Original Article

Dentin Permeability of Carious Primary Teeth

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Abstract

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*

Objectives

The most common pathology of the dentine is dental caries. Changes occurring in the dentine structure in response to the caries process take place either within the dentine itself or in the adjacent pulp. The ultimate pulpal response is either complete blockage or a reduction in the diameter of the dentinal tubules to prevent toxic material from entering the pulp.[1] However, the deposition of minerals within the tubules ultimately leads to dentine destruction and the development of reparative sclerosis. This sclerotic material differs from physiological sclerosis in its formation, which is stimulated by mechanisms such as the caries process, some restorative procedures, and attrition; in such cases, its formation is restricted to the vicinity of the affected area. The tissue that is deposited on the pulpal aspect of dentine in response to dental caries is called tertiary dentine. Unlike secondary dentine, which is physiological and forms throughout the vital life of the tooth, the formation of tertiary dentine is localized to the affected area.

The lack of a correlation between clinical signs and symptoms and the histopathological status of the primary dental pulp make it difficult to determine which modality offers the best chance for long-term success in the treatment of carious primary teeth. Changes in pulpal healing and its defensive capacity with aging, beginning with physiological root resorption (RR) and ending with exfoliation, are also debated. Some authors report that the structure of deciduous pulp is similar to that of the young permanent pulp, adding that the healing capacity of primary pulp does not decrease until exfoliation.[2-4]

Other investigators claim that the healing capacity decreases with regressive changes in the pulp during RR due to the aging.[5,6] A thorough understanding of the pulpal healing capacity

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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 Kırzıoğlu[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 cmH_2O). 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

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

Primary second molar teeth					
n = 60					
Grade 1			**Grade 2**		
n = 30			*n* = 30		
RR1	RR2	RR3	RR1	RR2	RR3
n = 10	*n* = 10	*n* = 10	*n* = 10	*n* = 10	*n* = 10

Table 2: Dentin permeability measurements for carious teeth groups

	Dentin permeability (Lp)								
Carious lesion depth	**Grade 1**				**Grade 2**				
Root resorption	Mean	SE	Min	Max	Mean	SE	Min	Max	*n*
RR1	2.681	0.244	1.530	3.781	13.17	1.613	7.86	22.16	20
RR2	3.470	0.628	1.255	7.126	14.54	2.26	8.12	31.26	20
RR3	4.066	0.75	1.258	8.124	18.77	2.71	12.06	35.21	20

Figure 1: dentine permeability device

4.066 ± 0.75 µL/cm²/min cmH_2O 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 cmH_2O, 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 Kırzıoğlu[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 Kırzıoğlu[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 cmH_2O, which is the same as the physiological pulpal pressure.[14-19] Our device applied hydrostatic pressure of 50 cmH_2O, 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 was divided into four equal areas on standard digitized radiographs by considering the above-mentioned values, and the regions closest to the pulp and deeper than 0.6 mm were excluded from the study. Because the mean dentine thickness of deciduous second molars exceeds that of deciduous first molars,[21] we chose deciduous teeth to perform a more accurate evaluation.

Studies of the permeability of carious dentine in permanent teeth have reported that carious dentine is less permeable than normal dentine.[22-25] In our study, the dentine permeability increased significantly with the depth of the caries in all groups and with varying degrees of RR. In permanent teeth, the lower dentine permeability of carious teeth compared with normal teeth has been attributed to defensive reactions triggered by the pulp and the formation of a sclerotic dentine structure. Deciduous teeth respond more rapidly and effectively to pathogens than permanent teeth because they have a larger apical foramen and are supported by a rich blood flow.[26] 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 pulpal 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.

References

1. Love RM, Jenkinson HF. Invasion on dentinal tubules by oral bacteria. Crit Rev Oral Biol Med 2002;13:171-83.
2. Sari S, Aras S, Günhan O. The effect of physiological root resorption on the histological structure of primary tooth pulp. J Clin Pediatr Dent 1999;23:221-5.
3. Sari S, Aras S, Günhan O. The effect of physiological root resorption on repair potential of primary tooth pulp. J Clin Pediatr Dent 1999;23:227-33.
4. Monteiro J, Day P, Duggal M, Morgan C, Rodd H. Pulpal status of human primary teeth with physiological root resorption. Int J Paediatr Dent 2009;19:16-25.
5. Dard M, Kerebel LM, Kerebel B. A transmission electron microscope study of fibroblast changes in human decidous tooth pulp. Arch Oral Biol 1989;34:223-8.
6. Ten Cate AR, Oral histology development, structure and function. 4th ed. St. Louis: Mosby Year Book; 1994.
7. Ertürk MS, Kırzıoğlu Z. *In vitro* evaluation of dentin permeability of fluorotic primary teeth with a new electronic hydraulic conductance measurement system with photosensors. Arch Oral Biol 2007;52:1057-63.
8. Pashley DH, Livingstone MJ, Greenhill JD. Regional resistance to fluid flow in human dentine *in vitro*. Arch Oral Biol 1978;23:807-10.
9. Wenzel A, Fejerskov O, Kidd E, Joyston-Bednal S, Groeneveld A. Depth of occlusal caries depth assessed clinically by conventional film radiographs and by digitized, processed radiographs. Caries Res 1990;24:327-33.
10. Büyükgüral B, Cehreli ZC. Effect of different adhesive protocols vs calcium hydroxide on primary tooth pulp with different remaining dentin thicknesses: 24-month results. Clin Oral Invest 2008;12:91-6.
11. Kramer WS, Ireland RL. Measurements of the primary teeth. J Dent Child 1959;26:252-61.
12. Koutsi V, Noonan RG, Horner JA, Simpson MD, Matthews WG, Pashley DH, *et al.* The effect of dentin depth on the permeability and ultrastructure of primary molars. Pediatr Dent 1994;16:29-35.
13. Youngson CC, Jones JCG, Fox K, Smith IS, Wood DJ, Gale M. A fluid filtration and clearing technique to assess microleakage associated with three dentine bonding systems. J Dent 1999;27:223-33.
14. Abou Hashieh I, Franquin JC, Cosset A, Dejou J, Camps J.

Relationship between dentine hydraulic conductance and the cytotoxicity of four dentine bonding resins *in vitro*. J Dent 1998;26:473-77.
15. Banomyong D, Palamara JE, Burrow MF. Messer HH, Effect of dentin conditioning on dentin permeability and micro-shear bond strength. Eur J Oral Sci 2007;115:502-9.
16. Elgalaid TO, Creanor SL, Creanor S, Hall AF. The repeatability of human dentine permeability measurement *in vitro*. J Dent 2008;36:42-8.
17. Hoang-Dao BT, Hoang-Tu H, Tran-Hung L, Camps J, Koubi G, About I. Evaluation of a natural resin-based new material (Shellac F) as a potential desensitizing agent. Dent Mater 2008;24:1001-7.
18. Senawongse P, Otsuki M, Tagami J, Mjör IA. Morphological characterization and permeability of attired human dentine. Arch Oral Biol 2008;53:14-9.
19. About I, Murray PE, Franquin JC, Remusat M, Smith AJ. The effect of cavity restoration variables on odontoblast cell numbers and dental repair. J Dent 2001;29:109-17.
20. Rayner JA, Southam JC. Pulp changes in deciduous teeth associated with deep carious dentine. J Dent 1979;7:39-42.
21. Finn S. Morphology of the primary teeth. In: Finn S, editor. Finn clinical pedododontics. 4th ed. USA: W.B Saunders Company, 1992. p. 48-57.
22. Sarnat H, Massler M. Microstructure of active and arrested dentinal caries. J Dent Res 1965;44:1389-401.
23. Pashley EL, Talman R, Horner JA, Pashley DH. Permeability of normal versus carious dentin. Dent Traumatol 1991;7:207-11.
24. Tagami J, Hosoda H, Burrow MF, Nakajima M. Effect of aging and caries on dentin permeability. Proc Finn Dent Soc 1992;88:(Suppl 1) 149-54.
25. Banomyong D, Palamara JEA, Messer HH, Burrow MF. Fluid flow after resin-composite restoration in extracted carious teeth. Eur J Oral Sci 2009;117:334-42.
26. Kopel HM. Considerations for the direct pulp capping procedure in primary teeth. J Dent Child 1992;60:141-9.
27. Fuks AB. Pulp therapy for the primary and young permanent dentitions. Dent Clin North Am 2000;44:571-596.
28. Contos JG, Corcoran JF, Laturno SAL, Chiego DJ, Regezi JA. Langerhans cells in apical periodontal cysts: An immunohistochemical study. J Endod 1987;13:52-55.
29. Lin PF, Fiore-Donno G, Lombardi T. Immunohistochemical detection of S-100 protein in human deciduous dental pulp. Ann Anat 1994;176:171-3.
30. Pashley DH, Pulpodentin complex. In: Hargreaves KM, Goodis HE. editors. Seltzer and Bender's dental pulp. Quintessence Publishing Co 2002;31:63-85.
31. Greeley MCB. Pulp therapy for the primary and the young permanent dentition. In: Forrester DC, Wagner ML, Fleming J, editors Pediatric dental medicine. Philadelphia: Lea & Febiger; 1981;456-60.