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Treatment of deep carious lesions by complete excavation or partial removal:

A critical review

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Abstract

Background—The classical approach to treatment of deep carious lesions approaching the pulp mandates removing all infected and affected dentin. Several studies call this approach into question.

Types of Studies Reviewed—A search of five electronic databases using selected key words to identify studies relating to partial versus complete removal of carious lesions yielded 1,059 reports, of which the authors judged 23 to be relevant. Three articles reported the results of randomized controlled trials.

Results—The results of three randomized controlled trials, one of which followed up patients for 10 years, provide strong evidence for the advisability of leaving behind infected dentin, the removal of which would put the pulp at risk of exposure. Several additional studies have demonstrated that cariogenic bacteria, once isolated from their source of nutrition by a restoration of sufficient integrity, either die or remain dormant and thus pose no risk to the health of the dentition.

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Keywords

Deep caries; deep carious lesions; partial caries removal; indirect pulp capping; pulpal exposure; stepwise excavation; alternative restorative treatment

The treatment of deep carious lesions approaching a healthy pulp presents a significant challenge to the practitioner. The traditional management of carious lesions of any kind dictates the removal of all infected and affected dentin to prevent further cariogenic activity and provide a well-mineralized base of dentin for restoration. When the procedure risks exposing or even breaching the pulp, however, the course of treatment becomes less predictable and may require such measures as indirect pulp capping (typically using a protective material such as a calcium hydroxide–based preparation), pulpotomy or, in the most extreme cases, pulpectomy. Choosing among these options can be daunting for the dentist—as well as for the patient, who is advised of the risks and asked to share in the decision.

To preclude or at least minimize the potential complications of complete excavation of carious dentin close to the pulp, several authors have investigated and proposed alternative approaches. One such method, stepwise (or two-step) excavation, involves the staged removal of carious tissue. At the patient's initial visit, once the clinician has established that the pulp still is vital, he or she partially removes necrotic infected dentin, often characterized as soft and removed easily by using hand instruments. The clinician then seals the lesion with a medicament such as calcium hydroxide and places a temporary restoration. At the second visit—typically some months after the first and, in some cases, up to two years later—the clinician removes all or most of the remaining infected tissue. The rationale for this approach is that by this point any remaining bacteria will have died, residual infected dentin as well as affected dentin will have remineralized, and reparative dentin will have been generated, making it easier for the dentist to remove any remaining carious tissue.

An even more controversial approach is conservative or ultraconservative removal of carious tissue, often referred to as "partial caries removal." In this method, the practitioner removes most but not all of the infected dentin, seals the cavity (with or without indirect pulp treatment) and proceeds with the restoration. The tradeoff for avoiding pulpal exposure—leaving behind a layer of infected dentin—is defended by citing the substantial evidence (discussed below) that cariogenic bacteria isolated from their source of nutrition by a restoration of sufficient integrity either die or remain quiescent and thus, given a vital pulp, pose no risk to the health of the dentition.

Studies comparing either partial caries removal or stepwise excavation with complete removal of infected tissue from deep carious lesions were the subject of a 2006 Cochrane Review.[1] The Cochrane article, while extremely valuable, is limited in scope by virtue of being a meta-analysis focused solely on the results of randomized controlled trials. In preparing this review, we sought to cast a wider net by performing a traditional review, taking into account observational studies and ancillary investigations that also might be of interest to the practitioner.

METHODS

We conducted a systematic search of five databases (MEDLINE, Evidence-Based Medicine Reviews, the Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials and OVID's Database of Abstracts of Reviews of Effects) using the following key words: deep caries; deep carious lesions; partial caries removal; indirect pulp capping; pulpal exposure; stepwise excavation; alternative restorative treatment (ART). We limited the

search to reports written in English describing studies using human subjects and published from 1950 through the first week of November 2007. The literature search yielded 1,059 articles, of which 23—including articles relating to restoration longevity, cariogenic activity and pulp vitality, as well as those directly addressing partial versus complete removal of deep carious lesions—reported results we deemed directly relevant.

RESULTS

We identified 10 articles[2–11] accounting for six studies (four of these articles reported follow-up results) that directly address the issue of partial removal of carious tissue from deep lesions (Table). Three investigations stood out by virtue of being randomized controlled trials: the 1987 study by Mertz-Fairhurst and colleagues,[2] the 1999 study by Ribeiro and colleagues[5] and the 2004 study by Foley and colleagues.[6]

Mertz-Fairhurst and colleagues[2] used a randomized split-mouth, four-celled design to compare sealed composite restorations in teeth treated via partial caries removal with both sealed and unsealed amalgam restorations in teeth from which all carious tissue had been removed. The study population consisted of 123 patients aged 8 to 52 years who had at least one pair of frank Class I lesions that, according to the investigators' radiographic evaluation, extended as far as halfway from the dentinoenamel junction (DEJ) to the pulp. A total of 156 pairs (312 teeth) were included in the study. The investigators evaluated restorations radiographically as well as clinically (using a modification of the Ryge/Snyder criteria[12]) at six months, one year and two years after treatment. They detected no significant differences among the three treatments —sealed conservative, sealed amalgam, unsealed amalgam—at any period. Mertz-Fairhurst's group followed up these patients across the next decade,[3,4] finally observing that "the bonded and sealed composite restorations placed over the frank cavitated lesions [had] arrested the clinical progress of these lesions for 10 years."[4]

The randomized controlled trial conducted by Ribeiro and colleagues,[5] in which they evaluated the performance of a dentin adhesive system, also served to test the relative performance of complete and partial caries removal. After etching, the investigators applied a bonding agent to both carious and noncarious dentin in 48 primary molars of 38 children aged 7 to 11 years. In one group, the clinicians removed carious dentin completely from the DEJ but only superficially from the remainder of the cavity; they treated a second group by completely excavating caries. The investigators extracted 40 teeth (20 from each group) at about the time of exfoliation (approximately one year after treatment) and subjected the teeth to radiographic and scanning electron microscopic analysis. These results, as well as evaluations of retention rates, marginal integrity and pulpal symptoms, indicated no significant differences between the two groups.

A more recent study by Foley and colleagues[6] compared the cariostatic effectiveness of alternative restorative materials in both partial and complete removal of carious tissue. The authors used a split-mouth design in 44 patients aged 3.7 to 9.5 years who had at least one pair of previously unrestored primary molars that had no pulpal involvement. They treated one tooth of each pair by complete caries removal and the other by incomplete caries removal followed by restoration using copper phosphate cement, glass ionomer cement (GIC) or both, or a material "of the operator's choice" (such as amalgam). At 24 months after treatment, teeth that had undergone partial caries removal followed by restoration with copper phosphate cement and GIC exhibited greater abscess or sinus formation than did teeth that had undergone other treatments. Restorations placed in teeth treated with GIC alone after partial caries removal, however, exhibited a durability and effectiveness comparable with those placed in teeth that had undergone complete caries removal.

In an observational study, Maltz and colleagues[7] investigated the effects of partial caries removal in 32 teeth with deep carious lesions. On the basis of clinical, radiographic and microbiologic evidence at reentry six to seven months after treatment (after which they placed a permanent restoration), the authors concluded that remineralization had taken place and that caries had been arrested. In follow-up studies of the same patients, the authors reported similar results 14 to 18 months after treatment[8] and 36 to 45 months after treatment.[9]

Fairbourn and colleagues[10] reported the effect of indirect pulp capping, after partial caries removal, on cultivable aerobic and anaerobic bacteria. These investigators restored 40 permanent asymptomatic teeth that had carious occlusal or interproximal lesions approaching the pulp after partial excavation of infected dentin in which zinc oxide–eugenol (Caulk IRM Intermediate Restorative Material, Dentsply Caulk, Milford, Del.) with or without a calcium hydroxide base (Dycal, Dentsply Caulk) was used. After five months, they isolated the teeth, excavated the remaining infected dentin and cultivated it to identify bacterial species. Both groups showed a dramatic decrease in colony-forming units (CFUs); nine of 20 teeth treated with the calcium hydroxide liner and five of 20 teeth treated with zinc oxide–eugenol had become operationally sterile (< 300 CFUs per milligram of dentin). The authors concluded that reentry to remove residual infected dentin with either restorative material may be unnecessary, provided that the restoration maintains an effective seal.

Marchi and colleagues[11] studied the effectiveness of two protective liners, calcium hydroxide and resin-modified glass ionomer, in the indirect pulp treatment of 27 primary molars. At four years after treatment, the success rate using the former was 88.8 percent and using the latter was 93 percent. The investigators defined “success” essentially as the absence of any “clinical radiographic signs or symptoms of irreversible pulp pathologies or necrosis.” The authors concluded that “indirect pulp capping in primary teeth arrests the progression of the underlying caries, regardless of the material used as a liner.”[11]

Several studies that did not focus on partial caries removal nevertheless are relevant to the treatment of deep carious lesions. There has been evidence for several decades, for example, that caries development is arrested in sealed lesions. Handelman and colleagues[13–17] have published extensively on this subject. Perhaps most frequently cited is their 1976 study,[13] in which they placed sealants on 60 teeth with carious lesions extending into the dentin; 29 unsealed teeth served as control specimens. They sampled teeth for bacterial culture at periods ranging from one week to two years; at the latter point, they found a substantial decrease in the number of cultivable microorganisms in sealed lesions when compared with the unsealed control teeth. Interestingly, they found the greatest amount of bacterial reduction within two weeks after treatment. In a subsequent study, Handelman’s group,[14] describing a radiographic analysis of teeth treated similarly to those in the 1976 study, reported a significant decrease in caries penetration in teeth in which the sealant remained intact. Bjorndal and colleagues,[18] performing stepwise excavation, cultured bacteria from the dentin of 19 teeth after the initial procedure and after intervals of six to 12 months; at the latter point, they observed that CFUs had been reduced substantially.

Two randomized controlled trials comparing stepwise and complete excavation, while only tangentially relevant to the partial caries removal technique, nevertheless are important for results relevant to the risk of pulpal complications after complete removal of deep caries. Magnusson and Sundell[19] reported postprocedural pulpal complications in eight (15 percent) of 55 teeth treated by stepwise excavation and in 29 (53 percent) of 55 teeth treated by direct excavation. Leksell and colleagues[20] similarly reported pulpal exposure in 10 (17.5 percent) of 57 teeth treated in stepwise fashion compared with 28 (40.0 percent) of 70 teeth treated by direct excavation.

A 2002 study comparing the efficacy of two materials used in conjunction with indirect pulp capping in 48 primary molars reported a success rate, as measured by absence of irreversible pulp pathology, of 96 percent for teeth treated with a proprietary adhesive resin system at two years after treatment.[21]

Al-Zayer and colleagues[22] retrospectively analyzed 187 primary posterior teeth (132 patients) treated with indirect pulp capping in which sufficient carious dentin was left to preclude pulpal exposure. The authors then followed up patients clinically and radiographically for periods ranging from two weeks to 73 months after treatment. Of the 187 teeth in the study, nine (4.8 percent) experienced complications, amounting to a 95 percent success rate.

Kreulen and colleagues,[23] using a split-mouth model, sampled carious dentin from molars before restoring the teeth using either a "biologically active" (that is, antimicrobial) resin-modified glass ionomer preparation or amalgam. They processed samples for viable bacteria and evaluated them for color and consistency. Dentin from the same sites similarly sampled and evaluated at six months after treatment in 39 patients from both groups exhibited a significant decrease in the mean number of bacteria and a significant "overall treatment" effect for color and consistency.

In a microbiological study of dentin samples taken from 40 carious lesions before and after undergoing ART, Bonecker and colleagues[24] found significant reductions in the frequency and proportions of total viable cells as well as of mutans streptococci (but not lactobacilli) in restorations sealed with a GIC.

Vij and colleagues[25] conducted a retrospective analysis of two approaches to treating carious lesions approaching the pulp in 226 primary molars (141 patients), including 133 teeth from a previous study[26] that used similar criteria for the same treatments. The investigators treated all teeth in two stages (not to be confused with stepwise excavation). First, they removed superficial carious tissue and temporarily filled the cavity with either zinc oxide–eugenol or GIC. Then, at a second appointment one to three months later, they either removed the remaining carious tissue completely and performed a pulpotomy followed by treatment with formocreosol or removed all but the deepest layer of remaining carious dentin and performed indirect pulp capping by using one of two GIC preparations. At three years after treatment, the success rate—as measured by the absence of swelling, abnormal mobility, pain and radiographic signs of pathology—was 94 percent for teeth treated by means of partial caries removal and indirect pulp capping and 70 percent for the group treated by means of formocreosol pulpotomy. While this study cannot serve to measure the relative merits of partial caries and complete caries removal per se, it demonstrates the relative superiority of partial caries removal to a technique (formocreosol pulpotomy) that some consider a viable alternative.

DISCUSSION

Is it necessary to remove all carious tissue from lesions approaching the pulp? Although there is substantial evidence to the contrary, most practitioners continue to follow the basic principle guiding any surgeon: that one must eradicate any and all affected tissue from the site of an infection. It is not clear, however, whether this principle is, or ought to be, followed at all times. In conventional endodontic therapy, for example, which has a high rate of clinical success, it is likely that viable bacteria and necrotic host tissue typically remain in the root canal system after instrumentation and obturation.[27]

The conventional treatment paradigm has a long history. G.V. Black, in his classic 1908 text, asserted that "it is better to expose the pulp of a tooth than to leave it covered only with softened dentine."[28] More recently, the majority of respondents to a survey on this subject indicated

that they would remove all carious tissue even if the procedure, in their judgment, would risk pulpal exposure; only about one in five respondents said they would choose to proceed with partial caries removal, and a slightly higher proportion indicated that they would initiate or refer the patient for endodontic treatment.[29] In another recent survey, conducted in 2006, the majority of respondents opted for pulpotomy as the treatment of choice in a similar scenario.[30]

Ironically, G.V. Black also stated that it is imperative that dentists understand the pathology of the caries process lest they be reduced to the role of mechanics.[31] It is interesting to speculate, given our ability to create a restoration with well-sealed margins and associated grooves and fissures, what Black would say about the subject of partial caries removal today. Several of the studies cited above (such as those by Handelman and colleagues,[13] Kreulen and colleagues,[23] Maltz and colleagues[7–9] and Bonecker and colleagues[24]) have demonstrated that bacterial counts under sealed restorations become drastically reduced. In their 2002 study, Maltz and colleagues,[7] citing significant decreases in counts of both aerobic and anaerobic viable bacteria and radiographic evidence of a mineral gain in affected areas, concluded that "complete dentinal caries lesion removal is not essential to the control of caries lesions"—a conclusion that was repeated in two follow-up studies.[8,9] Kidd,[32] who cited most of these same sources and several others, including studies of stepwise excavation and partial caries removal, concluded that "there is no clear evidence that it is deleterious to leave infected dentine."

Some of the best evidence for the rationale underlying partial caries removal can be found in studies of a related technique, the stepwise excavation approach. The literature regarding stepwise excavation[18–20,33,34] has reported consistently that residual carious dentin recedes and hardens under temporary restorations in the interim between the initial excavation and reentry. But as Kidd[32] stated, "Why re-enter?" In other words, if the goal is to avoid pulpal exposure and residual carious dentin poses no threat to the dentition, why subject the patient to a second excavation?

Assuming it is preferable to leave caries in deep restorations, must the practitioner alter his or her restorative technique? The previously cited survey of dentists conducted by the Practitioners Engaged in Applied Research and Learning (PEARL), a practice-based research network at the New York University College of Dentistry sponsored by the National Institutes of Health,[29] may hold an answer to that. The survey's respondents, who represented a wide range of approaches to restoration, stated that they expected that roughly the same percentage of their patients would require endodontic treatment three to five years after treatment regardless of whether the respondent favored complete or partial caries removal in deep lesions and regardless of the respondent's restoration technique. Evidence from the literature also suggests that a change of approach is unnecessary. Even before the advent of dentin bonding, the efficacy of bonding to enamel alone was demonstrated in a 17-year recall study of a large-particle ultraviolet light–cured resin-based composite in Class I and Class II restorations.[35] Moreover, Mertz-Fairhurst and colleagues[4] demonstrated that bonding to enamel alone (with carious dentin remaining) was sufficient at 10 years. Dentin bonding adds to our ability to seal restorations, but its long-term efficacy is still in question.[36]

Partial removal of caries from deep lesions usually involves complete removal of carious tissue from cavity walls but limited removal from the pulpal floor and axial wall, which are sites of reduced bond strength. Resin-based composite restoration polymerization shrinkage can result in retraction of the bonding agent from the pulpal floor or axial wall of sound dentin.[37,38] The resulting gap can fill with fluid, and with tooth deformation, the fluid is forced down open dentinal tubules, causing postoperative "occlusal loading sensitivity." While clinicians may find pulpal floor gaps more often when deep caries remains because of composite's inability

to bond completely to caries-infected and caries-affected dentin,[39–42] the chance of postoperative hypersensitivity might be reduced because the pulp is protected from fluid flow in the tubules by the low-permeability zone in deep infected dentin.[43,44] On the basis of these findings, one might suggest that infected dentin be removed completely from preparation walls but selectively from the pulpal floor or axial wall.

Finally, it is worthwhile to consider the recent meta-analysis[1] that pooled the results of four of the randomized controlled trials discussed earlier: those by the Mertz-Fairhurst,[2] Ribeiro,[5] Magnusson[19] and Leksell[20] research groups. The review is entitled "Complete or Ultraconservative Removal of Decayed Tissue in Unfilled Teeth," and while one can argue that "ultraconservative" does not apply to the focus of the studies by Magnusson and colleagues[19] and Leksell and colleagues[20] (stepwise excavation), the authors nevertheless came to the conclusion—tempered by their observation that the number of these trials is small—that "partial caries removal is … preferable to complete caries removal in the deep lesion, in order to reduce the risk of carious exposure [of the pulp]."[1] Apparently, dentists need more evidence before they will accept this determination—despite the fact that (to our knowledge) no study has been initiated to prove the desirability of removing all infected dentin. An observational study under way within the PEARL practice-based research network will attempt to fill in some of the gaps in our understanding of deep caries treatment and may provide the basis for a clinical trial.

CONCLUSION

On the basis of the studies cited in this review, one can state that there is substantial evidence that the removal of all infected dentin in deep carious lesions is not required for successful caries treatment—provided that the restoration can seal the lesion from the oral environment effectively. However, before this concept is accepted generally by the dental profession, additional clinical trials may be needed.

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ABBREVIATION KEY

ART
: Alternative restorative treatment

CFU
: Colony-forming unit

DEJ
: Dentino-enamel junction

GIC
: Glass ionomer cement

PEARL
: Practitioners Engaged in Applied Research and Learning

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TABLE

Summary of studies examining partial caries removal.

STUDY	STUDY DESIGN	FOLLOW-UP PERIOD	RESULTS
Randomized Controlled Trials			
Mertz-Fairhurst and colleagues[2–4]	Split-mouth randomized trial of 156 pairs of teeth, in subjects aged 8 through 52 years, comparing sealed resin-based composites after partial caries removal versus sealed and unsealed amalgams after complete caries removal	Clinical and radiographic follow-up at six months and at one, two, five and 10 years	No differences noted among groups at any time of follow-up
Ribeiro and colleagues[5]	Randomized controlled trial of 48 primary molars, in subjects aged 7 through 11 years, restored with a resin-bonded composite, comparing partial versus complete caries removal	Extracted near time of exfoliation and examined radiographically and via electron microscopy	No differences noted between groups
Foley and colleagues[6]	Split-mouth randomized controlled trial of 88 teeth in 44 subjects aged 3.7 through 9.5 years; teeth divided into four groups: complete or partial caries removal restored with copper phosphate cement with or without glass ionomer cement or amalgam	Restorations assessed clinically at six-month intervals for 24 months and radiographically at 12 and 24 months	Use of copper phosphate cement plus glass ionomer cement resulted in more abscess or sinus formation; use of glass ionomer cement alone resulted in no differences between groups
Observational Studies			
Fairbourn and colleagues[10]	Observational study of the effect on cultivatable flora after partial caries removal followed by zinc oxide eugenol with or without calcium hydroxide base in 40 permanent teeth	At reentry after five months, the remaining infected dentin was removed and cultivated for microbiological analysis	Nine of 20 teeth treated with calcium hydroxide and five of 20 teeth treated with zinc oxide–eugenol were sterile
Maltz and colleagues[7,9]**, Oliveira and colleagues**[8]	Observational study of partial caries removal in 32 subjects aged 12 through 23 years	Clinical, radiographic and microbiological data collected at reentry at six to seven, 14 to 18, and 36 to 45 months after treatment	Remineralization occurred and caries was arrested at each of the three times of follow-up
Marchi and colleagues[11]	Observational study of the effect of calcium hydroxide and resin-modified glass ionomer liners on indirect pulp caps of 27 primary molars in subjects aged 4 through 9 years	Examined at four years for clinical or radiographic evidence of pulp pathology	88 percent success for calcium hydroxide and 93 percent success for resin-modified glass ionomer