Removal Strategies for Carious Tissues in Deep Lesions

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Abstract

It used to be considered preferable to remove all carious tissues with any signs of disease, regardless of the consequences, even at the expense of the hard tissue, causing stress to, or exposing, the dental pulp. However, it is now understood that this is not only unnecessary but also undesirable. Bacteria can be sealed under restorations, depriving them of nutrition and inactivating them.

In asymptomatic, vital teeth with deep lesions, strategies for conservative carious tissue removal which reduce tissue loss and pulp exposure risk have to be balanced against removing adequate tissue to maximize restoration longevity. The criterion used to guide carious dentin tissue removal is hardness, judged by tactile feedback during examination. The levels are described as: Hard, Firm, Leathery, and Soft Dentin. The four main strategies for carious tissue removal are: Non-selective Removal to Hard Dentin (now considered to be overtreatment and too destructive and not recommended); Selective Removal to Firm Dentin; Selective Removal to Soft Dentin; and Stepwise Removal.

Other strategies for managing deep carious lesions are: Non-Restorative Cavity Control where lesions are made cleansable, and Sealing-In strategies (including Fissure Sealing in permanent and primary teeth and sealing using a preformed crown in primary teeth). These strategies for managing carious tissues result in a change in the biofilm (reduced bacterial diversity, numbers, and

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cariogenic potential). The guiding principles behind removal and sealing are underpinned by a desire to preserve tissue, avoid pulp exposure, and maximize tooth longevity.

2.1 The Aim of Caries Removal

It was over 300 years ago that van Leeuwenhoek detected "animalcules" in the dental plaque of two street beggars, using his microscope to look at the scrapings from their teeth. This discovery paved the way for the idea that dental caries is a bacterial disease, discussed in the previous chapter. Following this, the concepts of dental caries pathology revolved around the idea that, as a bacterially associated disease, it was an infectious disease. This meant that carious dental tissues, enamel and dentin, were treated as "infected" and needed to be completely removed before a restoration could be placed [1], aiming to eradicate bacteria from the tooth (again, treating caries as an infectious disease). In doing this, there was no distinction between carious tissue that was bacterially contaminated (previously termed "infected") and carious tissue that was non-contaminated but demineralized (previously termed "affected") tissue. The aim was to remove all dental tissues with any sign of disease. This surgical excision of all tissue with any sign of disease was carried out regardless of the consequences and it was considered better to remove it all, even at the expense of unnecessary hard tissue loss, causing stress to, or exposing, the dental pulp. As a result, the restorative cycle and, with it, the "death spiral of the tooth" [2] were initiated (see Chap. 1).

The underlying aims of this historical carious tissue removal approach no longer apply [3]:

- Removing all contaminated tissue (note that this term better captures the presence of bacteria without giving the notion that caries is an infectious disease) is not necessarily required, as bacteria can be sealed under restorations, thus depriving them from their nutrition and inactivating/killing them [4].
- Removing all demineralized tissue or, specifically, demineralized dentin (which is, as discussed, softer than sound dentin and a suboptimal bond substrate) is not needed (at least not in the whole cavity). Demineralized dentin can remineralize as long as the collagen fibers are intact, and can be "healed" [5].
- Achieving additional undercuts within the cavity was advantageous when placing amalgam restorations, but is not required today when using adhesive restorative materials.

As discussed, theoretically, all carious lesions—also cavitated ones—could be sealed to arrest them. Practically, sealing cavitated carious lesions is often not possible, as the underlying soft dentin increases the risk of fracture, while the reduced

bond strengths to such dentin increase the risk of retention loss. Thus, in many cases, SOME carious tissue removal is needed prior to placing a restoration. Consequently, the aim of carious tissue removal is to increase the longevity of the subsequently placed restoration by removing some or most aspects of carious dentin and enamel.

An additional aim could well be to remove most bacteria from the cavity to improve pulp outcomes. Two things, however, need to be highlighted here: Firstly, there is no strong data supporting the theory that large amounts of sealed bacteria harm the dental pulp. Secondly, the aim of removing bacteria to protect the pulp should never be superordinate to the aim of not harming the pulp during tissue removal. This immediately leads to the principles and priorities which should drive carious tissue removal.

2.2 Principles and Priorities

Based on this logic and the previously stated aim of why carious tissue is removed at all prior to placing a restoration, there are agreed guiding principles for carious tissue removal [3, 6]:

- "preserve non-demineralized and generalizable tissue;
- achieve an adequate seal by placing the peripheral restoration onto sound dentin and/or enamel, thus controlling the lesion and inactivating remaining bacteria;
- avoid discomfort/pain and dental anxiety (…)
- maintain pulpal health by preserving residual dentin (avoiding unnecessary pulpal irritation/insult) and preventing pulp exposure (…)
- maximize longevity of the restoration by removing enough soft dentin to place a durable restoration of sufficient bulk and resilience" [3].

However, the last two points conflict:

- Avoiding pulpal exposure is most relevant in deep lesions in teeth with vital, symptomless pulps. Any kind of exposure will be managed using endodontic treatments, which have either a poor prognosis (like direct capping) or are highly invasive and often shorten the lifetime prognosis of the tooth (e.g., root-canal treatment) [7–9]. It can be argued that under some circumstances direct capping of exposed pulps (under microscopic magnification using specific dressings, like mineral trioxide aggregate) will result in better outcomes than with conventional direct capping (without magnification and using calcium hydroxide based dressings) [10–13]. Similarly, alternatives for maintaining pulp vitality such as pulpotomy might be used to manage pulp exposures [14–16]. However, none of these methods has, so far, been unambiguously shown to be superior to the existing standards [17] or has entered routine clinical practice [18].

– Leaving carious dentin beneath restorations means leaving possibly soft, bacteria-containing, demineralized dentin with lower elastic modulus and reduced bonding capabilities than sound dentin. A number of *in vitro* studies show, to varying degrees, the possible detrimental effects of leaving such dentin on restoration integrity [19–21]. Also clinical studies find that very large amounts of carious dentin left under a restoration might destabilize the restoration [22–24].

In deep lesions in teeth with vital pulps, free from pathologic signs and symptoms, both aims need to be balanced against each other: in areas of deep lesions which are not at risk of pulp exposure, enough carious dentin will be removed to maximize restoration longevity, while in areas close to the pulp, pulp exposure needs to be avoided, and carious dentin should be left if possible (without compromising the restoration survival). However, the biggest problem is assessing this during carious tissue removal. How can this be done?

2.3 Assessing Carious Tissue Removal

A large number of studies have described carious tissue removal strategies for managing cavitated lesions. These studies have used a vast range of terms to assess and describe what was removed, what was left, and how exactly this was done. A number of issues should be clarified:

- Firstly, it is important to remember that the clinical appearances of carious tissues both during initial inspection (including radiographic assessment) and during removal do not always correlate with histologic findings (yielded from assessment of removed teeth, for example). There are a number of histologic terms, for example, which can be used to describe layers of carious dentin, and theoretically, one could relate carious tissue removal to these layers. However, as can be seen in the cross-sectional image of a tooth, it is obvious that these layers do not have clear-cut boundaries, but merge into each other, often gradually (Fig. 2.1). The resulting clinical appearance (for color or hardness characteristics, for example), also, therefore, appears as a gradient (Fig. 2.2), too: clinicians cannot clearly distinguish bacteria-containing from demineralized dentin, for example.
- Secondly, it is also important to note that no study so far has found it relevant to remove or leave carious dentin of a specific quality or a specific layer. Instead, the principles above should be adhered to, as these are based on clinical evidence. Thus, in summary, carious tissue removal strategies should not pretend to remove specific carious tissues or layers; giving them names like “complete” or “incomplete” excavation is therefore not helpful. For example, it remains unclear what “completely” or “incompletely” removed actually means (bacteria? soft

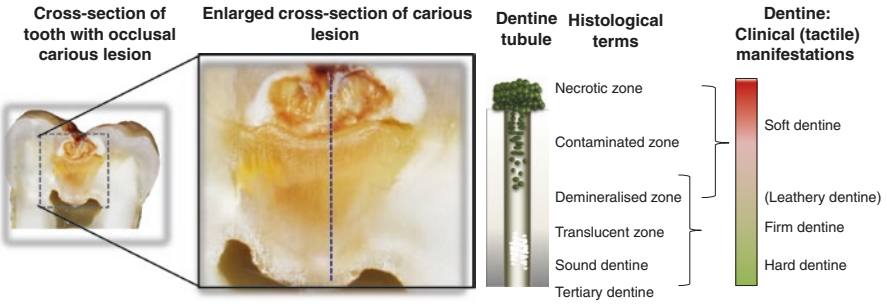

Fig. 2.1 Diagrammatic representation of the cross section of a carious lesion (after Ogawa et al. 1983 [25])

Fig. 2.2 Lower primary molar showing a gradient of color from *black* through *dark brown* to *light brown*, *golden yellow*, and *white*

dentin? discolored dentin? hydrolytically degraded dentin?). Moreover, it is very unlikely that any removal will be perfectly "complete" or "incomplete" (regardless of which criterion is chosen), as—again—the gradual changes between different dentin qualities will make it very hard for a clinician to be able to gauge accurately what exactly was removed or left (at least with most current means for assessing carious tissue removal). It might therefore be best not to describe carious tissue removal in terms of what one aims to do (completely or incompletely remove carious dentin), but how one aims to perform the removal (until soft dentin is removed, etc.). This is the approach that will be taken in this book.

One criterion, which has been consistently used in both daily practice and dental research, is the hardness of the removed or retained dentin [26]. In this book, hardness will be one major aspect to assess and describe carious tissue removal, which is why, although in some ways subjective, we will now describe what is meant when talking about soft, leathery, firm, and hard dentin [6]:

- Soft dentin: "Soft dentin will deform when a hard instrument is pressed onto it, and can be easily scooped up (e.g., with a sharp hand excavator) with little force being required."
- Leathery dentin: "Although the dentin does not deform when an instrument is pressed onto it, leathery dentin can still be easily lifted without much force being required." The hardness of leathery dentin is between that of soft and firm dentin.
- Firm dentin: "Firm dentin is physically resistant to hand excavation and some pressure needs to be exerted through an instrument to lift it."
- Hard dentin: "A pushing force needs to be used with a hard instrument to engage the dentin 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 dentin."

The hardness criterion has been validated against clinical outcomes in several studies [27]. Hardness is assessed using probes, or via tactile feedback during excavation. Hardness of the dentin correlates with the residual bacterial numbers within the dentin [28], with dentin softening preceding bacterial invasion [25, 29, 30]. Removing bacteria is not the focus of managing deep carious lesions, which is why this aspect is not central when judging an assessment strategy. However, carious tissue removal until only hard dentin remains has been found detrimental with regard to maintaining pulp vitality in teeth with deep carious lesions [27].

A range of other criteria for assessing the removed and retained dentin have been described, including moisture, color, dye stainability, etc. Most have been validated *in vitro*, often against the description "removal of bacteria" (which, as previously discussed, was historically relevant but does not seem to be central these days, at least when considering clinical outcomes for pulp vitality). More important, most methods have not been validated clinically and have not (yet) been found truly beneficial for patients. Instead, some of them, like stainability via caries detector dyes (see below), have been found harmful when dealing with deep lesions [27]. Thus, we will only briefly summarize the available evidence on further criteria:

- Moisture is associated with bacterial numbers, with moist or wet dentin harboring more bacteria than dry dentin, but so far there are no studies evaluating what the clinical impact might be of leaving or removing all moist dentin [27].

Although moisture often correlates with hardness, it is subjective and more difficult to assess (at least by tools currently available in the dental surgery), and it is therefore recommended that moisture is not the focus, but that hardness is instead assessed for evaluating carious tissue removal.

– In the past, color has been recommended as an indicator for carious lesion activity and the need to remove tissue. However, color is associated with a wide range of factors, among them the (past) presence of bacteria (bacterial by-products stain the dentin), but also the incorporation of external stains (for example, from existing amalgam restorations—Fig. 2.3—and foodstuffs). It is often the case that inactive lesions can be highly stained (dark, brown) (Fig. 2.4), but they can also be pale (Fig. 2.5). Removing such hard dentin, whether it is light or dark is, of course, not required and should be avoided. Therefore, color is not a good indicator of activity and instead of color, hardness should be assessed.

Fig. 2.3 Dark staining from an adjacent amalgam restoration, within a cavity that has been opened. The dentin is hard

Fig. 2.4 Dark and light carious dentin lesions. The dark lesions are hard to touch and arrested but the light lesions are soft and still active

Fig. 2.5 A *golden* colored lesion that is very hard to touch and inactive

– A method to determine the degree of bacterial contamination during carious tissue removal is Fluorescence Aided Caries Excavation (FACE). Because dentin, which has not been bacterially invaded, displays strong green autofluorescence in contrast to bacterially contaminated dentin, which exhibits red autofluorescence caused by bacterial by-products (porphyrins) [31], FACE can distinguish both types of dentin by using a violet light for excitation and a highpass filter to allow visual assessment of whether the tissue is bacterially invaded (red fluorescence) or not (green fluorescence) [32]. This is possible without the need for fluorescent dyes because it is based on tissue autofluorescence. FACE can be carried out using either SiroInspect (Sirona, Wals, Austria) or Fluoresce HD (Lares Research, Chico, CA, USA). Using FACE, the dentist can see which areas are heavily contaminated and which are not (Fig. 2.6). It is then up to the dentist to decide which areas need removal, while FACE might make removal more efficient as repeated probing of the dentin to measure hardness is not needed [33]. However, and most important, when treating deep carious lesions near to the pulp, removal of bacteria is not central, while maintaining pulp integrity is. FACE should be used with such considerations in mind; using it appropriately might allow to be efficient while selectively removing carious tissue. Because it is a relatively new method, long-term clinical investigations are still lacking and should be performed in the future [27].
– Caries detector dyes have been used for staining carious dentin, the idea being selective uptake of dye molecules into bacterially degraded dentin, but not non-degraded demineralized or sound dentin. Clinically, this highly selective stainability has not been demonstrated, mainly as no clear-cut border exists between different dentin layers as has been described above [34–38]. Instead, a color gradient of dye stain can be found in most cavities; in some instances, reactionary (tertiary) dentin is stained (as its structure is different from that of primary or secondary dentin), which could lead to removal of this non-carious dentin. Clinical studies have found the use of caries detector dyes to lead to more pulp

exposures and complications, which is why this assessment method is not recommended for deep lesions (at least not when using it to remove all stained dentin) [27].

In summary, the most common and versatile criterion for assessing and describing carious tissue removal is hardness of the dentin remaining in the cavity (or, vice versa, hardness of the removed dentin). Using these terms for describing differently hard dentin layers, one can deduce four main strategies for carious tissue removal which have been established in the last decades.

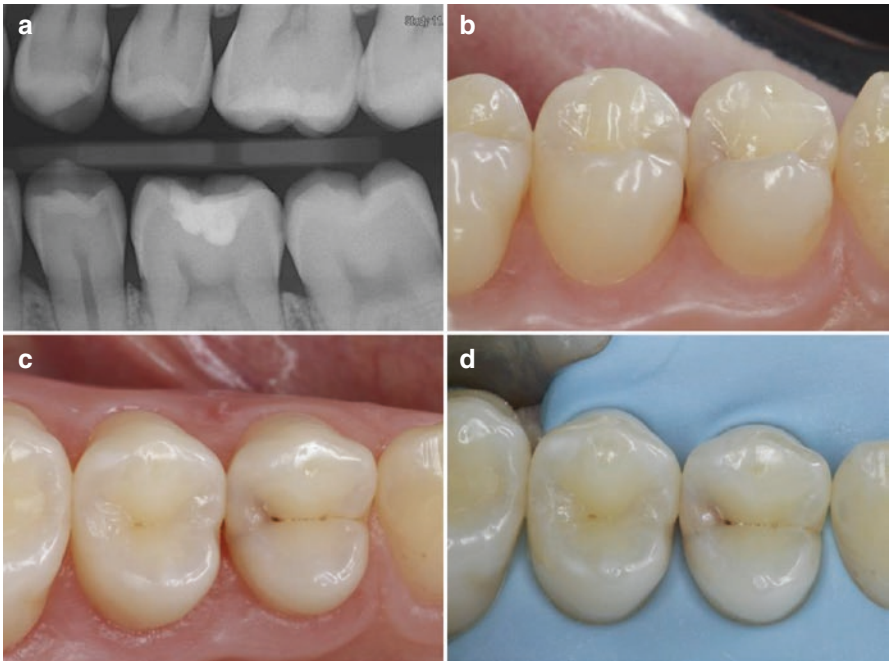

Fig. 2.6 (**a**) Bitewing radiograph showing a moderately deep carious lesion (middle third of dentin) in an upper left premolar (tooth 24) with high likelihood of a cavitated interproximal enamel surface. Tooth 24 showing clinical signs (dark and opaque appearance with distinct interproximal enamel breakdown) of a deep distal caries (**b**–**d**). Access cavity showing carious dentin under normal (**e**) and fluorescence light conditions using Fluorescence Aided Caries excavation with SIROInspect (**f**), where red autofluorescing, heavily contaminated dentin areas can clearly be distinguished from *yellow* to *green* fluorescing dentin which is not heavily invaded by bacteria. Situation after complete removal of *red* fluorescing dentin in the periphery, while some slightly *red* fluorescing dentin at the pulpal wall was left behind in order to avoid pulp exposure (**g** and **h**). Complete minimally invasive adhesive preparation (**i**) with matrix (**j**) in place (here: Palodent, Dentsply-Sirona; (**k**) Selective enamel etching with 37% phosphoric acid gel and application of an adhesive (here: Scotchbond Universal, 3 M–Espe, **l**). Application of consecutive increments of a nano-hybrid composite (here: Filtek Supreme XTE, 3 M–Espe, **m**–**p**). Completed restoration after removal of the rubberdam (**q**–**r**). Courtesy of Prof. Wolfgang Buchalla, Regensburg

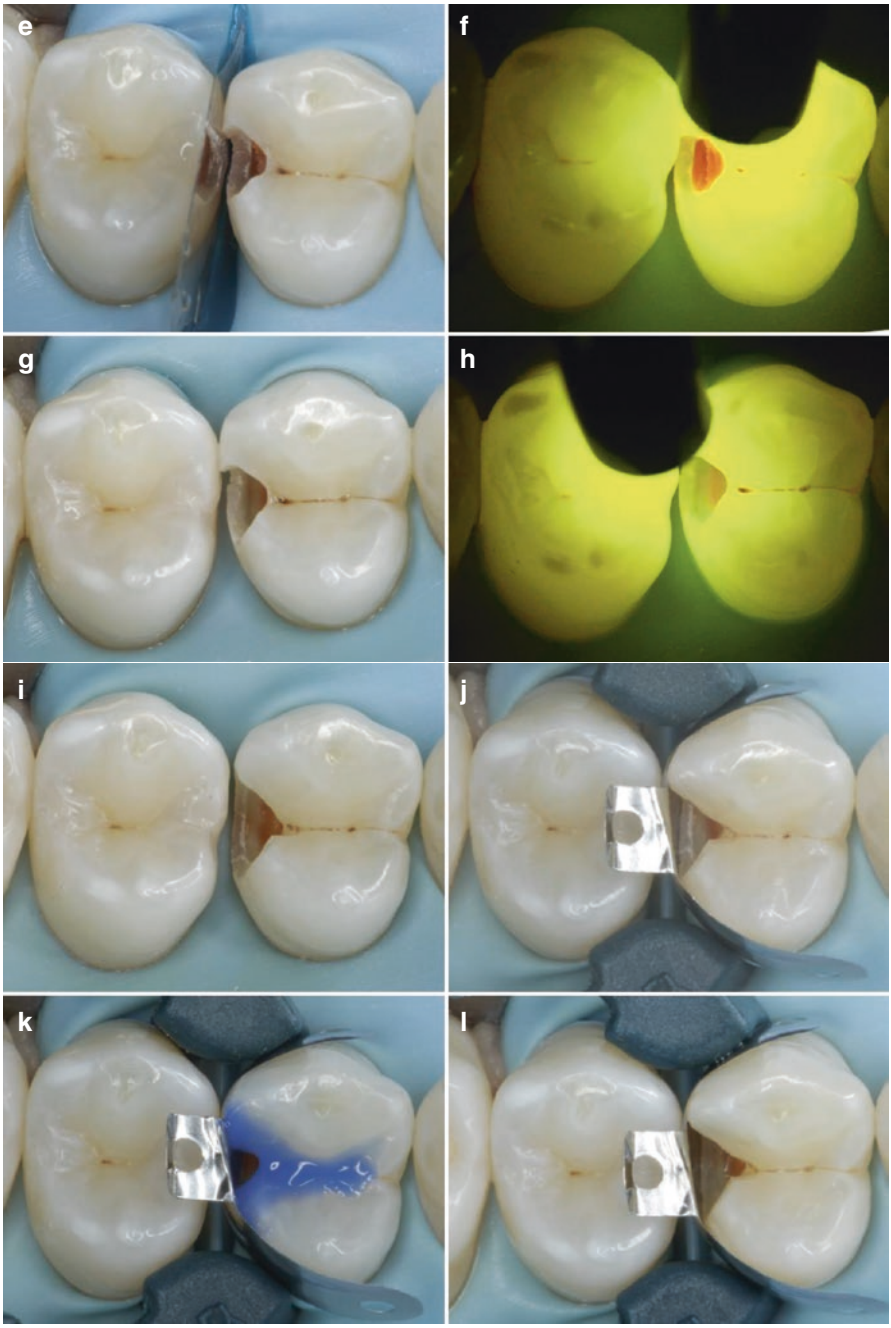

Fig. 2.6 (continued)

Fig. 2.6 (continued)

2.4 Removal Strategies

As these four main removal strategies will be discussed in detail in the next chapters, we will only briefly present an overview over these strategies here (Fig. 2.7):

Fig. 2.7 Removal strategies. (**a**) For deep carious lesions in teeth with sensible pulps, four strategies are available. (**b**) Non-selective removal to hard or firm dentin, which is not recommended for deep lesions, was the historically recommended approach. All softened and moist or even discolored dentin was completely removed from all of the cavity. (**c**) In stepwise removal, in the first step soft dentin is left in proximity to the pulp, and sealed temporarily. In the periphery, hard dentin is left, supporting the restoration and allowing a tight seal. The soft dentin is removed after 6 or more months (*dashed line*), until only firm dentin remains in the pulpo-proximal areas. (**d**) In selective removal to soft dentin, soft dentin is left in proximity to the pulp to avoid pulp exposure; hard dentin is left peripherally. (**e**) No Removal, involving non-restorative cavity management, fissure sealing, or—as shown—the Hall Technique

2.4.1 Non-Selective Removal to Hard Dentin

Non-selective Removal to Hard Dentin (formerly also known as "complete removal") aims to remove soft dentin, stopping the removal only when hard dentin (similar to healthy dentin) is reached. This is aimed for in all areas of the cavity: as the same criterion (the same endpoint) of carious tissue removal is used both peripherally and pulpally, it is termed non-selective (compare with selective removal, see below) [6].

Non-selective Removal to Hard Dentin includes the removal of demineralized dentin, which is in conflict with modern aims and the guidelines stated above. It is overtreatment and not necessary. Moreover, in deep carious lesions with vital painless pulps, such removal bears significant risks for the pulp [26, 39]. While this approach was the standard in the past, it is now considered overtreatment and not recommended any longer, especially when dealing with deep lesions in teeth with vital pulps [3]. It is not only not necessary, but also not desirable.

2.4.2 Selective Removal to Firm Dentin

In Selective Removal, not one but several different criteria (endpoints) are used to assess carious tissue removal in the periphery of the cavity and in proximity to the pulp. As described above, one guiding principle during carious tissue removal is to create an environment which allows the best adhesive seal for a restoration. This aim can be achieved when there is sound enamel and hard dentin at the periphery of the cavity. This approach also serves another guiding principle, maximizing restoration longevity. In the pulpal area of a cavity, however, another criterion (endpoint) is used, with firm dentin being left [6]. Although removable, this firm dentin is physically resistant to hand excavation and requires effort to remove it.

This approach is recommended for shallow or moderately deep lesions, but not deep lesions (i.e. those extending beyond the pulpal third or quarter of the dentin

radiographically) in teeth with vital pulps, as even removal to firm dentin risks pulp exposure and harm. The reason for it often being required for shallow or moderately deep lesions is that the cavity depth needs to be sufficient to allow enough sound enamel and dentin around the periphery for good quality bonding and a complete peripheral seal to be achieved.

2.4.3 Selective Removal to Soft Dentin

Selective Removal to Soft Dentin is recommended for deep carious lesions in teeth with vital painless pulps. Here, in the pulpal area of a cavity, avoiding pulp exposure and maintaining remaining dentin thickness are prioritized. Consequently, it is expected that leathery or, if needed, soft carious dentin will remain in the pulpal aspect of the cavity, serving the guiding principle of maintaining pulp vitality. A sharp excavator or a probe can be used to check the remaining carious dentin, which will deform and can be lifted up under little force [6]. In the periphery, achieving a good seal and maximizing restoration survival are prioritized, with peripheral enamel and dentin again being hard at the end of the removal process (Fig. 2.8).

Selective Removal to Soft Dentin has been convincingly shown to reduce the risk of pulpal exposure compared with Non-Selective Removal to Hard or Selective Removal to Firm Dentin [26, 27, 39]. Note that this removal technique has been previously known as partial or incomplete removal.

2.4.4 Stepwise Removal

Stepwise removal is carious tissue removal in two steps (visits) [40–42], essentially combining Selective Removal to Soft Dentin in the first step and, 6–12 months later, Selective Removal to Firm Dentin in the second step, with the carious dentin being sealed beneath a temporary restoration in-between. In the first step, demineralized soft dentin is left pulpally, aiming to avoid pulp exposure and irritation, while peripherally, carious tooth tissue is removed until only hard dentin is left, allowing a complete peripheral seal. For the temporary restoration, a restorative material should be chosen that will be durable for at least 12 months or (better) longer, as patients might not return before that, with lost temporary restorations being one major risk for stepwise excavated teeth [43]. It is also helpful for the material to be easily differentiated from tooth substance to avoid tooth removal accidentally when removing the temporary restoration during the second stage of the stepwise process. In the 6–12 months period between steps, sealed bacteria are deprived of dietary carbohydrates, with significantly reduced bacterial numbers in the carious dentin being found at the second step stage [41]. Furthermore, the remaining carious dentin is remineralized within this sealing period (with minerals obtained either from restorative materials, as described in Chaps. 3 and 5, or from the pulp), and reactionary (tertiary) dentin development is stimulated. All these mechanisms help to reduce the risk of pulp exposure in the second step (as less dentin needs to be removed and

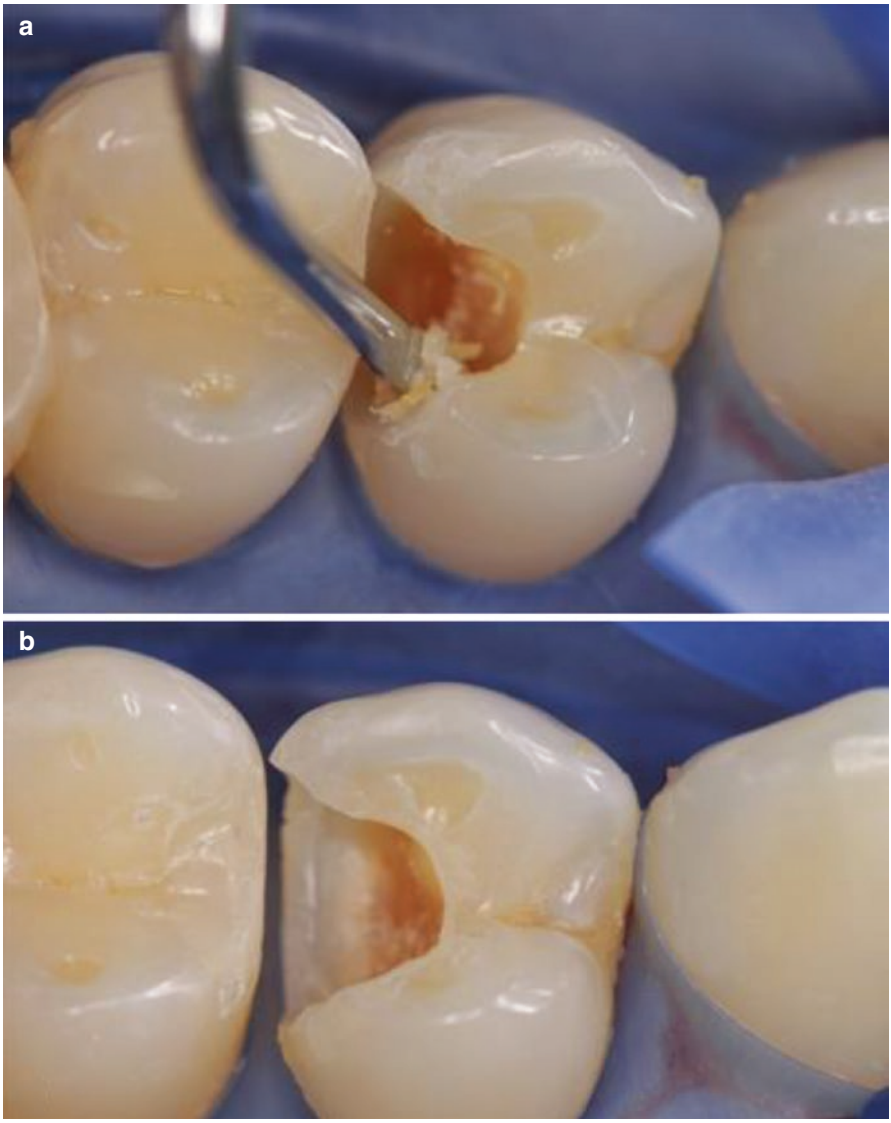

Fig. 2.8 Selective removal to soft dentin. A deep lesion in a tooth with a sensible tooth is treated. (**a**) In the periphery, only hard dentin, similar to sound one, and sound enamel is left. In the periphery, very soft dentin is spooned out with a hand excavator; (**b**) the remaining dentin is leathery, moist and discolored, and sealed under the restoration

the residual dentin thickness above the pulp is higher). After 6–12 months, the temporary restoration is removed and Selective Removal to Firm Dentin carried out until only firm dentin remains also pulpally. Note that this technique has previously been also known as "two-step excavation."

Stepwise removal has been shown to have higher risks of pulp exposure and, from the evidence so far, there seem to be equivalent restorative outcomes when compared with Selective Removal to Soft Dentin. It also adds costs, time, and discomfort to the patient without any tangible benefit [26, 43, 44]. This implies that there needs to be good justification for stepwise removal to be carried out. Such justification will be given in the next chapter.

2.5 Other Strategies for Managing Dental Carious Lesions

Having discussed the different strategies involving removal of the carious lesion to a greater or lesser extent and the situations where these might be applied, we now move on to summarize strategies for carious dentin where there is no active tissue removal carried out by the clinician.

2.5.1 Sealing in Strategies

There are currently only two situations where the carious lesion is not removed at all but only sealed into the tooth; fissure sealing over carious lesions and the Hall Technique for primary molar teeth.

2.5.2 Fissure Sealing

The first studies in this direction did not perform fissure sealing, but used "ultraconservative caries removal and sealing" with a restorative material. The landmark study investigated carious lesions extending up to halfway into dentin, i.e. does not directly relate to our discussion on management of the deep carious lesion [45]. The study looked at sealing in all of the carious lesion in permanent teeth using bonded and sealed composite restorations placed directly over frank cavitated lesions. These were compared with sealed conservative amalgam restorations and conventional unsealed amalgam restorations. The main aim of the study was to look at the materials; restoration longevity but also other outcomes such as pulpal pain were recorded. At 10 years (54% follow-up), both types of sealed restorations showed better clinical performance and longevity compared with the unsealed amalgam group. The authors also noted that, over the 10 years of the study, the bonded and sealed composite restorations arrested the clinical progress of these lesions. However, this is the only study on ultraconservative carious lesion management and did not include deep lesions. Although perhaps leading to the conclusion that further investigation is merited, the evidence does not support it being recommended as a standard part of practice and is not directly relevant to deep lesions.

Nowadays, fissure sealing over carious lesions can be used for both permanent and primary teeth but is limited to cases where the enamel surface is relatively intact. However, although there is a growing body of research to support it [46], the

research still lacks the level of detail to be able to give certainty to how deep or how extensive a lesion can be before fissure sealing is not adequate to provide a long-lasting solution [47]. The problems with fissure sealing extensive lesions are likely to be twofold.

Firstly, fissure sealant materials are low filled resins and do not have structural strength to withstand force. If a piece of cured sealant material is taken between the fingers, it can be snapped very easily. On the top of a sound tooth, this does not matter (although sealants do wear and break) because the material is placed on tooth structure that will support it. However, in the case of a deep lesion, even where there is very little cavitation visible (usually because the breach in enamel is at the base of a fissure and cannot be seen), the dentinal lesion has demineralized the dentin. While healthy dentin has around 70% mineralization, after being affected by the acids from the biofilm this is greatly reduced. This weakening is compounded by the proteolytic enzymes that are also travelling down the dentinal tubules and denaturing the collagen. Secondly, formerly moist and soft carious tissue becomes hard and dry while being sealed. This shrinkage and drying has not been quantified (stepwise removal studies have investigated it) but it is likely to have the effect of leaving the sealant on a base that is not sound; sealants placed under such conditions might not be strong enough to withstand masticatory forces (see Chap. 1).

Taken together, the underlying weakened dentin (caused by the carious lesion) and the possible sealed lesion drying and shrinking (when it is successfully sealed), means that placing a fissure sealant over a weak structure and then subjecting it to biting forces could result in a "trampoline" type of effect on the tooth and fracturing of the enamel. The sealant, while working well to seal the lesion, may not rebuild much of the tooth structural strength once it has been compromised.

2.5.3 The Hall Technique

The Hall Technique is a method for managing carious lesions in primary molars by sealing them in under preformed metal crowns (Fig. 2.9). The crowns are designed for primary teeth but have traditionally been used following "complete" caries removal (and often a pulp therapy) and after the teeth have been prepared for the crown. With the Hall Technique, after determining clinically and radiographically that the lesion has not irreversibly damaged the dental pulp, there is no carious tissue removal at all. The correct size of crown is chosen and simply pushed over the tooth to seal the lesion and the whole coronal tooth structure under the crown. Data on the Hall Technique has been published over the last 10 years with robust evidence from several randomized control trials. These have found the Hall Technique superior to comparator treatments, with success rates (no pain or infection) of 99% (UK study) [48] and 100% (Germany) [49] at 1 year, 98% and 93% over 2 years (UK and Germany), and 97% over 5 years (UK) [50]. The Hall Technique is now regarded as one of several biological management options for carious lesions in primary molars.

Fig. 2.9 Three crowns placed, using the Hall Technique, on upper primary molars. The teeth have not been prepared and no carious tissue was removed. The correct size of the crowns to fit over the teeth was chosen, the crown filled with glass ionomer cement, pushed over the teeth and held, by the child biting until the cement set

2.5.4 Atraumatic Restorative Treatment (ART)

This is a specific technique for carious lesion management using hand instruments only to remove carious tissue. Excavation is carried out to firm dentin in shallow lesions and to soft dentin in deep lesions. The cavity is restored and then the pits and fissures are sealed with an adhesive material such as a resin fissure sealant or high viscosity glass ionomer cement.

2.5.5 Non-Restorative Cavity Control (NRCC)

Non-restorative cavity control is a method for managing carious lesions by making them cleansable, where a decision has been made not to restore them (Fig. 2.10). The decision may have been made because the tooth is not restorable or because there is no clinical need to restore the lesion based on the principles and priorities stated before. The technique is generally limited to primary teeth or to root surface caries although it may have an application in groups with very high caries rates where there is a need to stage treatment through a stabilization phase.

Each tooth is judged on its own merits as to whether this is a suitable treatment option. However, more importantly, there are a number of additional conditions that have to be satisfied for NRCC to be successful including willingness and ability of the patient or the parent/carer to accept responsibility and their role in ensuring the success of the procedure.

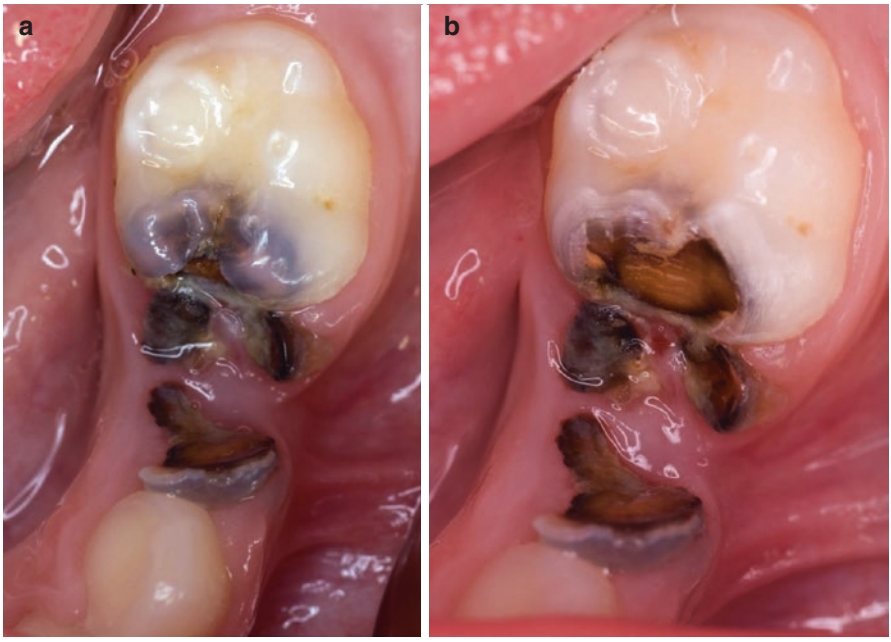

Fig. 2.10 (**a**) Lower second primary molar before the lesion is opened up using an air rotor with a diamond bur to remove enamel and some carious dentin. (**b**) After the lesion has been opened to expose the lesion to the oral environment transforming it from a sheltered highly cariogenic environment to a cleansable lesion. The parents were shown how to clean the lesions, and fluoride varnish was applied to them every 3 months to encourage remineralization. More information, also regarding to the managment of the retained carious roots, are given in Chap. 8

The cavities are made accessible to a toothbrush or adjunctive cleansing device. There may or may not be regular application of a fluoride-based substance such as fluoride varnish or silver diamine fluoride to the cavity and sometimes a layer of resin-modified glass ionomer cement-lining is placed (after removing the biofilm with a prophy brush and toothpaste). Lesions are monitored over time for progression, and there is intensive communication (using a theory-based approach such as motivational interviewing or coaching) and action planning to motivate the patient or their parent/carer to clean.

There has been very little high quality research into NRCC [49, 51]. The technique is still commonly misunderstood as a "do nothing" treatment but is actually very much the opposite. It requires twice daily maintenance, and not by the clinician; their responsibility is to hand over care of the lesion to the patient or parent/carer. This can be more challenging than carrying out technically difficult dentistry. We discuss it more in Chap. 8.

2.6 Summary

- The hardness of the retained or removed dentin can be used for describing and assessing carious tissue removal.
- Non-selective Removal to Hard Dentin is overtreatment, removes unnecessary tissue, and increases the risk of pulp exposure.
- For deep carious lesions in teeth with vital, painless pulps, three of the four strategies presented, namely Selective Removal to Soft Dentin, Stepwise Removal, or Sealing, can be carried out. These are presented in more detail in the subsequent chapters of this book.
- Strategies for conservative carious tissue removal have to be balanced against removing adequate tissue to maximize restoration longevity.

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