# Clinical Threshold for Carious Tissue Removal

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**KEYWORDS**

• Caries removal • Operative dentistry • Stepwise excavation
• Caries microbiology • Incomplete caries removal

*"The complete divorcement of dental practice from the studies of the pathology of dental caries, that existed in the past, is an anomaly in science that should not continue. It has the apparent tendency to make dentists mechanics only."*

Thus wrote GV Black in his textbook of operative dentistry in 1908.[1] This seminal text was in two volumes, and Volume 1 was entirely devoted to the pathology of the hard tissues of the teeth; his suggestions for caries management were based on his observations of the disease process.

Unfortunately, in the intervening century, something went strangely wrong, because in many dental schools the science of cariology and the technicalities of operative dentistry were taught and researched separately. Generations of students passed through operative technique courses and phantom head rooms restoring caries-free natural teeth or, even worse, plastic counterfeits. The eventual appearance of demineralized tissue in living patients on the clinic could be a considerable inconvenience, ruining stereotyped outline forms and preconceptions of appropriate depths, widths, and angles.[2]

Current practice in caries removal cuts back enamel to expose softened infected dentin. The enamel–dentin junction is instrumented further until it is hard and in some countries until it is also stain-free. Over the pulpal surface, softened, demineralized dentin is scooped away with sharp small spoons called excavators. The point of terminating excavation varies according to the country, dental school, the individual teacher's idiosyncrasy, and the presumed proximity of the softened tissue to the pulp. This article assembles the biologic evidence behind what needs to be removed and will, rather uncomfortably, challenge conventional teaching. Some will consider these suggestions to be heresy, while others may have been working in this way for years and will wonder what all the fuss is about.

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## WHAT IS CARIES?

It is perhaps unfortunate that the word caries is used to describe both the caries process and the caries lesion. The caries process occurs in the biofilm, a community of microorganisms with a collective physiology that respond to the environment at the site. The biofilm is always metabolically active with minute fluctuations in pH. The result may be nothing to see or there may be a net loss of mineral, leading to a caries lesion that can be seen. Thus, caries the process occurs in the biofilm, and the interaction of the biofilm with the tooth surface may result in the formation of caries the lesion, the consequence or reflection of the process.

## CARIES CONTROL BY NONOPERATIVE TREATMENTS

Wherever a patient can access and disturb the biofilm with a fluoride-containing dentifrice, a filling is not needed.[3] This simple cleaning measure will control caries lesion progression. No fillings are required in the following circumstances:

- White spot lesions including those on occlusal surfaces[1,4]
- Approximal caries lesions where the lesion is confined to the enamel, or just into dentin on bitewing radiograph. These lesions are unlikely to be cavitated in contemporary populations and should be given a chance to arrest with nonoperative treatments[3]
- Root surface lesions accessible to cleaning, both cavitated and noncavitated[5]
- Recurrent caries lesions adjacent to fillings, uncavitated or cavitated but cleansable, also do not require restorations. Amalgam fillings should not be replaced simply because of ditching and staining around them. Mild ditching, that a periodontal probe will not enter, and staining around a restoration are poor predictors of infected dentin beneath the restoration[6]
- Large cavitated lesions where overhanging enamel has been removed by the dentist, or has fractured away, are also cleansable and can be arrested by cleaning alone. This is a clinical observation. The author does not know of a clinical study that has addressed this in a controlled manner.

## WHEN IS A FILLING NEEDED TO CONTROL CARIES?

A cavitated lesion, where the patient cannot access the biofilm with a toothbrush, is likely to progress and requires restoration as part of caries lesion control.[3] Put simply, the filling restores the integrity of the tooth surface and allows the patient to clean again. Thus, from a cariological point of view, restoring the tooth is part of plaque control.

Fillings are required in the following circumstances:

- Cavitated occlusal lesions, (codes 3 or higher ICDAS II, see the article by Braga and colleagues elsewhere in this issue for further exploration of this topic); these are likely to be visible in dentine on a bitewing radiograph[7,8]
- Cavitated approximal lesions; these are clearly into dentin on a bitewing radiograph.[3]

## OBJECTIVES OF RESTORATION FROM A CARIOLOGICAL POINT OF VIEW

Caries removal and restoration should:

- Arrest caries lesion progression
- Provide an adequate base for the restorative material
- Produce a filling that the patient can clean.

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## PULPO–DENTINAL REACTIONS

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The advent of adhesive restorative materials was particularly exciting, because whereas amalgam could be regarded as a plug in a hole, bonded adhesive materials might be capable of improving cavity seal and even giving back some strength to tooth tissue undermined by demineralization. Good cavity seal is thought to be of great import, because it is leakage of bacteria that potentially damages a vital pulp.[9] Supporting tooth tissue undermined by demineralization may allow preparations to be much more conservative, preserving tissue that would have to be removed without the strengthening effect of the adhesive material.[10]

## AN OLD ARGUMENT

Discussions on how much demineralized tissue must be removed before restoration are hardly new. One can go back 150 years to Tomes[11] writing in 1859:

> *"It is better that a layer of discoloured dentine should be allowed to remain for the protection of the pulp rather than run the risk of sacrificing the tooth."*

Black,[12] however, did not agree for he wrote in 1908

> *"...it will often be a question of whether or not the pulp will be exposed when all decayed dentin overlaying it is removed....it is better to expose the pulp of a tooth than to leave it covered only with softened dentin."*

This article now focuses on the biologic arguments for and against vigorous caries removal before examining the research evidence on the consequences of incomplete caries removal.

## PULPO–DENTINAL REACTIONS TO DENTAL CARIES

Dentin is a vital, cellular tissue, containing the cellular processes of the odontoblasts. Thus dentin and pulp must be considered together. The ecological catastrophe in the biofilm, which is the caries disease process, is an assault on this vital tissue that is capable of defending itself. In 1967, Massler distilled current scientific knowledge on this matter including describing his own research performed over a period of 11 years on more than 800 human teeth.[13] His sense of frustration at some of his colleagues jumps from the page:

> *"It is somewhat disturbing to the biologically orientated clinical teacher to witness the overly focused attention of some dentists upon the operative and restorative phases of dentistry, the 'drilling and filling' of teeth, to the neglect of the disease process which caused the lesion (cariology) and the preoperative treatment of the wounded tooth–bone."*

A combination of defense and degenerative reactions characterizes the caries lesion in the pulpo–dentinal complex. Massler's particular contribution was to point out how essential it is to differentiate active from arrested lesions if one is to make any sense of the biologic reactions. From this, a logical management follows. This seeks to convert an active lesion into an inactive or arrested lesion, thus aiding the defense and healing processes in dentin and pulp before restorative procedures are attempted.

Massler showed that under an active lesion, the dentinal tubules were permeable, whereas under arrested lesions, there were sclerotic zones in the dentin that were impermeable to dyes and isotopes.[13] He pointed out that the plugging of the tubules forms a very effective barrier against further penetration of toxic materials toward the pulp. Thus it would be biologically crazy to damage this area by attacking it with a bur.

Massler described an active lesion as one characterized by an active bacterial colony on the surface (the infected layer) and a very wide layer of demineralized dentin beneath, containing few pathogenic microorganisms (the affected dentin). Massler subsequently pointed out that most lesions found clinically were a combination of active and arrested lesions. At the periphery of the lesion, an active lesion is often spreading under the overhanging enamel, along the enamel–dentin junction, while the central, more easily cleaned area is hard and partially remineralized. Thus, as stated at the beginning of this article, the lesion reflects the activity in the overlying biofilm.

## CAN AND SHOULD INFECTED DENTIN BE REMOVED?

If the biofilm at the tooth surface drives the caries lesion, all that must be removed to arrest the lesion is the biofilm. Supposing a clinician disagrees with this interpretation and wishes to remove all the infected dentin, can this be achieved? The answer is to this question is that it is not possible. Shovelton's review of 1968[14] showed that softening of dentin generally precedes the organisms responsible for it, but a few organisms will remain even if all the soft dentin is removed.

## CONVENTIONAL CARIES REMOVAL

The most commonly used criterion for the removal of infected dentin is to scoop out all the soft stuff with an excavator. At the enamel–dentin junction, some schools teach the area should be made stain-free as well as hard; others just say hard and ignore the stain. Because staining is an unreliable guide to the level of infection of the dentin, and because a few bacteria will remain whatever approach is adopted, leaving stain seems more conservative.[15]

Over the pulpal surface, stained dentin should remain so long as it is reasonably hard. Provided a tooth is symptomless and responds as vital to pulp testing, vigorous excavation over the pulpal surface seems positively contraindicated once the cavity floor is reasonably firm. The student, however, will find that teachers do not agree on what constitutes reasonably firm. The subjectivity of these assessments led to the development by Fusayama[16,17] of red dyes to be used clinically to differentiate infected from affected dentin. Infected dentin was shown to be an irreversibly damaged layer, while affected dentin was the inner, remineralizable zone. The same author tentatively suggested the dye staining front coincided with the bacterial invasion front.

Thus, in theory, this dye could be used to identify the carious tissue that is infected with bacteria and thus needs to be excavated. Subsequently, several studies[18–20] showed the dye does not necessarily discriminate infected tissue and use of the dye could lead to overpreparation of cavities, encouraging removal of excess tissue at the enamel–dentin junction[20] and removal of sclerotic and reparative dentin over the pulpal surface.[21]

## ULTRACONSERVATIVE CARIES REMOVAL

Thus far, this article has questioned the biologic basis for contemporary caries removal, which seeks to remove most infected demineralized dentin. Is this appropriate with the present knowledge about the disease and the way in which lesions progress? What would happen if most of the infected dentin were left and a restoration placed? Would the caries process arrest? There is much evidence to answer this question from:

Studies placing fissure sealants over carious dentin
Stepwise excavation studies
Studies where a final restoration was placed following incomplete caries removal

Randomized clinical trials com
removal.

## FISSURE SEALANT STUDIES

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Microorganisms were eliminate
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## STEPWISE EXCAVATION STUDIES

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Randomized clinical trials comparing conventional and ultraconservative caries removal.

## FISSURE SEALANT STUDIES

Several studies have examined the consequences of sealing over carious dentin.[22–30] All studies bar one[30] were prospective, and in many there were unsealed control lesions. Caries lesion activity was assessed in several ways, including clinical observation, clinical and radiographic lesion depth measurement, and microbiological sampling. Observation periods varied from 2 weeks to 5 years.

Some uniform themes emerge[2]:

Sealed lesions appeared to arrest clinically and radiographically
Microorganisms were eliminated or decreased with time
There was no pulpitis in sealed teeth
Lesions progressed where sealants were lost or in unsealed control teeth.

The study by Weerheijm and colleagues[30] is an interesting outlier. She accessed demineralized tissue in teeth with radiographic lesions in dentin under intact sealants. Cariogenic organisms were found in 50% of the teeth, and the dentin was often soft and moist, apparently indicating lesion activity.

## STEPWISE EXCAVATION STUDIES

In stepwise excavation, only part of the soft dentin caries is removed at the first visit during the acute phase of caries progression.[31–45] The cavity is restored and reopened after a period of weeks. Further excavation then is performed before a definitive restoration. The objective of the exercise is to arrest lesion progression and allow the formation of reparative dentin, making pulpal exposure less likely in vital teeth with deep carious lesions but no symptoms of irreversible pulpitis.

The procedure has been investigated scientifically for over 30 years.[2] These studies have involved baseline investigation of carious dentin and then a reanalysis after a period of sealing. Collectively these studies tell much about the consequences of sealing infected dentin in teeth.

Most of the studies are done in permanent teeth with deep lesions, although some studies have involved deciduous teeth.[31,33–35] There are often no controls. The amount of dentin removed at the first visit varies greatly from only access to carious dentin to removing the bulk of the carious dentin. The restorative materials are also very variable, including calcium hydroxide, zinc oxide and eugenol, amalgam, glass ionomer cement, and composite resin. Times to re-entry can be as short as 3 weeks or as long as 2 years.

Caries lesion activity has been assessed clinically, radiographically, and often by microbiological examination at the original visit and on re-entry.

Despite these very different methodologies, several themes emerge:

Clinical success is high, exposure usually avoided in the stepwise group, and there are rarely symptoms between visits. On the other hand, exposure is common in control, conventionally excavated lesions
The dentin often is altered on re-entry, being dryer, harder, and darker
Microbiological monitoring indicates substantial reductions in cultivable flora, although some microorganisms may survive
Several studies suggest the organisms have altered on re-entry to a less cariogenic flora.[42–44] Biologically this is entirely logical, because the supply of nutrients will

diminish. Not only are the organisms cut off from the oral environment, they are cut off from nutrients from the pulpal side also by tubular sclerosis and reparative dentin. They are in a stressful environment and adapt accordingly. One study even showed the flora on re-entry to be identical in the fully excavated control teeth and the teeth where soft, heavily infected dentin was left.[45] Collectively, these studies seem to put the final nail in the coffin of excavating demineralized dentin because it is infected. The few microorganisms that survive seem opportunistic squatters adapted to their new environment.

## WHY RE-ENTER?

It is only logical to question whether re-entry is needed. The final excavation allows the dentist to be sure there is no exposure, but it is unlikely to alter the microbiology. Not re-entering is the basis of the indirect pulp capping technique.[46–48] The difference in caries removal between the two techniques is the amount of soft dentin removed. In indirect pulp capping the dentist attempts to remove as much as possible, and because there is no way of knowing the proximity of the pulp, this is a fine and difficult judgment. No such worry exists in stepwise excavation.

## STUDIES WHERE THE FINAL RESTORATION WAS PLACED OVER SOFT DENTIN

Two studies selected less advanced lesions and did not re-enter to remove the remaining soft dentin in the treatment groups. The work of Ribero and colleagues[49] (1999) on deciduous teeth concluded that the clinical performance of the restorations was not adversely affected by the incomplete caries removal after a year. The study by Mertz-Fairhurst and colleagues[50] (1998) was remarkable for a 10-year follow-up of occlusal restorations in permanent teeth placed over moist, soft, infected dentin left both at the enamel–dentin junction and over the pulp. Remarkably, half the patients were still available for recall after 10 years. Lesion progression was arrested, and there were no more clinical failures in this group than in the control groups with conventional caries removal, although it is not known if this observation would have changed if all the patients had been available for recall.

Finally a randomized controlled clinical trial of the Hall technique of stainless steel crowns on deciduous teeth must be added to the evidence.[51] In this technique, primary molar teeth with caries lesions affecting two or more surfaces are restored with a preformed stainless steel crown. Unlike the traditionally taught technique, however, no caries removal takes place and no tooth preparation is performed. The crown simply is filled with a glass ionomer cement and placed on the tooth with either finger pressure or the child's occlusal force. The study was performed in general practice, and the control restorations were conventionally placed fillings. Results at 2 years showed only 2% of teeth with pulpal pathology in the Hall group compared with 15% in the conventionally restored group. Loss of restoration or caries lesion progression occurred in 5% of the Hall group but in 46% if the control group. When children and care givers were asked at placement which technique they preferred, the Hall technique was favored by most.

## SYSTEMATIC REVIEW; COMPLETE VERSUS ULTRACONSERVATIVE REMOVAL OF DECAYED TISSUE

The included papers in this study were two stepwise excavation studies, one on permanent teeth and one on deciduous teeth and two studies where caries was sealed permanently into teeth.[52] Several conclusions were drawn:

Partial caries removal in symp
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No detriment to the patient in
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Partial caries removal in symptomless, primary or permanent teeth reduces the risk of pulpal exposure

No detriment to the patient in terms of pulpal symptoms was found

Partial caries removal would appear preferable in the deep lesion to reduce the risk of carious exposure

There is insufficient evidence to know whether it is necessary to re-enter and excavate further in the stepwise excavation technique, but studies that did not re-enter reported no adverse consequences

There is a need for further randomized control clinical investigations of the need to remove demineralized tissue before restoring teeth. In particular the use of the technique in approximal lesions needs investigation, and the possibility of an adverse effect on the filling material should be studied. For instance, would a composite restoration placed on soft dentin be more liable to fracture?

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