation. What does a minimally invasive approach to caries management involve?

- A: Adoption of a preventive philosophy
- B: Designing individualised risk assessments for patients
- C: Early detection of carious lesions
- D: Efforts to remineralise non-cavitated lesions
- E: When operative intervention is unequivocally required, the procedure used should be as minimally invasive as possible

IDA irish dental association CPD