doi:10.1111/j.1365-2591.2006.01188.x

Effect of placement of calcium sulphate when used for the repair of furcation perforations on the seal produced by a resin-based material

L. Zou[1,2], J. Liu[3], S.-H. Yin[2], J. Tan[2], F.-M. Wang[1], W. Li[1] & J. Xue[1]

[1]Key Laboratory of Oral Biomedical Engineering, Ministry of Education, Sichuan University, Chengdu; [2]Department of Operative Dentistry and Endodontics, Sichuan University, Chengdu; and [3]Department of Orthodontics, Sichuan University, Chengdu, China

Abstract

Zou L, Liu J, Yin S-H, Tan J, Wang F-M, Li W, Xue J. Effect of placement of calcium sulphate when used for the repair of furcation perforations on the seal produced by a resin-based material. *International Endodontic Journal*, **40**, 100–105, 2007.

Aim To evaluate the sealing ability of calcium sulphate when used under composite resin for the repair of furcation perforations having different diameters.

Methodology Perforations of different diameter were created in the floors of pulp chambers in 60 extracted human molar teeth with either a number 3 (1 mm diameter) or 5 (1.5 mm diameter) round bur. The specimens of each group were divided into four sub-groups which were repaired with composite resin either alone or in combination with calcium sulphate that created an artificial floor (15 teeth group^{-1}). Eight teeth without furcation perforations served as negative controls. In the leakage detection device, 1 mol L^{-1} glucose solution was forced under a pressure of 1.5 KPa from the crown towards the pulp chamber floor. The concentration of leaked glucose was measured at 1, 2, 4, 7, 10, 15 and 20 days using a glucose oxidase method and the data evaluated using the rank sum test.

Results The specimens with larger perforations repaired with composite resin alone had significantly more leakage ($P < 0.05$). Using calcium sulphate as an artificial floor significantly decreased leakage of smaller perforations ($P < 0.05$). In groups repaired with calcium sulphate under composite resin, leakage in smaller perforations was markedly lower than that in larger ones ($P < 0.05$). No significant difference was found between the specimens with 1 or 1.5 mm perforations repaired with resin alone ($P > 0.05$).

Conclusions Calcium sulphate significantly improved the sealing ability of 1 mm perforations repaired with composite resin but not for 1.5 mm perforations.

Keywords: furcation perforation repair, matrix, sealing ability.

Received 30 March 2006; accepted 14 July 2006

Introduction

Pulp chamber floor perforations are caused iatrogenically, by pathological resorption or by caries. Such perforations result in periodontal involvement which may induce destruction of tissue, proliferation of epithelium and bone resorption. Obviously, active treatment is required to prevent tooth loss.

Correspondence: Shi-Hai Yin, DDS, PhD, West China College of Stomatology, Sichuan University, 14#, 3rd section, Renmin South Road, Chengdu 610041, China (Tel.: 86 28 85534235; fax: 86 28 85582167; e-mail: hx_yinshihai@yahoo.com.cn).

Many methods have been described to repair such perforations. Nonsurgical methods are generally preferred because a surgical approach can lead to chronic pocket formation (ElDeeb *et al.* 1982). However, even with nonsurgical repair, the prognosis may be unfavourable as the result of the inadequate sealing ability or extrusion of materials through the repaired defect (Benenati *et al.* 1986, Balla *et al.* 1991). The concept of an internal matrix was then proposed to overcome these potential problems (Lemon 1992).

Several materials have been used as an internal matrix, including hydroxyapatite, collagen, calcium phosphate cement, mineral trioxide aggregate and calcium sulphate (plaster of Paris) (Lemon 1992, Alhadainy & Himel 1994, Arens & Torabinejad 1996, Chau *et al.* 1997, Pecora *et al.* 1997, Hatem & Ali 1998, Jantarat *et al.* 1999). However, although an internal matrix has been reported to be a successful barrier against over-extension of materials (Lemon 1992, Chau *et al.* 1997), periodontal pocket formation and epithelial migration remain as possibilities (Himel & Alhadainy 1995).

Calcium sulphate is recommended as a space filler in bone because it assists the regeneration of periodontal tissue and excludes epithelial tissue from the site of bone formation (Sottosanti 1992). Furthermore, it has been widely used as an internal matrix in contact with the periodontal tissue because of its biocompatibility, stable character, rapid set and low cost. Most importantly, the natural rate of resorption of the plaster coincides with that of new bone growing into a defect (Bahn 1966).

Many *ex vivo* studies have evaluated the effects of an internal matrix on the sealing ability of repair materials (Aguirre *et al.* 1986, Chau *et al.* 1997, Jantarat *et al.* 1999, Mittal *et al.* 1999). However, it is still not clear whether the size of furcation perforations influences the effectiveness of a furcation perforation repair when a matrix is used to provide a barrier. To date, those studies that have examined the influence of the size of perforation drew contradictory conclusions. Some authors stated that the size of teeth in relation to the size of the perforation was directly proportional to the prognosis (Himel *et al.* 1985, Alhadainy *et al.* 1998), whilst others considered that there was no relationship between them (Salman *et al.* 1999).

In the present study, the sealing effect of calcium sulphate used under composite resin to repair furcation perforations of different diameters was examined *ex vivo* with a new quantitative method for microleakage detection using glucose solution.

Materials and methods

Sixty-eight freshly extracted human maxillary and mandibular permanent molars with separate and well-developed roots, intact furcation and no root caries were selected. The teeth were sterilized in 10% formalin for 2 weeks (Tate & White 1991, Goodis *et al.* 1993). After removal of calculus and soft tissue by ultrasonic scaling, the teeth were stored at 4 °C in normal saline solution before use. Root surfaces were covered with three layers of nail polish, especially in the furcation location. The teeth were randomly divided into four experimental groups containing 15 teeth and eight controls.

Preparation of specimens

Access cavities were prepared and the pulp chambers opened in the 60 experimental teeth using a number 4 round bur (carbide burs FG-4, SS White Burs, Lakewood, NJ, USA) in a high-speed handpiece with water spray. Perforations were then made in the centre of the pulp floor using a number 3 round bur (1 mm diameter) or a number 5 round bur (1.5 mm diameter) (carbide burs FG-3 and FG-5, SS White Burs) in high-speed handpieces respectively (Fig. 1). The width of each perforation was standardized by the different diameter of the burs and its depth depended on the dentine–cementum thickness from the pulp floor to the furcation area. Teeth were then rinsed with water and dried with oil-free air. A moistened cotton pellet was placed in the furcation area to coat the perforation area. All teeth were stored in the incubator at 37 °C for

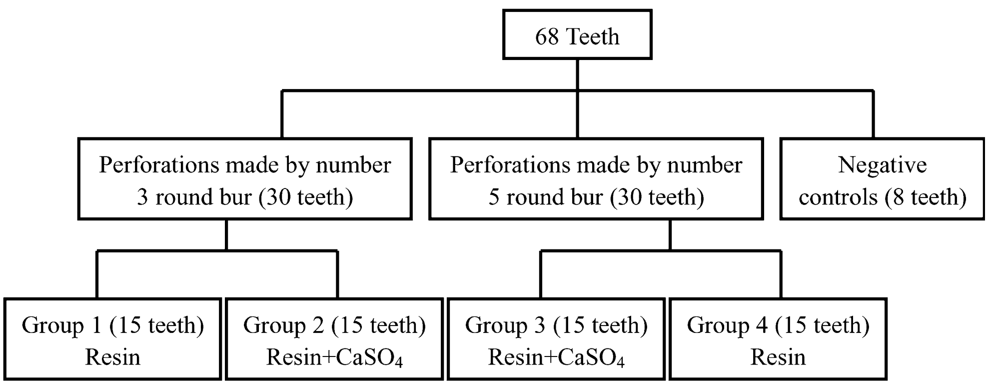

Figure 1 Distribution of experimental groups and experimental flow diagram.

24 h. The roots of teeth were then inserted into a moist sponge and the perforations repaired.

Furcation repair

Group 1

Perforations created with the number 3 round bur were repaired with composite resin (Clearfil AP-X, Kuraray, Japan) alone. Primer was applied on the perforation of the pulp chamber floor from pulpal side with a sable hair brush for 20 s, and dried with air. The bonding agent was smeared on the surfaces and light cured for 10 s. A small amount of material was carried into the perforations with a plastic spatula, condensed slightly and light cured for 40 s. Then incremental layers were applied in the same way until the perforations were filled completely.

Group 2

Perforations created with the number 3 round bur were repaired using a matrix of plaster of Paris (Dental Plaster, Boral Australia Gypsum Limited, Melbourne, Australia) as a barrier and composite resin. The technique of placement of the matrix was similar to that described by Lemon (1992). Plaster of Paris was mixed with sterile water. The mixed slurry was placed into the perforation site and condensed with endodontic pluggers until a solid base was created under the perforation. Excess plaster of Paris was removed to the level of the external surface of the perforation using an endodontic spoon excavator. Perforations were then repaired with composite resin. Resin was placed into the perforations as in group 1.

Group 3

Perforations created with number 5 round burs were repaired as in group 2 with calcium sulphate and composite resin.

Group 4

Perforations created with number 5 round burs were repaired with resin alone as in group 1.

Negative control group

Eight teeth served as controls. Standard access cavities were prepared in each tooth with a number 4 round bur in the high-speed handpiece and the furcations remained intact.

The root canal orifice and apical part of each root were filled with sticky wax. After repairing the perforations, the plaster matrix was removed from the root side using an endodontic spoon excavator.

Measurement of microleakage

The leakage detection device proposed by Xu *et al.* (2005) was used. The coronal section of each tooth was fixed to the end of a 5 mL Eppendorf vial with sticky wax. The furcations and roots of teeth protruding from the vial were immersed into 2 mL distilled water in a sterile 5 mL centrifuge tube that could be sealed completely. A suitable hole was made in the middle of the Eppendorf vial cap through which a 15-cm-long glass tube was placed into the pulp chamber of tooth. Sealing between the glass tube and the Eppendorf vial cap was obtained with sticky wax. A glucose solution (1 mol L^{-1}, containing 0.2% NaN_3) was injected into the pulp chambers through the glass tube until the top of the solution was 15 cm higher than the pulp floor. The models were then transferred to an incubator that provided 100% humidity at 37 °C.

A 10 μL sample solution was drawn from the centrifuge tube at 1, 2, 4, 7, 10, 15 and 20 days, respectively. Because water in the centrifuge tube could evaporate at 37 °C, a corresponding amount of distilled water was added to maintain a constant volume of 2 mL either before or after drawing the sample. After enzymatic glucose oxidase was added into the sample separately, it was analysed with a SmartSpec 3000 spectrophotometer (Bio-Rad; Hercules, CA, USA) at 500 nm wavelength.

Statistical analysis

Raw data were recorded as mmol L^{-1} and analysed for statistical significance. As the data of leakage in terms of glucose concentration was not normally distributed, values were analysed using rank sum test with a significance level of $P < 0.05$.

Results

All experimental groups demonstrated glucose leakage to varying degrees whilst the negative control group had none. Figure 2 illustrates the median leakage of the experimental groups; all had the tendency for increased leakage throughout the experimental period.

The specimens in group 4 (larger perforations repaired with composite resin alone) had significantly more leakage ($P < 0.05$). Four samples in group 4 and one sample in group 3 (larger perforations repaired with calcium sulphate and composite resin) had low degrees of leakage on the first day. Leakage was observed in all experimental teeth after 10 days.

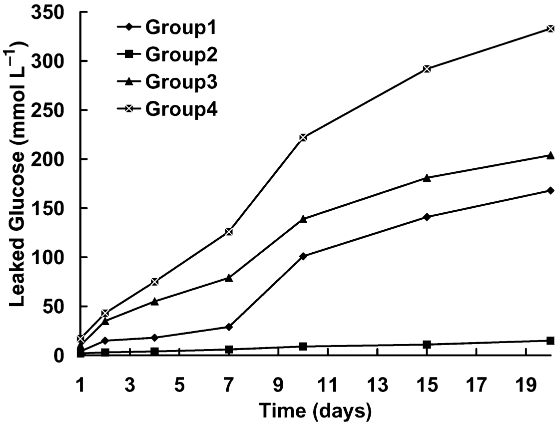

Figure 2 Leakage of glucose in the experimental groups.

The concentration of leaked glucose in group 2 (smaller perforations repaired with calcium sulphate and composite resin) was significantly lower than that in group 1 (smaller perforation repaired with resin alone) from the seventh day on ($P < 0.05$). Using calcium sulphate as an artificial floor did not significantly decrease leakage of the larger perforations (groups 3 and 4) ($P > 0.05$).

Leakage in group 2 (smaller perforations) was markedly lower than that in group 3 (larger perforations) ($P < 0.05$). No significant difference was found between the specimens in groups 1 and 4 (both repaired with resin alone) ($P > 0.05$).

Discussion

The prognosis of a root-filled tooth with a perforation depends on (Sinai 1977, Aguirre *et al.* 1986): (i) the size and location of the perforations; (ii) the duration that the perforation was open to contamination; (iii) the feasibility of sealing the perforation; (iv) the accessibility of the main canal system; and (v) the repair materials.

Clinical investigations have demonstrated that the prognosis of furcation perforations caused by resorption or caries was poor (Sinai 1977). It might be that such defects are too large to achieve adequate, high-quality and complete filling (Himel *et al.* 1985, Alhadainy & Abdalla 1998). Those authors observed that the size of teeth in relation to the size of the perforation was directly proportional to the prognosis, and larger teeth had better results. However, Salman *et al.* (1999) reported that there was no relationship between tooth type and either perforation size or linear relationship of bone to furcation perforation defect. This contradiction was perhaps due to the different experimental designs, such as the number of samples, the diameter of perforations and the different observation periods.

In the present study, the group of larger perforations had significantly more leakage than the smaller ones when calcium sulphate was used as a matrix ($P < 0.05$). On the other hand, although the concentration of leaked glucose in the group of smaller perforations was lower than that in the larger ones, no significant difference was found between groups repaired with resin alone ($P > 0.05$). The results showed that using calcium sulphate as a matrix improved the sealing ability of the composite resin. For groups without a matrix, there was no significant relationship between the size of perforation and leakage. One of the causes might be related to the diameters of the defects; the diameter of a number 3 round bur is 1 mm and that of a number 5 round bur is 1.5 mm. This difference may not have been sufficient to affect the results.

Microleakage existed in every experimental group and the concentrations of leaked glucose increased with observation time. Glucose could be detected in some samples in groups 3 and 4 (larger perforations) within 24 h. Even in group 2 (smaller perforation repaired with resin plus calcium sulphate as matrix) with the least leakage, glucose could be observed in all teeth after 10 days.

Various methods have been developed to investigate the influence of a matrix on sealing of perforation repairs. Dye leakage and bacterial penetration techniques are popular (Alhadainy & Abdalla 1998, Jantarat *et al.* 1999). However, the dye penetration method has large variations and is often not reproducible or comparable (Wu & Wesselink 1993). Bacterial penetration is more clinically relevant but the metabolites of the bacteria, such as endotoxin and enzyme, might penetrate through the space between the dentine and the materials without being detected even if the bacteria themselves could not pass through. In this study, a novel method for detection of microleakage (Xu *et al.* 2005) was applied. The method is simple and is able to quantify microleakage with high sensitivity. In this study, glucose was selected as the tracer because of its small molecular size. The enzymatic glucose oxidase was used to test the concentration of glucose (Freeman 2004).

Efforts should be made to simulate bone or granulomatous tissue in the periradicular region when perforations are repaired. Some authors used a moist cotton pellet (Chau *et al.* 1997, Mittal *et al.* 1999) in the furcation area and others used nothing (Jantarat *et al.* 1999). In the present study, a moist florist's sponge was used (Lee *et al.* 1993). Perforations were repaired using an operating microscope, which provided better visibility and allowed more precise procedures.

Light-cured composite resin was selected as a repair material because it was the most popular materials in clinical practice (Sweeney *et al.* 2002). In addition, it was reported that the light-cured materials were better than chemically cured materials in sealing the perforations of pulp chamber floors (Alhadainy & Himel 1993).

The purpose of the internal matrix was to provide a better operating platform for the repair materials. In some studies, the calcium sulphate was not removed fully from the perforations (Himel & Alhadainy 1995, Alhadainy & Abdalla 1998, Mittal *et al.* 1999). Thus, the thickness of the calcium sulphate was variable and the matrix occupied some of the teeth defect to decrease the thickness of the repair material and its contact area with dentine. Thus, calcium sulphate should be removed completely from the perforations during repair (Lemon 1992).

Calcium sulphate could not be expected to seal the perforation because of its high permeability (Alhadainy & Abdalla 1998). Additionally, Bahn (1966) found that calcium sulphate was absorbed within the lesion at 6 months *in vivo*.

Conclusion

Calcium sulphate barrier significantly improved the sealing ability of 1 mm furcal perforations repaired with composite resin but it had no effect in 1.5 mm defects.

Acknowledgements

This work was supported by grants from the National Key Technologies R&D Programme of the Tenth Five-Year Plan of the Ministry of Science and Technology, China (grant no. 2004BA720A23).

References

Aguirre R, ElDeeb ME, ElDeeb ME (1986) Evaluation of the repair of mechanical furcation perforations using amalgam, gutta-percha, or indium foil. *Journal of Endodontics* **12**, 249–56.

Alhadainy HA, Abdalla AI (1998) Artificial floor technique used for the repair of furcation perforations: a microleakage study. *Journal of Endodontics* **24**, 33–5.

Alhadainy HA, Himel VT (1993) Comparative study of the sealing ability of light-cured versus chemically cured materials placed into furcation perforations. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics* **76**, 338–42.

Alhadainy HA, Himel VT (1994) An in vitro evaluation of plaster of Paris barriers used under amalgam and glass ionomer to repair furcation perforations. *Journal of Endodontics* **20**, 449–52.

Alhadainy HA, Himel V, Lee WB, Elbaghdady YM (1998) Use of a hydroxylapatite-based material and calcium sulfate as artificial floors to repair furcal perforations. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics* **86**, 723–9.

Arens DE, Torabinejad M (1996) Repair of furcal perforation with mineral trioxide aggregate. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics* **82**, 84–8.

Bahn SL (1966) Plaster: a bone substitute. *Oral Surgery, Oral Medicine, Oral Pathology*, **21**, 672–81.

Balla R, LoMonaco CJ, Skribner J, Lin LM (1991) Histological study of furcation perforations treated with tricalcium phosphate, hydroxylapatite, amalgam, and Life. *Journal of Endodontics* **17**, 234–8.

Benenati FW, Roane JB, Biggs JT, Simon JH (1986) Recall evaluation of iatrogenic root perforations repaired with amalgam and gutta-percha. *Journal of Endodontics* **12**, 161–6.

Chau JYM, Hutter JW, Mork TO, Nicoll BK (1997) An in vitro study of furcation perforation repair using calcium phosphate cement. *Journal of Endodontics* **23**, 588–92.

ElDeeb ME, ElDeeb M, Tabibi A, Jensen JR (1982) An evaluation of the use of amalgam, Cavit, and calcium hydroxide in the repair of furcation perforations. *Journal of Endodontics* **8**, 459–66.

Freeman VS (2004) Carbohydrates. In: Bishop ML, Fody EP, Schoeff LE, eds. *Clinical Chemistry: Principles, Procedures, Correlations*, 5th edn. Philadelphia, PA, USA: Lippincott Williams and Wilkins, pp. 275–6.

Goodis HE, Marshall GW Jr, White JM, Gee L, Hornberger B, Marshall SJ (1993) Storage effects on dentin permeability and shear bond strengths. *Dental Materials* **9**, 79–84.

Hatem A, Ali I (1998) Artificial floor technique used for the repair of furcation perforations:a microleakage study. *Journal of Endodontics* **24**, 33–5.

Himel VT, Alhadainy HA (1995) Effect of dentin preparation and acid etching on the sealing ability of glass ionomer and composite resin when used to repair furcation perforations over plaster of Paris barriers. *Journal of Endodontics* **21**, 142–5.

Himel VT, Brady J, Weir J (1985) Evaluation of repair of mechanical perforations of the pulp chamber floor using biodegradable tricalcium phosphate or calcium hydroxide. *Journal of Endodontics* **11**, 161–3.

Jantarat J, Dashper SG, Messer HH (1999) Effect of matrix placement on furcation perforation repair. *Journal of Endodontics* **25**, 192–6.

Lee SJ, Monsef M, Torabinejad M (1993) Sealing ability of a mineral trioxide aggregate for repair of lateral root perforations. *Journal of Endodontics* **19**, 541–4.

Lemon RR (1992) Nonsurgical repair of perforation defects: internal matrix concept. *Dental Clinics of North America* **36**, 439–57.

Mittal M, Chandra S, Chandra S (1999) An evaluation of plaster of Paris barriers used under various materials to repair furcation perforations (in vitro study). *Journal of Endodontics* **25**, 385–8.

Pecora G, Baek SH, Rethnam S, Kim S (1997) Barrier techniques in endodontic microsurgery. *Dental Clinics of North America* **41**, 585–602.

Salman MA, Quinn F, Dermody J, Hussey D, Claffey N (1999) Histological evaluation of repair using a bioresorbable membrane beneath a resin-modified glass ionomer after mechanical furcation perforation in dogs' teeth. *Journal of Endodontics* **25**, 181–6.

Sinai IH (1977) Endodontics perforations: their prognosis and treatment. *Journal of the American Dental Association* **95**, 90–5.

Sottosanti J (1992) Calcium sulfate: a biodegradable and biocompatible barrier for guided tissue regeneration. *Compendium of Continuing Education in Dentistry* **13**, 226–34.

Sweeney M, Creanor SL, Smith RA, Foye RH (2002) The release of mercury from dental amalgam and potential neurotoxicological effects. *Journal of Dentistry* **30**, 243–50.

Tate WH, White RR (1991) Disinfection of human teeth for educational purposes. *Journal of Dental Education* **55**, 583–5.

Wu MK, Wesselink PR (1993) Endodontic leakage studies reconsidered. Part I. Methodology, application and relevance. *International Endodontic Journal* **26**, 37–43.

Xu Q, Fan MW, Fan B, Cheung GSP, Hu HL (2005) A new quantitative method using glucose for analysis of endodontic leakage. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology* **99**, 107–11.