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1 **Contemporary operative caries management: consensus recommendations on**  
2 **minimally invasive caries removal.**

3

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21

## 22 *Abstract*

23 The International Caries Consensus Collaboration (ICCC) presented recommendations on terminology  
24 and on carious tissue removal and managing cavitated carious lesions. It identified dental caries as the  
25 name of the disease which dentists should manage and control activity of existing cavitated lesions to  
26 preserve hard tissues, maintain pulp sensibility and retain functional teeth long-term. The ICCC  
27 recommended the level of hardness (soft, leathery, firm, and hard dentine) as the criterion for  
28 determining the clinical consequences of the disease and defined new strategies for carious tissue  
29 removal: 1) *selective removal of carious tissue*—including *selective removal to soft dentine* and *selective*  
30 *removal to firm dentine*; 2) *stepwise removal*—including stage 1, *selective removal to soft dentine*, and  
31 stage 2, *selective removal to firm dentine* 6 to 12 months later; and 3) *non-selective removal to hard*  
32 *dentine*—formerly known as *complete caries removal* (a traditional approach no longer recommended).  
33 Adoption of these terms will facilitate improved understanding and communication among researchers,  
34 within dental educators and the wider clinical dentistry community. Controlling the disease in cavitated  
35 carious lesions should be attempted using methods which are aimed at biofilm removal or control first.  
36 Only when cavitated carious dentine lesions either are non-cleansable or can no longer be sealed, are  
37 restorative interventions indicated. Carious tissue is removed purely to create conditions for long-lasting  
38 restorations. Bacterially contaminated or demineralized tissues close to the pulp do not need to be  
39 removed. The evidence and, therefore, these recommendations support minimally invasive carious  
40 lesion management, delaying entry to, and slowing down, the destructive restorative cycle by preserving  
41 tooth tissue, maintaining pulp sensibility and retaining the functional tooth-restoration complex long-  
42 term.

43

## 44 *Introduction*

45 The prevalence of dental caries has decreased in many countries over the last three decades. Despite  
46 this significant achievement, dental caries, a preventable disease, still remains the most prevalent  
47 worldwide, affecting billions of people and generating significant global healthcare costs <sup>1,2</sup>. Therefore,  
48 how the oral healthcare profession manages dental caries has become the central theme in reducing its  
49 burden globally. Strategies to achieve this must be evidence-based and/or informed. Recommendations  
50 are becoming supported by evidence synthesised from clinical studies <sup>3</sup>. However, this is complicated  
51 by the use of different terms describing more or less the same management strategies. Researchers  
52 and clinicians are not speaking the same professional language. Another complicating factor is the gap  
53 between research findings and their implementation into clinical practice. The reasons for this difference  
54 are complex but there are a number of likely contributing factors such as inconsistencies in clinical  
55 guidelines among professional groups, differences in dental education, which relies often on out-dated  
56 concepts, national healthcare policies and remuneration systems <sup>4</sup>. These issues need to be tackled if  
57 the oral healthcare profession is to be seen worldwide as a responsibility-taking health promoting  
58 organisation.

59 An initial step in achieving these changes was the establishment of the International Caries Consensus  
60 Collaboration (ICCC); 21 international clinical experts in cariology, operative dentistry, biomaterials  
61 science, clinical trials, systematic reviews and guideline development from 12 countries met in Belgium  
62 in February 2015, to develop expert consensus for recommendations on dental caries related  
63 terminology and for dealing with carious tooth tissue removal and managing cavitated carious lesions  
64 <sup>5,6,7</sup>.

### 65 *Why are such recommendations necessary?*

66 For the oral healthcare practitioner who treats patients on a daily basis, dental caries and its sequelae  
67 makes up the bulk of their workload. The traditional management approach has been to remove all  
68 carious tissue, in the erroneous belief that this will stop the caries process, and restore the resulting  
69 cavity with a dental restorative material. Over the last 30 years however, better understanding of the  
70 caries process and clinical trial evidence on carious tissue removal methods have supported  
71 contemporary alternatives to this outdated “drill and fill” protocol. The clinical circumstances around  
72 when to use which method are daunting and somewhat confusing, with information dispersed throughout  
73 an ever expansive literature. In addition, the same methods are explained using different terminology in  
74 different countries. This paper, therefore, discusses what the alternative terms for the methods mean  
75 and when to do what in the operative management of the cavitated carious lesion which has not  
76 responded to non-operative prevention regimes in the first instance. This paper deals with teeth with  
77 cavitated caries lesions where the pulp is diagnosed as vital (positive sensibility test) or reversibly  
78 inflamed.

### 80 *What is dental caries?*

81 Dental caries is the disease that results from an ecologic shift in the bacteria within the dental plaque  
82 biofilm. An initially balanced population of commensal micro-organisms in a healthy plaque biofilm alters  
83 as an increasingly favourable environment for aciduric and acidogenic microflora develops within the  
84 stagnating biofilm, after stimulation by frequent consumption of fermentable dietary carbohydrates. The  
85 resulting shift in biofilm activity brings about an imbalance in de- and re-mineralisation, leading to net  
86 mineral loss within dental hard tissues; the earliest sign and symptom is the carious lesion <sup>8</sup>. Dental  
87 caries is not an infectious disease, which needs be “cured” by removing bacteria. Instead, it can be  
88 managed behaviourally by controlling its causative factors, i.e. the supply of fermentable carbohydrates  
89 and the presence and maturation of the bacterially-populated dental biofilms. If, however, such patient  
90 behaviour change is not initiated by the practitioner along with their oral healthcare team, or the  
91 responsibility taken by the patient to adhere to such preventive advice, and thus the lesion activity is not  
92 controlled, the cariogenic biofilm promotes further lesion progression. If lesion activity continues  
93 unchecked, it will lead to pulpal inflammation, pain and dental infection.

95 *Why restore teeth?*

96 Traditional restorative management involves carious tissue removal and reasons for this have  
97 historically included to:

- 98 1 withstand the packing of restorative materials and to help retain the restoration mechanically  
99 (for example, dental amalgam),
- 100 2 remove bacteria so stopping the caries process,
- 101 3 remove demineralised discoloured dentine.

102 However, thanks to research leading to a better understanding of the caries process and improved  
103 evidence from clinical studies, these reasons need updating, clarification and translation into clinical  
104 practice:

- 105 a. With the development of adhesive bioactive / bio-interactive restorative materials, removal  
106 of such large quantities of dental hard tissues is no longer justified.
- 107 b. Given the adverse effects that a good peripheral seal of the adhesive restorative material  
108 to prepared cavity walls have on the viability of remaining bacteria and their cariogenicity,  
109 carious tissue removal simply to remove bacteria in order to halt the caries process is  
110 neither logical nor justified<sup>9-12</sup>. In a similar fashion, neither is disinfecting the cavity prior to  
111 restoring, in order to kill all remaining bacteria.
- 112 c. Demineralised, but structurally intact dentine that can be remineralised should be preserved  
113<sup>13-15</sup>. However, clinical discrimination between these layers of infected and affected dentine  
114 is difficult.

115 Carious lesions will arrest if the biofilm is regularly disturbed, “any lesion at any stage of its  
116 progression can arrest”<sup>8</sup> (Figure 1). However, there are circumstances where this is not possible  
117 and these are related to patient behavioural factors or where it is desirable to restore lost structure,  
118 integrity, form and/or aesthetics. The contemporary aims of operative restorative management have  
119 now evolved to:

- 120 1. aid biofilm control on a restored, rather than from a cavitated, tooth surface and thereby manage  
121 caries activity at this specific location;
- 122 2. protect the pulp-dentine complex and arrest the lesion activity by sealing the coronal part with  
123 an adhesive dental material;
- 124 3. restore the function, form and aesthetics of the tooth.

125 In conclusion, the only evidence-based reason for selective carious tissue removal is to create a  
126 sufficiently large cavity volume and surface area to provide restoration bulk and bond to, whilst  
127 maintaining adequate tooth structure to support the restoration, so as to optimize tooth-restoration  
128 complex longevity.

129 *What are the guiding principles for removal of carious tissue?*

130 Carious tissues should only be removed when there is no feasible alternative management such as  
131 cleaning cavities regularly with brush and fluoride toothpaste, a method particularly suitable in primary  
132 teeth. The guiding principles behind that process of removal are to:

- 133 1. preserve non-demineralised and remineralisable tissue,
- 134 2. achieve an adequate peripheral seal by placing the restoration material onto sound dentine  
135 and/or enamel where achievable,
- 136 3. avoid discomfort/pain and dental anxiety. Use methods that have a proven track record of  
137 initiating no or low levels of anxiety and pain, such as Atraumatic Restorative Treatment (ART),  
138 Hall technique on primary dentition, chemomechanical agents (e.g. Carisolv™ gel (Rubicon  
139 Lifesciences, Sweden)) etc.
- 140 4. maintain pulp health by avoiding dentine excavation close to the pulp so minimising the risk of  
141 pulp exposure, i.e. leave softer affected dentine in close proximity to the pulp if required.  
142 Avoiding pulp exposure significantly improves the lifetime prognosis of the tooth and reduces  
143 long-term management costs <sup>16-18</sup>.
- 144 5. maximise longevity of the tooth-restoration complex by removing enough soft dentine to place  
145 a durable restoration of sufficient bulk and resilience, whilst maintaining sufficient surrounding  
146 tooth support for the restoration.

147 When dealing with permanent teeth with sensible (vital) pulps free from pathologic signs and symptoms,  
148 these last two aims, maintaining pulp health and maximising tooth-restoration complex longevity, should  
149 be balanced against each other. In deep carious dentine lesions (radiographically involving the inner  
150 (pulpal) third or quarter of dentine, or with a clinically assessed risk of pulp exposure), preservation of  
151 pulp health should be prioritised (Figure 2A). In shallow or moderately deep carious lesions (those not  
152 reaching the inner third or quarter of the dentine), maintenance of tooth-restoration complex longevity  
153 might have more significance (Figure 2B).

154 *How should different carious lesions be managed?*

155 The decision process as to which management strategy to use should follow a rational justifiable  
156 pathway (as described here), with the single most important question being, “When does one need to  
157 intervene operatively (invasively)?”

158 The recommended minimally invasive operative interventions described here are for:

- 159 • primary and permanent teeth (distinctions are discussed where relevant);
- 160 • teeth that are pain-free (or presenting with reversible pulpitis only);
- 161 • teeth with an active carious lesion extending into dentine
- 162 • where there is no irreversible pulp pathology detected

163 *Non-cavitated carious lesions*

164 Non-cavitated (i.e. cleansable) incipient lesions can be managed non-operatively using biofilm  
165 disruption / removal (regular toothbrushing using fluoridated toothpaste)<sup>19</sup> coupled with adjunctive topical  
166 remineralisation therapies where necessary (targeted at high caries risk individuals), or by therapeutic  
167 fissure sealing over the early lesion, predominantly carried out for occlusal pits and fissures <sup>20</sup> (Figure  
168 3).

169 *Non-cavitated but radiographically extensive carious lesion*

170 Occlusal lesions that appear clinically non-cavitated but radiographically extend significantly into dentine  
171 might not arrest through biofilm control alone. Such lesions can be therapeutically fissure sealed but the  
172 integrity of the sealant must be monitored and consideration given to the possibility of a ‘trampoline’  
173 effect from the underlying softer infected, completely demineralised dentine leading to mechanical failure  
174 of the sealant. If that happens the tooth eventually will also require further invasive restoration. The  
175 positive evidence for therapeutic fissure sealants is increasing <sup>21,22</sup>.

176 *Cavitated carious lesions*

177 Cavitated dentine lesions that are accessible to visual-tactile and activity evaluation are potentially  
178 cleansable lesions (i.e. lesions that are assessed as being cleansable by the motivated patient). These  
179 can be made inactive, i.e. not requiring further operative treatment as their progression is unlikely and  
180 as such, can be managed non-operatively (non-invasively), i.e. via biofilm removal through oral hygiene  
181 procedures and fluoridated toothpaste or remineralisation therapies. Lesions that are not cleansable are  
182 likely to be pathologically active and progress, but might be made into cleansable lesions (‘Non-  
183 Restorative Cavity Control’). This type of cavity modification appears applicable for use in primary teeth  
184 and was advocated by GV Black in 1908. Currently, more evidence is required for guiding the  
185 practitioner, particularly related to the age when the Non-Restorative Cavity Control can start. This  
186 includes additional supporting control measures such as application of fluoride varnish, remineralising  
187 agents or placing a layer of high-viscosity glass-ionomer over the floor of the cavity. Lesions with surface  
188 cavitation that cannot be managed by making them cleansable should be considered non-cleansable  
189 and therefore, active. These lesions usually need further operative interventions for their management  
190 (Figure 4).

191 *Clinical presentation of carious dentine*

192 Given the available clinical and microbiological evidence, the level and extent of carious tissue removal  
193 can be centred around levels of hardness of the remaining dentine <sup>3,23</sup>. These subjective hardness levels  
194 include the descriptors soft, leathery, firm and hard. For practical purposes, assessing the force required  
195 for a sharp dental explorer to make a mark on carious tooth tissue is currently the most practical way for  
196 the clinician to assess its degree of “softness” or “hardness”. Some practical guidance is offered below  
197 to describe the physical properties that are associated with different histological states of dentine. It  
198 should be remembered that these states are only part of a continuous spectrum of presentation of  
199 carious dentine and do not exist in discrete zones or layers (Figure 5).

200 *Soft dentine*

201 Soft dentine deforms when a dental explorer (sharp probe) is pressed onto it, with a latent “stickiness”.  
202 It can be easily scooped up (e.g. with a sharp hand excavator) with little force being applied. This dentine  
203 consistency is often described as caries-infected dentine and can appear moist in consistency.

204 *Leathery dentine*

205 Leathery dentine does not deform when an instrument is pressed onto it. Without much force, it can still  
206 easily lifted – a latent “tackiness” can be elicited. There may be little difference between leathery and  
207 firm dentine with leathery being a transition on the spectrum between soft and firm dentine. This dentine  
208 consistency is often described as caries-affected dentine.

209 *Firm dentine*

210 Firm dentine is physically resistant to hand excavation requiring some pressure to be exerted through  
211 an instrument to lift it.

212 *Hard dentine*

213 A pushing force needs to be used with a dental explorer instrument to engage the dentine and only a  
214 sharp cutting edge or a bur will lift it. A scratchy sound or ‘cri dentinaire’ can be heard when a straight  
215 probe is taken across the dentine. This consistency classically signifies sound dentine.

216

217 *How should carious tissue be removed in teeth with sensible, asymptomatic pulps?*

218 Previous terms for removal of carious tissues described the outcome of the excavation process and  
219 were problematic. The criteria that demarcate the extent to which carious tissues are removed have not  
220 been defined or agreed. These might include tissues being free from bacteria, demineralised dentine,  
221 discoloured dentine or even “soft dentine”. Furthermore, there are no commonly used and easily  
222 accessible technologies available to reliably assess any of these rather subjective endpoint criteria in a  
223 clinical setting. Lastly, if more advanced techniques are available in the future that can, for example,  
224 measure bacterial load or mineral loss, it is most likely that areas of dentine will be found where there is  
225 incompletely removed carious tissue seen after previously attempted complete removal and vice versa.  
226 In other words, when to stop removing carious tissue is arbitrary and dependent upon the operator’s  
227 understanding of the caries process in the individual tooth and patient that is being treated.

228

229 Thus, it seems logical to use procedural definitions to describe exactly what has been *done* instead of  
230 measuring what was attempted to *achieve*. Using this rationale, the term “selective removal” is preferred.  
231 In selective removal, different excavation criteria are used when assessing the periphery of the cavity  
232 as opposed to the area in close proximity to the pulp. The periphery of the cavity should ideally be  
233 surrounded by ‘sound’ enamel to allow the optimal adhesive seal. The peripheral dentine should ideally  
234 be hard – with similar tactile characteristics to sound dentine, such as a scratching noise when scraping  
235 the surface with a sharp hand excavator or dental probe. However, firm / leathery carious tissue should



236 be left towards the pulpal aspect of the cavity, with only enough of it removed to allow a durable bulk of  
237 restoration to be placed, whilst avoiding pulp exposure at all costs. Following this rationale, five main  
238 strategies for removing carious dentine, based on the hardness of the dentine are proposed. Decisions  
239 regarding the use of these strategies are guided by the lesion depth and activity (Figure 6).

240 **Non-Selective Removal to Hard Dentine** (formerly known as complete excavation or complete caries  
241 removal) uses the same criterion to assess the endpoint of carious tissue removal for all parts of the  
242 cavity, i.e. peripherally and pulpally. Only hard sound dentine remains so that demineralised dentine,  
243 'free' of bacteria is 'completely' removed. *This unnecessarily aggressive traditional operative approach*  
244 *is considered gross over-treatment and no longer advocated.*

245 **Selective Removal to Firm Dentine** leaves 'leathery' dentine pulpally; there is a feeling of resistance  
246 to a hand excavator whilst the cavity margins and peripheral dentine are left hard (scratchy) after  
247 excavation is complete. *"Selective Removal to Firm Dentine" is the treatment of choice for both*  
248 *dentitions, in shallow or moderately deep cavitated dentine lesions (i.e. lesions radiographically*  
249 *extending less than the pulpal third or quarter of dentine). In deeper lesions, "Selective Removal to Firm*  
250 *Dentine" puts the pulp at risk of "physiological stress" or exposure, which is why other strategies should*  
251 *be considered in these cases.*

252 **Selective Removal to Soft Dentine** is recommended in deep cavitated lesions (i.e. extending into  
253 pulpal third or quarter of the dentine). Soft carious tissue is left over the pulp to avoid exposure and  
254 "stress" to the pulp, encouraging pulp health, whilst peripheral enamel and dentine are prepared to hard  
255 dentine, to allow an adhesive seal to be achieved by placement of a durable restoration. *"Selective*  
256 *Removal to Soft Dentine" reduces the risk of pulp exposure in deep lesions significantly compared with*  
257 *"Non-Selective Removal to Hard Dentine" or "Selective Removal to Firm Dentine".*

258 **Stepwise Removal** is carious tissue removal in two stages / visits <sup>12,24,25</sup>. Soft carious tissue is left only  
259 over the pulp in the first visit and peripheral dentine is prepared to hard dentine, to allow a complete and  
260 durable seal of the lesion. A provisional restoration, sufficiently durable to last up to 12 months is placed  
261 (e.g. high-viscosity glass ionomer cement). After this time, the restoration is removed and the previously  
262 retained carious dentine is further removed until firm dentine is reached, formed during the restoration  
263 period as the caries process arrests. There is clinical evidence that the second removal stage may be  
264 omitted as this increases risk of pulp exposure <sup>3,26,27</sup>. The second visit also adds additional cost, time  
265 and potential discomfort to the patient. In the primary dentition, teeth have a limited lifespan so Stepwise  
266 Removal is not considered necessary for primary teeth and "Selective Removal to Soft Dentine" should  
267 be carried out.

### 268 *How should carious tissue removal be carried out?*

269 There are several methods and different technologies for clinical carious tissue removal, including  
270 excavation with hand instruments, tungsten carbide / ceramic / carbon-steel / polymer burs, air-abrasion,  
271 sono-abrasion, chemo-mechanical agents, and lasers. Studies on clinical advantages and  
272 disadvantages of the different excavation methods indicates some evidence finding hand or chemo-  
273 mechanical excavation potentially advantageous towards selective removal <sup>28-31</sup>. These technologies

274 may also reduce pain and discomfort during treatment in comparison to the other methods mentioned  
275 above <sup>32</sup>, although further evidence is required.

276

### 277 *Examples of specific caries management protocols*

#### 278 Atraumatic Restorative Treatment (ART)

279 ART uses hand instruments for opening small cavities and for removing carious tissue. The cavity is  
280 sealed with an adhesive restorative, usually a high-viscosity glass ionomer cement that simultaneously  
281 is used to seal any available remaining pits and fissures. In small and medium dentine cavities, ART  
282 follows the “Selective Removal to Firm Dentine” protocol whilst in deep lesions the “Selective Removal  
283 to Soft Dentine” is followed <sup>33</sup>.

284

#### 285 Hall Technique

286 The Hall Technique is a method for sealing carious lesions in primary molar teeth using preformed metal  
287 crowns. The correct size of crown is chosen to fit the tooth, filled with glass ionomer luting cement and  
288 seated firmly over the tooth. This avoids the need for tooth tissue removal and local anaesthetic and in  
289 two randomised control trials children preferred the technique to conventional restorations <sup>34,35</sup> and  
290 results indicated that this technique outperformed conventional restorations <sup>36,37</sup>. The technique  
291 compares favourably with conventional crowns <sup>38</sup>. Appropriate lesions and how to carry out the  
292 technique are explained at { [HYPERLINK "https://en.wikipedia.org/wiki/Hall\\_Technique"](https://en.wikipedia.org/wiki/Hall_Technique) }.

293

#### 294 *How should the resulting cavity be managed?*

295 Traditionally, cavity disinfection and cavity lining procedures have been advocated after removing  
296 carious tissue, prior to restoring the cavity definitively. Cavity disinfection has been advocated to reduce  
297 the number of remaining bacteria. However, given that the presence and number of bacteria are of  
298 limited importance in continued caries progression and the development of caries associated with  
299 restorations and sealants (CARS, also known as secondary or recurrent caries), the necessity for cavity  
300 disinfection is now questionable. Studies have shown no difference in restoration survival rate after  
301 disinfecting cavities compared to no cavity disinfection <sup>39</sup>. Cavity disinfection procedures do increase  
302 treatment time and cost.

303

304 Cavity lining (most commonly accomplished with calcium hydroxide or its derivatives) has been used  
305 traditionally when treating deep carious lesions in an attempt to keep the pulp-dentine complex viable  
306 and functioning through reducing the number of residual viable bacteria, remineralising dentine, inducing  
307 reactionary dentine, isolating the pulp and protecting pulp cells from noxious stimuli <sup>40</sup>. Again, the  
308 antibacterial effects are of limited relevance <sup>41,42</sup>. Remineralisation of remaining demineralised dentine  
309 seems to be mediated by pulp cell activity and may not be aided by separate liners <sup>43</sup>. Although certain  
310 liners seem capable of inducing tertiary dentine production and reducing pulpal inflammation <sup>44</sup>, the  
311 evidence is sparse and the clinical relevance unclear <sup>27,45,46</sup>. The isolation of the pulp against thermal  
312 insult is relevant when placing thermally conductive restorative materials (i.e. dental amalgam). Isolating

313 the pulp when placing resin-based restorations might be beneficial as monomers may penetrate through  
314 dentine into the pulp <sup>47,48</sup>. In summary, placement of separate cavity lining materials are not necessary  
315 to control pathological progression within the sealed lesion, but might help impede monomer penetration  
316 and avoidance of fracture of the remaining dentine when resin composite is the restorative material.  
317 More clinical evidence is required for the latter.

### 318 *How should the cavity be restored?*

319 The choice of materials for restoring cavities should be guided by the location and extent of the lesion,  
320 the caries risk, lesion activity and specific patient conditions and environment. There is no definitive  
321 evidence to support particular materials for restoring teeth after selective carious tissue removal to soft  
322 or firm dentine.

323

### 324 *What should be done to make these suggested changes work*

325 It takes a long time to change clinical practice in medicine and dentistry. It is acknowledged how difficult  
326 it can be to change patients' behaviour / lifestyle and it is no different in trying to change the professions'  
327 own attitudes. Contemporary knowledge is necessary for this change to take place but alone, this is not  
328 sufficient. Minimally invasive clinical skill sets, for detection, diagnosis and operative techniques need  
329 to be mastered as well as nurturing the right attitude for evidence-based change to deliver the best oral  
330 healthcare for patients. An important starting point for such change are dental training institutions  
331 globally. Cariologists and particularly faculty-based instructors at the skill laboratories and those  
332 employed in the clinic should be trained in-house in contemporary Cariology and cavity treatments that  
333 furnish them with the knowledge to then educate dental students <sup>4</sup>.

334

### 335 *Summary recommendations*

- 336 1. Preventing carious lesions means managing the disease, the caries process, with inputs from  
337 both the oral healthcare team and the patient. For existing lesions, dentists, alongside and  
338 leading their oral healthcare teams, should work with the patient to manage oral health and as  
339 a consequence to control disease activity. In doing so, dental hard tissues are preserved,  
340 initiation of the destructive restorative cycle is avoided and the tooth retained in clinical function  
341 for as long as possible. Further recommendations for managing non-cavitated lesions are  
342 beyond the remit of this paper.
- 343 2. When carious lesions are non-cleansable by the patient and sealing is no longer an option,  
344 minimally invasive operative restorative interventions are indicated.
- 345 3. Restorations are placed in cavitated lesions to help the patient in plaque biofilm control, to  
346 protect the dentine-pulp complex and restore the function, form and aesthetics of the tooth.  
347 Carious tissue removal aims to create conditions for a long lasting tooth-restoration complex,  
348 preserving healthy and remineralisable tissue, achieving a sufficient physical seal and

- 349 maintaining pulp health. It is accomplished preferably with methods that minimise dental anxiety  
350 and pain/discomfort for the patient.
- 351 4. In deeper lesions in teeth with sensible (vital) pulps, preserving pulp health should be prioritised  
352 over “mechanical” restoration success, whilst in shallow or moderately deep lesions, restoration  
353 longevity might be considered the more important factor.
- 354 5. For teeth with shallow or moderately deep lesions, “Selective Removal to Firm Dentine”  
355 excavation protocols should be followed.
- 356 6. In deep lesions (radiographically extending into pulpal third or quarter of the dentine) in primary  
357 and permanent teeth, “Selective Removal to Soft Dentine” should be performed.
- 358 7. In permanent teeth, Stepwise Removal might also be an option for deep lesions (with the  
359 understanding that the second stage visit may not be necessary).
- 360 8. Hardness of the dentine should be the primary criterion for assessing, describing and reporting  
361 on carious tissue and its removal. There is insufficient published evidence to recommend one  
362 method for carious tissue removal over another. Variations will always occur due to the different  
363 MI operative skill sets practiced by dentists the world over.
- 364 9. Cavity disinfection currently has no significant evidence-base for its inclusion in routine  
365 operative caries management protocols.
- 366 10. Recommendations for restoring teeth with particular restorative materials after using different  
367 carious tissue excavation protocols cannot be made at present.

368

## 369 **Notes**

370 The following are members of the ICCC (International Caries Consensus Collaboration: Falk  
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376 Contributors: Falk Schwendicke, Jo E. Frencken, and Nicola Innes conceived the collaboration and  
377 organized the consensus meeting. All members of the ICCC attended the meeting, contributed to  
378 content, drafted and revised the original manuscripts <sup>5,6</sup>.

379

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392 Declaration of interest at the organisational and individual consensus conference levels are detailed in  
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494 Figure 1: An arrested and remineralised carious lesion on the buccal surface of a lower first permanent  
495 molar. The lesion was active (detectable by being rough when a ball ended probe is dragged across  
496 the surface) whilst the tooth was erupting and the area was caries prone by being sheltered by the  
497 gingivae but is now inactive (smooth when a ball ended probe is dragged across the surface). The  
498 patient's oral hygiene habits improved and the area around the gingivae has not undergone  
499 demineralisation indicating that during the last stages of eruption the biofilm was removed and  
500 cleaning has continued. The lesion shape follows the shape of the gingiva and the white area can be  
501 thought of as a scar from previous disease. Note this is an example of an incipient lesion that has not  
502 taken up dietary stains to form the arrested "brown spot lesion".

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522 Figure 2. A) Radiograph of a maxillary left first permanent molar with a deep carious lesion extending  
523 to the inner (pulpal) 1/3 of dentine where preservation of pulp health should be prioritised during  
524 operative intervention and B) a shallow carious lesion in the mandibular left second molar (confined to  
525 the inner third of the dentine) where the tooth-restoration complex longevity might have more  
526 significance when deciding on the minimally invasive operative management options.

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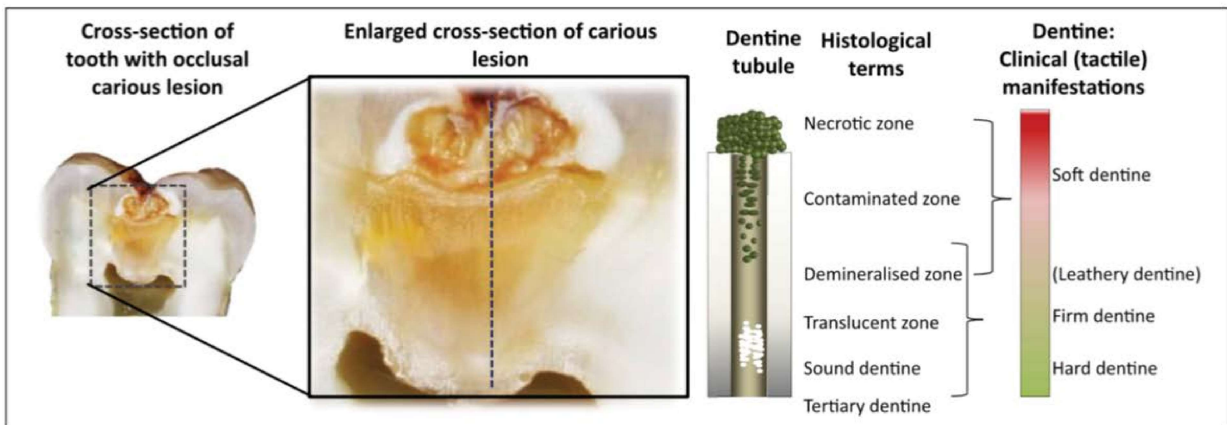
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Figure 3. Radiograph showing therapeutic fissure sealants over occlusal surface carious lesions in primary molars. A) radiograph taken when the child was 5 years old showing initial carious lesions in all four right first primary molars. These were fissure sealed and radiograph B) was taken 2 years later. There is no clinical or radiographic evidence of progression of any of the lesions. The fissure sealants were repaired as necessary in order to maintain the seal.



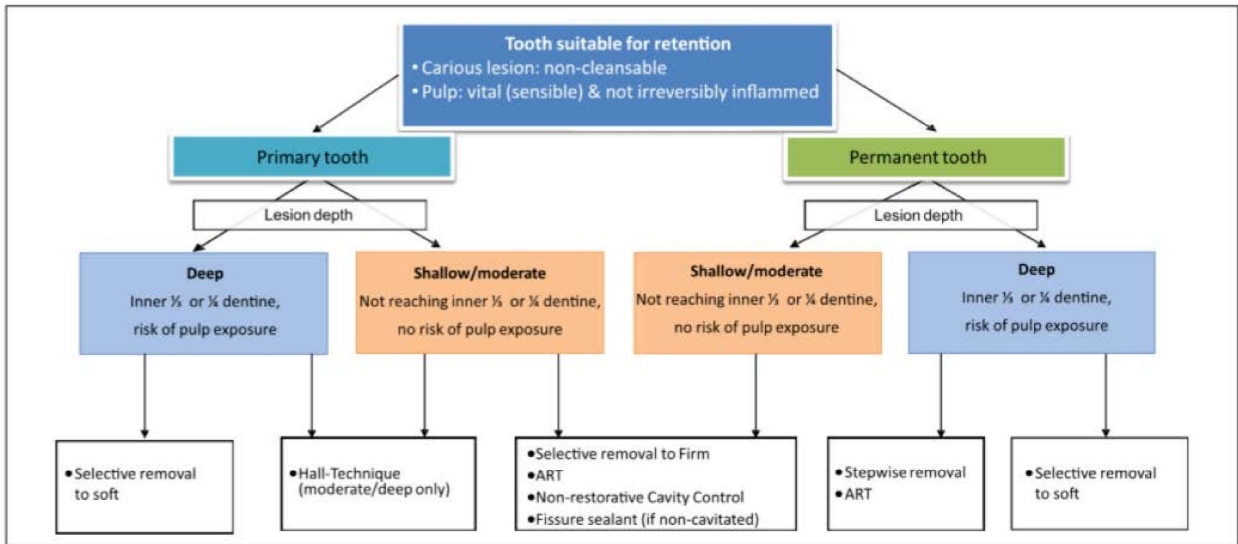
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Figure 4. A maxillary first permanent molar with a carious lesion showing surface cavitation. This has created a sheltered microniche that will support a cariogenic biofilm to thrive. The lesion is considered clinically non-cleansable from examination and therefore, active. These lesions usually need operative intervention.



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Figure 5. Diagrammatic representation of the carious cavitated lesion (after Ogawa et al., 1983) <sup>13</sup>



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586 Figure 6. Decision-making flowchart for the minimally invasive operative management non-cleansable  
 587 carious lesions in retainable teeth with vital pulps <sup>7</sup>.

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