Abstract

The aim of the study was to evaluate the efficiency of three types of different bonding systems in pulp protection of primary molars by comparing them with calcium hydroxide liner.

Material and methods: 53 children (120 primary molars) with different occlusal deep carries were included in our study. The teeth were restored with the same type of compomer but using different bonding protocol, thereby being randomly assigned into 4 groups: group 1 (control) - calcium hydroxide cement; group 2 - self-etch adhesive system; group 3 - total-etching + ethanol-based adhesive; group 4 - ethanol-based adhesive without prior acid conditioning. The teeth were clinically and radiologically evaluated for 2 years. The thickness of the remaining dentine was determined on peri-apical X-ray, using DentPrep v0.2 software.

Results and discussions: No significant differences in symptomatology were recorded during the study period, in none of the 4 bonding protocols.

Conclusions: The study claims that the calcium hydroxide liner as dentin–pulp complex protection was not mandatory for the success rate of restorative treatment. The success was achieved also through the other 3 investigated methods.

Keywords: indirect pulp treatment, calcium hydroxide, primary teeth.

Introduction

The caries process can lead to marked changes within the pulp-dentine complex, which can vary considerably depending on the severity of the disease and the age of the pulp. Where deep dentine lesions are concerned it is currently taught that the peripheral aspect of the cavity should be rendered completely caries free (1). This should be followed by careful excavation of caries at the base of the cavity, overlying the pulp until hard, stained dentine is reached, thus gradually reducing the bacterial load within the cavity (2). Although, in deep carious lesions the attempt of complete removal of altered dentin might result in exposure of the dental pulp. When caries are thought to extend close to, or into the pulp, excavation of the pulpal caries can be stopped at stained but firm dentine (2). In order to prevent such exposures, the indirect pulp capping procedure has been advocated as a conservative therapy of the dentin–pulp complex more than 200 years ago (3). Calcium hydroxide lining is applied over the pulpal dentine prior to placement of the definitive restoration. This is classically referred to as the indirect pulp cap. The difficulty with this technique is to assess how rapid the carious process has been, how much tertiary dentine has been formed and knowing exactly when to stop excavating to avoid pulp exposure (1).

The indirect pulp capping syntagma was recently replaced by the indirect pulp treatment syntagma (IPT). IPT is a procedure performed in a tooth with a deep carious lesion adjacent to the pulp when the caries near the pulp is left in place to avoid pulp tissue exposure and is covered with a biocompatible material. A radiopaque base such as calcium hydroxide, zinc oxide and eugenol, or
glass ionomer cement is placed over the remaining affected dentin to stimulate healing and repair. The tooth then is restored with a material that seals the tooth from microleakage (4).

There are many studies proving the effectiveness of IPT for the restoration of deep caries in primary molars (5, 6, 7, 8, 9, 10). Calcium hydroxide seems to remain the most commonly used and predictable lining material in IPT, being biocompatible, inducing pulp-dentin remineralization and reducing bacterial infection (9, 11, 12, 13), despite the fact that is soluble and low strain-resistant. Therefore, it is questionable if only calcium hydroxide liner is responsible for the long-term success rate of IPT (9) or there is another key-factor contributing to this achievement. Recent clinical studies outlined that preventing infiltration of bacteria to affected dentin by a good marginal seal is technically more important than the type of lining material (6, 8, 9). Thus, IPT should not be considered a material dependent technique (9).

Moreover, similar results in pulp protection as calcium hydroxide were obtained using adhesive resin system in class I composite restorations (6) and also resin-modified glass ionomer cement and even gutta-percha (8, 9). In IPT cases, the acid etchant and/or the bonding systems may induce the reduction of bacterial contamination from tooth structure (14, 15, 16), similar to initial bactericidal effect of calcium hydroxide (9, 17, 18). On the other hand, the use of acidic conditioners and adhesive resins without a pulpal protection may lead to irreversible pulp reactions in deep cavities (19, 20), especially if the remaining dentin thickness (RDT) is below 0.5 mm (21). While the skill and expertise of the clinician can help minimize removal of such iatrogenic dentin (22, 23), exact judgment of the cavity depth (and thus, the RDT) is often impossible, as most assessments are made simply by visual examination, and the limitation of visual perception may render such judgments inaccurate and subject to variation (23, 26). Finally, clinical situations in which the color of the affected carious lesion left at the deepest site of cavity preparation may disguise a functional pulp exposure (13) and thus complicate estimation of exact cavity depth.

The purpose of the study was to evaluate the clinical and radiographic success rates of three different bonding protocols comparing with calcium hydroxide liner for protection of the dentin–pulp complex of primary molars with different RDT. The null hypothesis tested was that protection of the dentin–pulp complex of primary molars with the tested bonding techniques results in similar clinical and radiographic outcomes as compared to calcium hydroxide - compomer when IPT is performed in class I compomer restorations.

Materials and methods

Operative procedures

Fifty-three children between 5 and 10 years old (mean, 8 years), both sexes, participated in the study. The main criterion for inclusion was the presence of at least one pulpally healthy primary molar with a carious lesion limited to the occlusal surface of the tooth. Informed consent was obtained from parents. Class I cavity preparations and caries removal were made except the caries lesions near the pulp: infected dentin was removed and affected dentin was left at the deepest levels, without any evidence of pulp exposure (exclusion criterion). In these terms, the operator performed indirect pulp therapy with either the tested adhesive resins or calcium hydroxide.

Prepared teeth were randomly assigned into one of the following restorative treatment protocols by another operator who was blinded to the final cavity preparation:

1. Group 1 (control): A small amount of CH cement (Dycal, DeTrey/Dentsply) was applied on the deepest region of the cavity. Then, a polyacid-modified resin-based composite material (Dyract AP, DeTrey/Dentsply) was applied with a maximum of 2-mm-thick increments, each photo-polymerized for 40 s.

2. Group 2: A self-etch adhesive system (OptiBond All-in-One, KerrHawe) was applied and light-cured. The remaining procedures for restoring the cavity with Dyract AP were accomplished in accordance with the protocol followed in group 1.

3. Group 3: Enamel and dentin surfaces were etched with 37.5% phosphoric acid gel (Kerr Etchant, KerrHawe) for 30 and 15 s, respectively and washed with air-water jet for 15 s. A single-bottle adhesive (OptiBond Solo Plus, KerrHawe)
was applied on the entire cavity and margins and light-cured as per the manufacturer’s instructions.

4. Group 4: OptiBond Solo Plus was applied on the entire cavity and margins without prior acid conditioning and light-cured. The cavities were further restored, finished, and sealed as with groups 1, 2 and 3.

OptiBond® Solo Plus (Kerr) is a fifth-generation bonding systems, introduced during the mid 1990s, which combined primer and adhesive in one bottle while maintaining high bond strengths.

OptiBond® All-In-One (Kerr) is a fluoride releasing seventh-generation bonding systems, is the “all in one” adhesives that combine etch, prime, and bond in a single solution. This adhesive category was introduced in late 2002. Laboratory studies show bond strengths and margin sealing to be equal to sixth-generation systems (24).

Image analysis
Postoperative radiographs of teeth were obtained using a paralleling device (Dentsply Rinn) in order to minimize deformation. All films were processed under the same automatic conditions. Radiographs were scanned and the RDT of each tooth was measured using ProDent v0.2 software (25). The reference for exact calibration of the image was provided by a 2-mm stainless-steel orthodontic wire, attached to the radiographs of all teeth.

The remaining dentin thickness (RDT) was measured (in mm) between the deepest region of the cavity and the dentin–pulp border. Two additional measurements were made 0.5 mm mesial and distal to the initial measurement point, and the mean value of three measurements was recorded as the RDT for each tooth. The teeth were subsequently divided into four groups (21, 26): (1) RDT<0.5 mm; (2) RDT ranging from 0.5 to 1.0 mm; (3) RDT between 1.0 and 1.5 mm, and (4) RDT>1.5 mm.

Statistical comparisons between the treatment groups with respect to RDT were made with one-way analysis of variance (ANOVA) and Tukey honestly significant difference (HSD) tests at P<0.05.

Clinical and radiographic evaluations
When one or more of the following sings was detected at 1, 3, 6, 9, 12, 18 and 24 months (6, 27), the treatment was recorded as a failure: (1) clinical symptoms (spontaneous pain and/or sensitivity to pressure/percussion, fistula, and/or edema, abnormal mobility); (2) radiolucencies at the interradicular and/or periapical regions, as determined by radiographs; and (3) internal or external (pathologic) resorption that was not compatible with the expected resorption due to the exfoliation process.

All data were analyzed with SPSS statistical software (V.11.5, SPSS) using Fisher’s exact test at P<0.05 to examine the effect of the treatments in each recall period.

The marginal quality of the restorations was evaluated according to the modified US Public Health Service clinical rating system27. Comparisons among the treatment groups with respect to marginal integrity criteria and recall periods (baseline and 3, 6, 9, 12, 24 months) were made with Fisher’s exact test at P<0.05.

Results
The mean, minimum and maximum (mm) values of remaining dentine thickness (RDT) of teeth with respect to treatment groups are presented in Table 1. The distribution of teeth according to RDT groups is presented in Table 2. The distribution of restored teeth with minimal RDT (≤0.5 mm) was 3.3% for group 1, 8.3% for group 2, 8.3% for group 2, and 10% for groups 4 (Table 2).

<table>
<thead>
<tr>
<th>Group No.</th>
<th>Mean±SD</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.02±0.41</td>
<td>0.29</td>
<td>2.21</td>
</tr>
<tr>
<td>2</td>
<td>1.09±0.39</td>
<td>0.33</td>
<td>2.45</td>
</tr>
<tr>
<td>3</td>
<td>1.21±0.29</td>
<td>0.42</td>
<td>2.56</td>
</tr>
<tr>
<td>4</td>
<td>0.83±0.16</td>
<td>0.28</td>
<td>1.17</td>
</tr>
</tbody>
</table>

Table 1
RDT of teeth with respect to treatment groups

<table>
<thead>
<tr>
<th>Group/remaining dentin thickness (mm)</th>
<th>Group 1, n (%)</th>
<th>Group 2, n (%)</th>
<th>Group 3, n (%)</th>
<th>Group 4, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>0.5–0.9</td>
<td>12</td>
<td>40</td>
<td>12</td>
<td>40</td>
</tr>
<tr>
<td>0.5–1.0</td>
<td>13</td>
<td>43</td>
<td>13</td>
<td>43</td>
</tr>
<tr>
<td>1</td>
<td>14</td>
<td>47</td>
<td>9</td>
<td>30</td>
</tr>
<tr>
<td>&gt;1.5</td>
<td>14</td>
<td>47</td>
<td>9</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 2
Distribution of teeth with respect to RDT
The majority of restored teeth were maxillary and mandible first molars. A total of six teeth had exfoliated uneventfully, as recorded at the 12th- and 18th-month recalls in all 4 groups. In four of the group 1 tested teeth infrequent episodes of sensitivity were recorded, but with no other symptoms of irreversible pulpal lesions were present. There was no significant differences of postoperative sensitivity among the tested groups (Fisher-test, p=1.0) and the RDT mean for the four involved teeth was significantly greater than the other 26 teeth (mean 1.63±0.31, min = 1.28, max = 2.3 vs. mean 1.01±0.35, min = 0.29, max = 2.21 - Mann-Whitney U test, p=0.031).

When excluding the exfoliated teeth, the overall success rate of restorative treatment was 100% after 24 months. There was no cause–effect correlation between the remaining dentine thickness and clinical and radiological outcome.

The assessment of the marginal microleakage as criterion for failure was not eloquent. There was a great tendency toward “Bravo” marginal discoloration and marginal integrity scores after 9 months (Fisher’s exact test, P<0.05), but no clinical or radiological signs of treatment failure.

Discussions

Although the randomization was made considering the restorative treatment, there were significantly lower RDT values of the control groups, that might be explained by chance variation. The teeth with pink outline of a pulp horn were excluded, but the color of affected dentin left at the deepest site of the cavity preparation may alter the perception of pulpal critical cavity depth, explaining the existence of a really small amount of remaining dentin for some of the studied teeth.

Clinical test are less accurate with regard to ongoing physiological/pathological processes in the pulp witch have to be assessed by histological exams. Due to the ethical considerations, the clinical and radiological interpretations remain the only relaying tools for success rate evaluation of restored teeth.

Existing studies reveal a maximal reactionary dentinogenic activity in depth cavity preparation with a remaining dentine thickness of less than 0.5mm (20). The rank order of materials from greatest to the least stimulatory effect on production of reactionary dentin was calcium hydroxide, composite resin, RMGI, and ZOE cements (20). These observations might explain the ability of dentin–pulp complex to react without endodontic complications and / or compromised physiologic root resorption; the buffering effect of RDT is critical for protection of the pulp from the possible cytotoxic effects of adhesive resins and the stimulation of reactionary dentinogenic activity may have assisted in providing pulp protection in the early phase of healing (20). Over time, the pulpal response would decrease (21), owing to the spontaneous decrease in dentin permeability through the deposition of sclerotic dentin (27). These responses are believed to be mediated by the activation endogenous signaling molecules such as TGFβS, which can be found at the dentinal matrix and are solubilized either by cavity conditioning agents or calcium hydroxide (26).

The attempt of underlining a correlation between indirect evidence of “clinical microleakage” and treatment failure failed. Nevertheless, microleakage and mechanical failure aspects of filling materials can take years to become apparent in patients, therefore, longer follow-up periods and, if possible, histological investigation of restored primary teeth after exfoliation may be necessary to confirm the effect of reduced marginal seal on the pulpal status.

As the depth of the cavities or the remaining dentine thickness was not reported as criteria in pulp-response studies, comparisons of the present clinical/radiographic results with those of previous IPT studies have not been possible (6, 8). Nevertheless, the high success rate obtained herein corroborates with those of Falster et al (6), who reported 96% success after 2 years in adhesive class I primary molar IPTs without pulpal protection.

Conclusions

The present study also confirms that the application of calcium hydroxide over the affected dentin is not a determinant factor of the successful outcome of IPT (6) and leads to the conditional acceptance of the null hypothesis that similar reactions have been observed in groups
1–3 in mainly shallow and medium deep cavities compared to calcium hydroxide / compomer in deeper cavities.

Dentin–pulp complex prevention of primary teeth is a permanent and actual problem that needs more attention in order to find reliable methods for deciduous vital teeth reconstruction.

References