Long-term Survival of Indirect Pulp Treatment Performed in Primary and Permanent Teeth with Clinically Diagnosed Deep Carious Lesions

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Abstract

Introduction: This retrospective study examined clinically and radiographically the 3-year survival of teeth treated with indirect pulp treatment (IPT) performed between 2000 and 2004. **Methods:** Sixty-six uncooperative children (4-18 years old) with at least one tooth with clinically diagnosed deep caries were included. Radiographically, the lesion depth was greater than two thirds of the dentin thickness. Incomplete excavation was performed leaving infected carious dentin at the center of the cavity. After placement of a layer of resin-modified glass ionomer as liner, the teeth were restored. A 3-year survival analysis (Kaplan-Meier) was performed. Failure was defined as the presence of either a clinical symptom (pain, swelling, or fistula) or radiologic abnormality at recall. In total, 86 of 125 (69%) treated primary molars and 34 of 45 (76%) treated permanent teeth were available for both clinical and radiographic evaluation. **Results:** The survival rate was 96% for primary molars (mean survival time, 146 weeks) and 93% for permanent teeth (mean survival time, 178 weeks). **Conclusion:** This study shows that IPT performed in primary and permanent teeth of young patients may result in a high 3-year survival rate. *(J Endod 2010;36:1490–1493)*

Key Words

Caries detector, caries management, deep caries, indirect pulp capping, indirect pulp therapy, indirect pulp treatment, infected dentin, resin-modified glass ionomer, ultraconservative caries treatment

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The discussion of how much carious dentin must be removed in order to arrest the carious process exists already more than 150 years (1). With reference to the outcome of the histologic studies of Reeves and Stanley (2), infected dentine should be completely removed in order to arrest the carious process. However, it has been reported that carious progression was arrested for at least 10 years when bonded, and sealed composite restorations were placed directly over frank cavitated lesions extending into the dentin (3). Therefore, complete dentine carious removal may not be a prerequisite to arrest carious progression (4, 5). A randomized clinical trial with the "Hall technique," in which there is no carious excavation, showed that caries is a disease that will arrest in the right circumstances (6). Taking into account the beneficial outcome in five clinical studies (7), indirect pulp treatment (IPT) is recommended as an appropriate procedure for treating primary teeth with deep carious lesions and asymptomatic pulp inflammation provided that the restoration seals the cavity properly. In summary, the traditional concept of complete carious removal has been challenged.

With IPT, carious dentin near the pulp is preserved to avoid pulp exposure and is covered with a biocompatible material (8). Pulpal inflammation is inevitable once the dentin is affected. The remaining dentin thickness after carious excavation is a key determinant regarding the state of the pulp (9, 10). There is poor correlation, however, between the histologic findings and the clinical diagnosis of pulpal injury. Subjacent to deep carious lesions, the pulp presents chronic inflammatory exudates, including lymphocytes, macrophages, and plasma cells (11), indicating that pulpitis has been developed even in absence of unprovoked pain. On the other hand, for many years, the importance of inflammation in maintaining pulpal health has been underestimated. Inflammation was considered an undesirable side effect, frequently leading to pulp necrosis. In view of recent results, the inflammatory process should be re-examined to understand its potentially beneficial effect on pulp regeneration (12). Despite extensive pulpal inflammation because of deep caries, a conservative approach can still generate a favorable prognosis for pulpal repair.

When pulp exposure has occurred during complete excavation in primary or young permanent teeth, (partial) pulpotomy is a treatment option for teeth diagnosed with reversible pulpitis (7, 13). In case of symptoms referring to irreversible pulpitis, such as unprovoked pain, vital pulp techniques are associated with poor clinical outcomes. In those cases, vital pulpectomy is usually needed to save the tooth. Because of the difficulties in cleaning and filling morphologically complex root canal systems, the placement of a root canal filling does not always prevent coronal bacterial contamination (14, 15). As a result, in some cases, periapical lesions may emerge. In previous outcome studies and systematic reviews, the average success rate for root canal therapy performed in teeth with vital pulps is rather high (16–18). In Toronto studies, a success rate of 93% was recorded (17). Interestingly, many outcome studies reported both periapical index scores 1 and 2 as "healed" or "successful" (17, 19) despite score 2 representing mild periapical inflammation (20). When score 2 would not be considered "successful," the success rate for vital teeth would drop to 70% (21). In animal studies (22–24), posttreatment apical periodontitis was present in a high percentage of teeth up to 12 months after performing vital pulpectomy.

Recent studies showed IPT-treated teeth remaining symptomless and free of radiologic abnormalities for years (5, 7). The pulp maintains its healing potential and

defence capacity against advancing carious lesions (25) and acts as the best barrier against bacterial invasion (26). In addition, performance of IPT is simpler, more patient friendly, and cheaper than a root canal treatment.

This retrospective study evaluated treatment success of deep carious lesions in primary and permanent teeth. The purpose was to investigate the 3-year survival rate of functional (clinical and radiological successful) primary and permanent teeth treated with IPT.

Materials and Methods

Study records were selected from a patient pool visiting the faculty clinic of the Department of Cariology Endodontology Pedodontology of Academic Centre for Dentistry Amsterdam. Sixty-six children (40 boys and 26 girls, 4-18 years old) with at least one tooth with clinically diagnosed deep caries were referred to one operator between 2000 and 2004. IPT was performed in teeth that met the following criteria:

1. Restorable permanent and posterior primary teeth without a history of spontaneous, persistent pain or sensitivity to palpation/percussion and/or presence of other clinical signs of inflammation (abscess, sinus tract, and abnormal mobility).
2. Radiographically, the absence of signs of periapical or furcation pathology and/or of pathological resorption. However, in 30% of the children, no appropriate preoperative radiograph could be made because of limited cooperation.
3. Teeth at risk of pulp exposure when complete removal of carious dentine would be performed.

In total, 125 primary molars and 45 permanent teeth (9 front teeth, 8 premolars, and 28 molars) were treated with IPT. In primary molars and permanent teeth, 79.1% and 41.2%, respectively, of the restorations comprised more than one surface. Patients' cooperation did not influence the indication for IPT. All patients with deep carious lesions were treated consecutively. Pulpotomy was only performed when a vital pulp was exposed during the excavation procedure (estimated 5% of all deep carious lesions). Subsequently, the tooth was excluded from the study. In one primary tooth, pulp exposure led to the diagnosis "pulp necrosis," also resulting in exclusion from the study. Referring to the age of the children, about 20% to 30% of the permanent teeth treated with IPT were immature at the start of treatment.

The criteria for radiographic evaluation were (1) the presence of an appropriate posttreatment radiograph and (2) the lesion depth was more than two thirds of the dentin thickness assessed on a preoperative radiograph or the restoration depth was greater than two thirds of the dentin thickness assessed on postoperative radiograph. Eighty-six (68.8%) of 125 primary molars and 34 (75.6%) of 45 permanent teeth met these criteria and were available for both clinical and radiologic evaluation.

In primary as well as permanent teeth, IPT was performed similarly. After administering local anesthesia and placing a rubber dam, the dentin-enamel junction was completely excavated. The biomass near the pulp was removed with caution. In one *in vivo* study, specific tactile information was given about the carious removal procedure; excavation in deep cavities (with excavator) of primary molars was stopped when the remaining dentin showed increased resistance to manual instrumentation, coming out in scales or chips (27). The treatment protocol in the present study included also the use of a prophy brush to achieve this level of excavation. In order to remove the biomass (Fig. 1*A*) from the infected dentin, a spoon excavator (#153/154; Ash Lustra, Dentsply, Addlestone, UK) was used and/or a prophy brush (Screw type black brushes, Crescent, Dentsply Rinn, Elgin, IL; 2000 rpm) with fluoride toothpaste. The Caries Detector (Kuraray Co, Tokyo, Japan) applied in accordance with the manufacturer's instructions was used only to check the proper excavation of the dentin-enamel junction. Infected dentin, showing intact parts and dark red staining after application of the Caries Detector (Fig. 1*B*), was retained and covered by a layer of resin-modified glass ionomer (RMGI) liner (Vitrebond; 3M ESPE, St. Paul, MN).

All permanent teeth were restored with adhesive filling materials (Z100 or Ketac-Molar, 3M ESPE). Nine primary teeth were restored with a preformed metal crown (Stainless Steel Crowns, 3M ESPE) cemented with glass ionomer (Ketac-Cem, 3M ESPE). All other primary teeth were restored with adhesive filling materials (Dyract, Dentsply Caulk, York, PA, and Ketac-Molar, 3M ESPE).

Survival was defined as teeth without clinical or radiologic signs or symptoms. The recall interval was 3 to 6 months depending on the level of dental hygiene. At recalls, the clinical performance of the teeth was examined by percussion and palpation along with the presence of signs of inflammation (pain, abscess, sinus tract, and abnormal mobility). Treatment was considered radiologically successful when (1) the contours width and structure of the periodontal margin were normal and (2) no signs of pathological tooth resorption were present. Pulp sensitivity tests could not be performed in many of the very young children, and test outcomes were not reliable in the anxious (older) children.

Radiographic treatment outcomes and chart notes for each tooth were independently reviewed by two calibrated investigators. When opinions differed, discussion was followed by consensus agreement. In case of doubt, the treatment was regarded as a failure. The Cohen kappa coefficient was used to assess the inter- and intraobserver agreement of the radiographic assessments.

Kaplan-Meier survival analyses were performed on the censored data of both primary and permanent teeth. Statistical analyses were performed using SPSS for Windows, version 12.0.1 (SPSS Inc, Chicago, IL).

Results

The assessment of the radiographs revealed an inter- and intraexaminer agreement of 0.72 and 0.80 (Cohen kappa), respectively. The 3-year survival analyses of IPT treatment, assessed radiographically, showed a survival rate of 96% for primary molars (2 failures; mean [standard deviation] survival time, 145.6 weeks [2.4 weeks]) and 93% for permanent teeth (Fig. 2*A-D*) (1 failure; mean [standard deviation] survival time, 178.1 weeks [8.5 weeks]). Failures in primary teeth were caused by intraradicular bone resorption. The permanent tooth failed because of apical bone resorption.

During the evaluation period, no clinical symptoms were observed in primary molars as well as permanent teeth referring to inflammation of the pulp. The approximal enamel wall of one primary and one permanent molar restored with a class I RMGI restoration fractured after 16 months and 12 months, respectively. Repair of the restorations did not influence the survival of the teeth.

Discussion

This study contributes to the debate among cariologists and endodontologists whether IPT is a valuable approach to pulp preservation in teeth with deep carious lesions (28). The conservative child-friendly IPT approach limits the discomfort for uncooperative children by reduced treatment time.

In the present study, deep carious lesions were defined as lesions comprising more than two thirds of the dentin thickness. Pulp exposure could be expected if direct complete excavation were pursued. Either pre- or postoperative radiographs were used to assure the lesion depth.

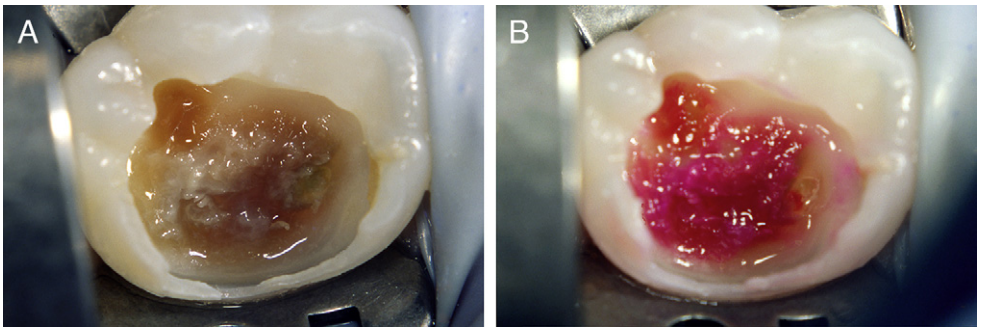

Figure 1. *(A)* A second mandibular primary molar after excavation of the dentin-enamel junction (DEJ). The biomass is still present in the center of the cavity. *(B)* The same tooth after removing the biomass with a prophy brush and fluoride toothpaste only. The Caries Detector was used for inspection of the DEJ. After drying the cavity, the RMGI liner was applied, and the cavity was restored with a compomer.

Because no pulpal excavation was performed, lesion depth could also be assessed by postoperative radiographs.

As reported by Leksell et al (29) and Kassa et al (30), up to 50% of deep carious lesions may actually have severe pulp involvement. Therefore, it seems reasonable to assume that many teeth in the present study suffered severe pulp involvement. Ninety-three percent of IPT-treated permanent teeth and 96% of primary molars remained nevertheless symptomless and free of intraradicular/periapical radiolucency for up to 3 years. Future clinical investigations, using sophisticated diagnostic tools (19), may provide more detailed information about the outcomes of vital pulp techniques.

Pulpal necrosis can develop without clinical symptoms (11, 31). A low incidence of pulpal necrosis after IPT was reported (5) for 1 (3%) of 32 IPT-treated teeth. In this study, using radiographic criteria, more than 90% of the treated teeth remained free of apical radiolucency. As reported in the present study and in other investigations (5, 7), clinical outcomes achieved by IPT, as treatment for asymptomatic pulpal inflammation, were not inferior to those of pulpectomy treatment (15, 21, 19). Recently, it has been questioned (19) whether the traditional strategy for treating deep caries (complete excavation resulting in pulp exposure and vital pulpectomy) still provides the best solution. Furthermore, in some cases with deep caries, without any pretreatment symptoms, spontaneous or persistent pain can develop after complete excavation. A recent cohort study supports this view, reporting a greater incidence of adverse events in deep cavities and pulpally exposed teeth than in teeth with moderately deep or shallow cavities (odds ratio = 7.8) (9). Therefore, performing IPT may avoid or delay root canal infection and thus root canal treatments.

An adequate sealing of the remaining infected dentine is of the utmost importance in the investigated treatment strategy (IPT) for deep carious lesions. It has been shown that carious dentin beneath a restoration contains a decreasing number of viable bacteria over time and "dries out" (5, 32), which is a parameter for lesion arrest (1, 5). In addition, a shift toward a less cariogenic microflora was observed (33). In another study (34), a more microorganisms were detected in teeth submitted to partial carious removal compared with the complete carious removal group. However, after sealing the cavity, the level of bacterial colonization was similar in the two groups (35).

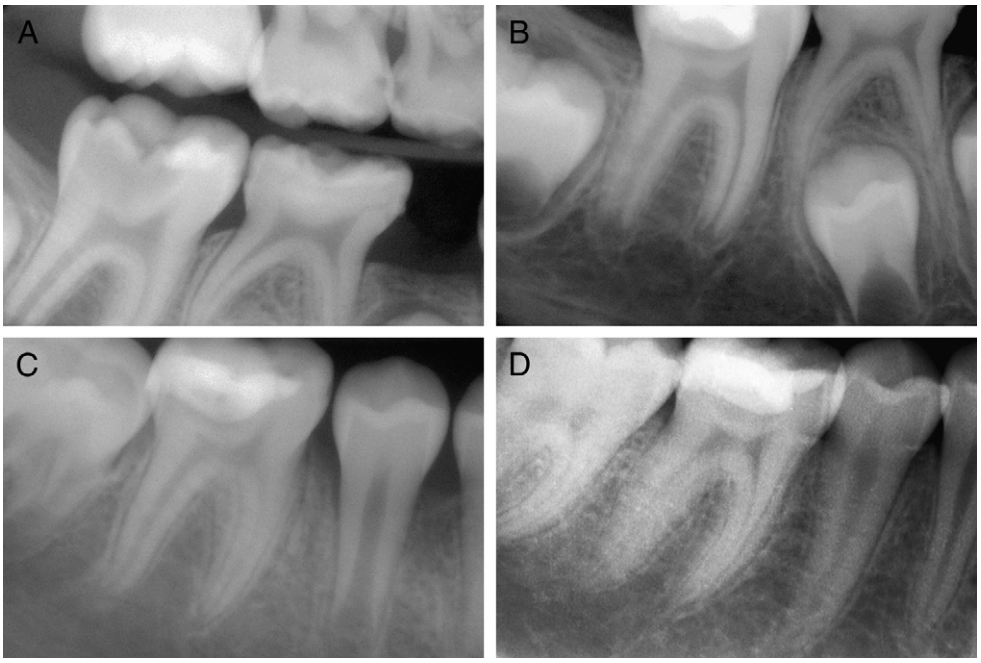

Figure 2. (*A*) The first mandibular permanent tooth before IPT in a 6.5-year-old girl. (*B*) The same (immature) tooth 1 week after IPT. (*C*) Almost 2.5 years after IPT. (*D*) The first mandibular permanent tooth completely matured 5 years after IPT (2 years after finishing the clinical evaluation).

Underneath the restoration, a number of microorganisms may survive but not in sufficient quantity to advance the disease or they are no longer carious active. Sealing of carious dentin arrested the carious process in deep carious lesions, promoted deposition of tertiary dentin, and induced mineral gain in the radiolucent zone (36).

Studies on stepwise excavation advocate removal of carious tissue after the reaction of the pulpodentin complex after the first excavation step (36, 37). This study supports the conclusion of Maltz et al (5) that the indication for reopening the cavity to remove remaining carious dentin lacks biological support.

Calcium hydroxide is traditionally the material of choice in deep carious treatment because of its alkaline biocompatible properties and the induction of pulpodentin remineralization. However, in a study investigating the pulpodentin complex response to a RMGI liner applied in deep cavities, this material was found to be biocompatible comparable to calcium hydroxide (38). This was confirmed in a 4-year follow-up study (39). Teeth were treated with an IPT technique combined with either a calcium hydroxide or RMGI liner. No significant difference in success rate (89% and 93%, respectively) was found. Additionally and in contrast to calcium hydroxide, RMGI prevents microleakage (40).

Since starting to perform IPT 10 years ago, we apply this approach in every patient (anxious or not) who presents with one or more deep cavities in vital primary or permanent teeth that meet the criteria described in this study. Our 10-year experience with incomplete carious excavation confirms the results of the present study.

Conclusions

The results of this retrospective study on the survival rate of primary and permanent teeth after performing IPT are promising. An estimated 96% of primary molars and 93% of permanent teeth survived 3 years without showing adverse clinical symptoms or pathological signs on traditional radiographs. Although studies with high-quality research design are necessary to confirm the previously mentioned results, the traditional strategy of complete carious removal to manage deep carious lesions in primary and permanent teeth with asymptomatic pulpitis may be questioned.

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