Dentin Permeability of Carious Primary Teeth

KG Ulu Güzel, Z Kirzioglu1, S Özkorucuklu2

Department of Paediatric Dentistry, Faculty of Dentistry, Adnan Menderes University, Aydin, 1Department of Paediatric Dentistry, Faculty of Dentistry, Suleyman Demirel University, Isparta, 2Department of Physics, Faculty of Art Science, Istanbul University, Istanbul, Turkey

Background: Many in vitro studies have used dentine permeability to evaluate the efficacy of various restorative and preventative procedures. The easiest way to evaluate dentine permeability is to calculate its hydraulic conductance (Lp) using fluid filtration methods. Research has examined electronic hydraulic conductance measurement methods that give more precise and reliable results for the permeability of dentine than the classical method. To our knowledge, no study has examined the dentine permeability of carious primary teeth. Aim: This in vitro study determined the dentine permeability of carious primary molars precisely with a new electronic hydraulic conductance measurement system and compared them with healthy primary molars. Design: The study examined 60 carious and noncarious primary second molars with no restorations, fractures, or cracks at different root resorption stages. Results: The results showed that the dentine permeability increased with the severity of caries in primary teeth. Conclusion: The dentine permeability of carious primary teeth was higher than that of noncarious primary teeth. Therefore, treatment of primary teeth should be performed more quickly.

Keywords: Carious, dentin permeability, primary teeth

Abstract

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Address for correspondence: Dr. KG Ulu Güzel, Department of Paediatric Dentistry, Faculty of Dentistry, Adnan Menderes University, Aydin, Turkey. E-mail: gorkemulu@yahoo.com
and defensive potential, especially during various stages of RR, is a prerequisite for selecting the appropriate treatment option for the successful treatment of carious deciduous teeth.

In 2007, Ertürk and Kirzıoğlu[7] developed a new electronic hydraulic conductance measurement system for evaluating dentine permeability in the Computer Science Research and Practice Centre at X University, using the principles described by Pashley et al.[8] Their system automatically produces an air bubble at high pressure. This system was improved, and a new electronic hydraulic conductance measurement system with photosensors was constructed. This fully automated system can achieve pressures close to the pulpal pressure, creating an environment similar to that of the oral tissues.

This study evaluated the in vitro permeability of primary molar teeth with a range of natural dentine caries and compared them with noncarious primary molars.

METHODS

Collection of teeth

Prior to the study, patients and their parents were informed about the extracted teeth would be used in an in vitro study and their informed consent was obtained under a protocol approved by the X Ethical Committee. This study examined 60 carious and primary second molars with no restorations, fractures, or cracks and different degrees of RR which were extracted for orthodontic purpose. The teeth studied were cleaned using water to remove any exogenous material. Radiographic lesion depth was graded according to the modified system of Wenzel et al.[9] as follows: grade 1, superficial dentine caries; and grade 2, deep dentine caries without pulpal exposure. The method of Büyükgüral and Cehreli[10] was used to analyze the depth of carious lesions. The region delineated by two lines between the pulp horn and the top of the dentine was subdivided into four areas. Lesions in the upper region were identified as superficial dentine caries (Grade 1), and lesions in the third region were identified as deep dentine caries. The remaining lesions were not included in this study. The physiological degree of RR was determined according to the standardized values outlined by Kramer and Ireland.[11] Teeth were subdivided into three groups: RR1, teeth with RR involving less than one-third of the root; RR2, teeth with RR involving one-third to two-thirds of the root; and RR3, teeth with RR involving more than two-thirds of the root.

The 60 primary second molars were categorized using these criteria, as shown in [Table 1].

Specimen preparation

The crown was separated from the root 2–3 mm apical to the enamel–cementum junction using a water-cooled diamond-coated disc (Struers Minitom, Denmark). Any residual pulpal tissue was removed carefully. Crown segments were cemented to a Plexiglas ring using cyanoacrylate cement (Zapit, Dental Ventures of America, Anaheim Hills, CA, USA). Carious areas were estimated using a digital microscope system enabling three-dimensional imaging (KH-7700 Digital Microscope System, Hirox-USA, Hackensack, NJ, USA).

Measuring dentine permeability

The new electronic hydraulic conductance measurement system was used to measure dentine permeability. This fully automated system consists of an oxygen pressure tank, pressure reservoir, solenoid valves capable of producing an air bubble automatically, four photosensors for detecting the movement of the air bubble in a capillary tube, an electronic hydraulic conductance measurement system connected to the photosensors, polyethylene tubes connecting the pressure reservoir to the capillary tube, and a capillary tube connected to the vacuum chamber device [Figure 1].

The electronic hydraulic conductance measurement system determined the amount of deionized water that passed through each dentine disc (µL/min) under constant pressure (50 cmH2O). The hydraulic conductance for each crown was calculated.

The hydraulic conductance (Lp) of the carious and noncarious teeth was recorded and analyzed statistically using the Statistical Package for the Social Sciences (SPSS, ver. 18.0).

RESULTS

The hydraulic conductance (Lp; mean ± SD) of the grade 1 carious teeth was 2.681 ± 0.244, 3.470 ± 0.628, and

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**Table 1: Design of the dentin permeability of the carious primary second molar teeth study**

<table>
<thead>
<tr>
<th>Primary second molar teeth</th>
<th>Grade 1</th>
<th>Grade 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>n = 60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RR1 (n = 10)</td>
<td>RR2 (n = 10)</td>
<td>RR3 (n = 10)</td>
</tr>
<tr>
<td>RR1 (n = 10)</td>
<td>RR2 (n = 10)</td>
<td>RR3 (n = 10)</td>
</tr>
<tr>
<td>RR1 (n = 10)</td>
<td>RR2 (n = 10)</td>
<td>RR3 (n = 10)</td>
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</tbody>
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4.066 ± 0.75 µL/cm²/min cmH₂O for RR1, RR2, and RR3, respectively. The hydraulic conductance (Lp) of the grade 2 carious teeth was 13.17 ± 1.613, 14.54 ± 2.26, and 18.77 ± 2.71 µL/cm²/min cmH₂O, respectively [Table 2]. Comparing the study groups using Mann–Whitney U and Kruskal–Wallis tests, significant differences were observed between carious teeth (grade 1 and grade 2) for all degrees of RR (P < 0.001). No significant difference was observed between RR1, RR2, and RR3 with regard to grades 1 and 2. Thus, dentine permeability increased in parallel with the severity of caries in primary teeth.

**DISCUSSION**

Most studies of dentine permeability have examined permanent teeth, whereas few such studies have examined deciduous teeth.[7,12] Pashley et al.[8] measured dentine permeability using a hydraulic conductance measurement system that they developed. This method has some disadvantages, such as being a subjective technique that can give different results in different measurement sessions. Ertürk and Kirzoğlu[7] evaluated the disadvantages of the method and developed a new measurement system using air bubbles. Although the volumes of the air bubbles formed during the measurement of the dentine discs in their system are very close, the inability to produce air bubbles with equivalent volumes and the absence of a mechanism for automatically adjusting the systemic pressure are drawbacks of their method. Therefore, we modified the system of Ertürk and Kirzoğlu[7] to obtain more accurate and reliable results. Our modified system creates an air bubble automatically and then tracks it with electronic photosensors. The data produced by our device are input directly to a computer using computer software. Our device can generate air bubbles with a standard volume, enabling repeated measurements with the same air bubble on the same or different teeth.

Hydrostatic pressure is an important variable when measuring dentine permeability. Many studies apply hydrostatic pressures of 3–20 psi. Elevated hydrostatic pressure is important for measuring the amount of leakage and enabling the system to stay in balance.[13] Therefore, previous studies have generally used very high hydrostatic pressures. A few studies have made measurements with hydrostatic pressures of 15 cmH₂O, which is the same as the physiological pulpal pressure.[14–19] Our device applied hydrostatic pressure of 50 cmH₂O, which is close to the physiological pulpal pressure.

In a study of permanent teeth, About et al.[19] noted that the diffusion of cytotoxins was increased after teeth were etched with acid when the dentine thickness was less than 0.5 mm, affecting the repair capability of the dentine by significantly reducing the number of odontoblasts. Rayner and Southam[20] noted that the pulp remained healthy in teeth with a dentine thickness of 0.9 mm, whereas they observed inflammation when the thickness decreased to 0.6 mm. In our study, the dentine
We chose deciduous evaluation of dentin in our study,[27] In permanent teeth, the blood flow decreases because of apical narrowing, and calcified scar tissue forms in response to any damage. By contrast, because caries lesions progress faster in deciduous teeth, the reparative dentine becomes weaker and irregular in structure, as the lesion progresses more rapidly.[27]

Deciduous teeth display a different response and severe destruction associated with the differentiation of pulp cells into odontoclasts. Nonetheless, it has been claimed that impaired circulation in the apical area during the beginning of physiological RR in deciduous teeth might delay the generation of reparative dentine.[28] Lin et al.[29] reported that deciduous teeth have high capacities for defensive and reparative processes because they are rich in undifferentiated mesenchymal cells. This feature is responsible for the differentiation of these cells into macrophages and odontoblasts in certain cases.[30] In deciduous teeth, the microleakage occurring because of high dentine permeability and low enamel and dentine thicknesses plays an important role in pulp irritation, and the localization of pulpal tissue is different from that of permanent teeth. In addition, the protection of the pulp from exterior forces is reduced because of the closeness of the pulpal horns to the exterior surface of the teeth.[31]

In this study, we compared the degree of RR and permeability. Although they increased in parallel, this correlation was not significant. Studies of dentine permeability are affected by many variables such as sample preparation, pressure values, and the presence/absence of a smear layer. We believe that standardization of the measurement of dentine permeability and additional, more detailed studies will have positive effects on clinical practice.

In conclusion, we tried to create an environment similar to the oral environment with our new fully automated electronic hydraulic conductance measurement system. This study found that the dentine permeability of carious primary teeth was higher than that of noncarious primary teeth. Therefore, treatment of primary teeth should be performed more quickly.

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**Conflicts of interest**

There are no conflicts of interest.

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