Effect of Heat and Sonic Vibration on Penetration of a Flowable Resin Composite Used as a Pit and Fissure Sealant

Hae-Jung Kim* / Hyung-Jun Choi** / Ki-Yeol Kim*** / Kwang-Mahn Kim****

Objective: To evaluate penetration of a flowable resin composite into fissures using three different application methods: (1) conventional, (2) heat, and (3) sonic vibration. Study design: Forty-five sound maxillary third molars were divided randomly into three groups (n=15 per group). The occlusal surfaces of the teeth were etched and flowable resin composites were applied into the fissure using the assigned application method. The crowns were sectioned and examined with an optical microscope to assess penetration. In addition, three-point flexural strength was analyzed. Results: The sonic vibration group exhibited significantly greater penetration into the fissure compared with the other test groups (p<0.001). The heat group exhibited greater penetration into the fissure compared with the conventional group (p=0.003). However, three-point flexural strength was similar among all groups (p>0.05). Conclusions: Sonic vibration and heat increased penetration into fissures. Notably, sonic vibration exhibited the greatest penetration. We found that the application method did not influence the three-point flexural strength.

Keywords: Pit and fissure sealant, penetration, sonic vibration, heat.

INTRODUCTION

Although occlusal surfaces constitute only 12.5% of all tooth surfaces of the permanent teeth, they contribute to more than two-thirds of the total dental caries experienced by children.[1] The pits and fissures on occlusal surfaces have narrow, deep, and constrictive morphologies.[2] This geometric configuration of the fissures may also be an obstacle to prevention and remineralization of carious lesions, as the removal of plaque and penetration of fluoride are compromised within the fissure.[3] In the 1960s, pit and fissure sealants were introduced as a measure to prevent dental caries within the occlusal surface.[4] The ability of sealants to penetrate successfully into pits and fissures can ensure increased clinical longevity in sealant retention.[5] Factors influencing sealant penetration into fissures include the entrapment of air within the fissure, accumulation of organic substances within the fissure, and viscosity of the sealant resin[6]; notably, the viscosity is altered by the use of vibration.[7] Previous studies have evaluated penetration using vibration methods: Lee et al reported that the use of ultrasonic vibration after bond application may improve resin penetration into the dentin tubules of teeth and may increase dentin bonding strength[8]; additionally, Tadokoro et al reported that sealant penetration in pits and fissures was readily improved by using the vibration etching technique.[9] However, no reports are available regarding the effects of heat and sonic vibration on penetration when using a flowable resin composite as a pit and fissure sealant.

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The purpose of this study was to examine penetration of the flowable resin composite used as a pit and fissure sealant using the following three application methods: conventional, heat, and sonic vibration. In addition, we aimed to compare three-point flexural strength of the flowable resin composite among these methods. Two null hypotheses were tested: (1) heat and sonic vibration would not result in significant differences in penetration of the flowable resin composite used as a pit and fissure sealant and (2) heat and sonic vibration would not affect three-point flexural strength of the flowable resin composite.

MATERIALS AND METHOD

A flowable resin composite (CharmFill Flow HV, Dentkist, Inc., Gunpo, Korea) was used as a pit and fissure sealant. It contains 70.3% barium glass, which comprises a much higher filler content than that present in traditional pit and fissure sealants.[10]

Preparation of teeth

Ethical approval for procurement of the teeth was obtained on June 23, 2016 from the Institutional Review Board of Dental Hospital of Yonsei University (IRB No. 2–2016- 0009). Human maxillary third molars were stored for no longer than 1 week in 0.1% thymol solution after extraction. Caries detection was carried out visually under a clinical light source; teeth that were suspected to have caries were excluded. In addition, a dental explorer was used to examine the presence of plaque in fissures; teeth that plaques were removed from fissure by the dental explorer were excluded, even if those teeth appeared to be sound. Of 80 teeth from 50 total volunteers, only 45 fresh teeth were used in this study; the teeth were randomly assigned to one of three groups (conventional group, heat group, and sonic vibration group; n=15 teeth each).[6,9,11,12]

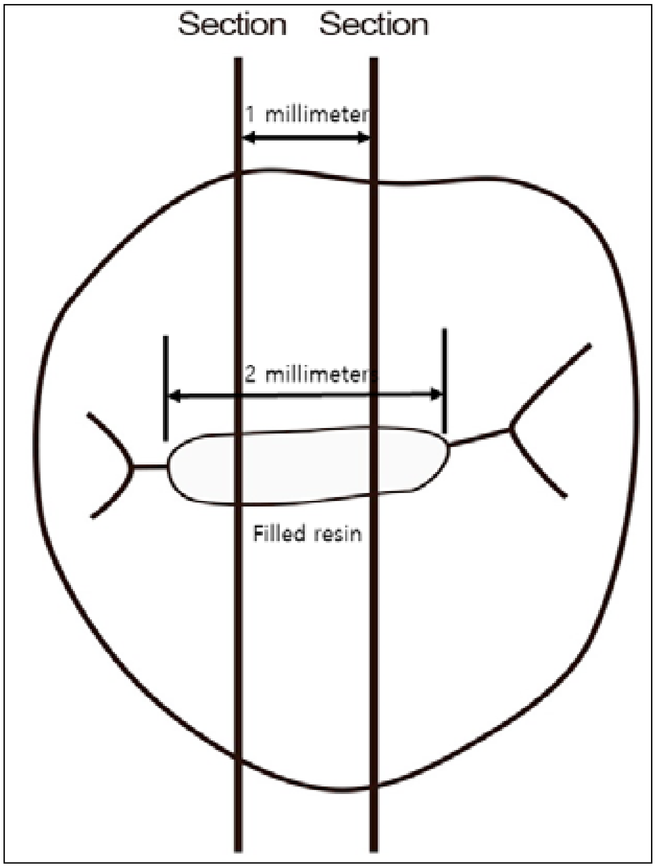
Flowable resin composite application

To remove biofilm prior to sealing, the occlusal surfaces of the teeth were cleaned for 20 seconds without a pumice slurry, using a rotating brittle brush (Ecoden Icb Brush, Yangzhou Dentp Import & Export Co., Ltd., Yangzhou, China) fixed in a slow-speed, contra-angle handpiece. All teeth were rinsed thoroughly with air-water spray, and then stored in distilled water at room temperature for 24 hours until ready for use. Teeth were etched in 35% phosphoric acid gel (Scotchbond™ Universal Etchant, 3M ESPE, St. Paul, MN, USA) for 20 seconds; then, they were washed thoroughly for 15 seconds and dried with oil-free compressed air for 10 seconds until the occlusal surface began to appear chalky.

The sonic vibration instrument was designed by attaching the 0.5-millimeter diameter round tip of a periodontal probe (Probe Bpcp10, Osung Mnd Co., Ltd., Gimpo, Korea) to the handle of an electric toothbrush (Oral-BTriZone3000, Braun Gmbh, Kronberg, Germany). This instrument vibrates perpendicularly and horizontally in a simultaneous manner; the end of the tip operates perpendicularly to the occlusal surface at a frequency of 380 Hz (amplitude of 0.27 millimeters) and horizontally to the occlusal surface at a frequency of 85 Hz (amplitude of 0.3 millimeters).

Flowable resin composites were applied into fissures that were 2.0 ± 0.1 millimeters in length (Figure 1). In the conventional group, flowable resin composites, stored at 25°C for 5 minutes, were applied into fissures for 20 seconds without vibration using a sonic vibration instrument that had also been stored at 25°C for 5 minutes. In the heat group, flowable resin composites, stored at 50°C for 5 minutes, were applied into fissures for 20 seconds without vibration using a sonic vibration instrument that had also been stored at 50°C for 5 minutes. In the sonic vibration group, flowable resin composites were applied into fissures for 20 seconds in the same manner as described for the conventional group, but with the addition of sonic vibration. An LED light-curing unit (Elipar™S10, 3M ESPE, St. Paul, MN, USA) was used as a light-curing agent.

Figure 1. Image showing fissure sealing and sectioning on the occlusal surface. The fissure was filled with flowable resin composite within the length of 2.0 ± 0.1 millimeters, and the tooth was then cross-cut longitudinally in the buccolingual direction to provide specimens that were 1.0 ± 0.1 millimeters thick.



Sectioning and microscope analysis

The crowns were sectioned buccolingually, with two parallel cuts through the sealed fissure, to obtain specimens of 1.0 ± 0.1-millimeter thickness (Figure 1), using a rotating polishing machine (Ecomet, Buehler Ltd., Lake Bluff, IL, USA) with 600, 800 grit silicon carbide paper (Deerfos, Incheon, Korea) under tap water. Thus, for each tooth, a polished specimen with a length of 1 millimeter was acquired. Both polished sides of each specimen were examined; in total, 90 surfaces were photographed and observed under an optical microscope (Zeiss AXIO Imager A1m, Carl Zeiss MicroImaging, Inc., Thornwood, NY, USA) at 50× magnification.

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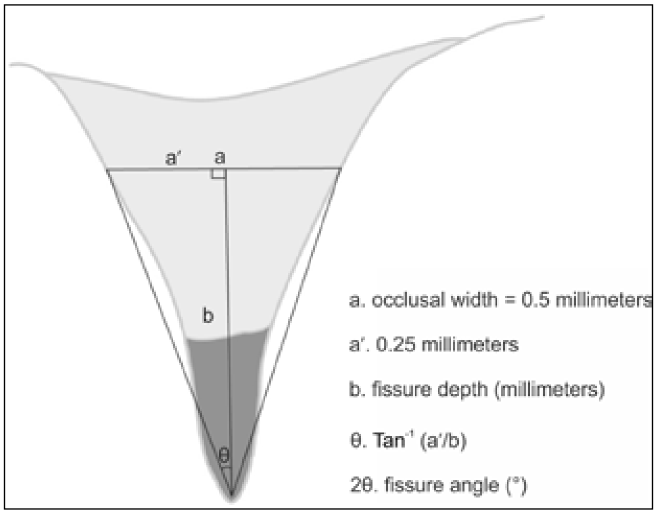
Fissure depth and fissure angle

Figure 2 comprises a schematic diagram showing the method used to calculate fissure depth and fissure angle. The occlusal width (a) refers to the point where the width of the fissure orifice is 0.5 millimeters. The fissure depth (b) was measured from the occlusal width to the deepest point of the fissure. The fissure angle (2θ) was calculated according to the following equation (1):

Fissure angle $(2\theta) = 2\mathrm{Tan}^{-1}(a'/b)$ (1)

Figure 2. Schematic diagram of the measurement system used to calculate fissure depth and fissure angle.



Penetration

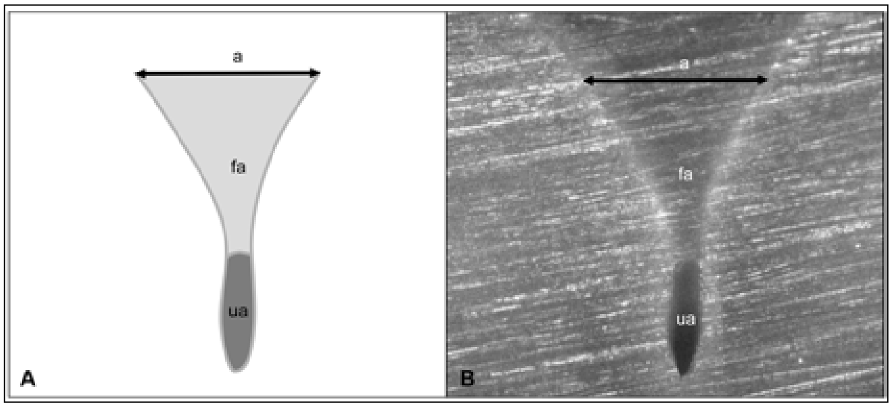
Figure 3 comprises representative images showing the method used to calculate penetration. Fig. 3A and 3B depict a schematic diagram and an optical micrograph of the sectioned fissures, respectively. The filled area (fa) constitutes the fissure area that was filled with the flowable resin composites, from the occlusal width to the deepest point reached by the flowable resin composites. The unfilled area (ua) refers to the fissure area that was not filled by the flowable resin composites. The fissure area (fa+ua) comprises the area from the occlusal width to the bottom of the fissure. Penetration was calculated according to the following equation[3] (2):

$$\text{Penetration (\%)} = \frac{\mathbf{fa}}{\mathbf{fa+ua}} \times 100 \qquad (2)$$

Three-point flexural strength

Three-point flexural strength was assessed to determine whether heat and sonic vibration affect mechanical properties of the flowable resin composite, such as strength. For the three-point flexural strength test, specimen preparation was performed according to ISO 4049.[13] The stainless-steel mold (25 × 2 × 2 millimeters) was placed on a glass slide covered by a polyester film. In the conventional group, flowable resin composites that were stored at a temperature of 25°C for 5 minutes were then overfilled carefully into a mold, avoiding bubbles. In the heat group, flowable resin composites stored at a temperature of 50°C were prepared in the same manner as in the conventional group. In the sonic vibration group, the tip of the sonic vibration instrument, stored at a temperature of 25°C, was applied to the mold during the process of filling with flowable resin composites; after flowable resin composites stored at a temperature of 25°C were injected into the mold, the entire length of the material underwent vibration for 20 seconds. Each material was covered by a polyester film and a glass slide; then, pressure was applied to eliminate excess materials from the mold. One side of the material was irradiated using four overlapping exposure of 20 seconds with a LED light-curing until the entire length of the material had been irradiated. The curing method was equally applied on the other side of the material, and then the material was separated from the mold. Thirty specimens (n=10 for each group) were prepared for three-point flexural strength measurements. Subsequently, all specimens were stored in distilled water for 24 hours at 37°C. The specimen width and thickness were measured immediately before the test using a digital caliper (Mitutoyo Co., Tokyo, Japan) (accurate to 0.01 millimeters). Three-point flexural strength was tested at a crosshead speed of 1 millimeter/minute, using a flexural strength test apparatus (Instron5942, Instron, Norwood, MA, USA). The maximum load was recorded when the specimen fractured; three-point flexural strength (S) was calculated using the following formula: $S = 3Fl / 2bh^2$, where F, I, b, and h are maximum fracture load, distance between the supports (20 millimeters), width of the specimen, and height of the specimen, respectively.

Figure 3. Schematic diagram (A) and optical micrograph (B) of the measurement system used to calculate penetration: a. occlusal width = 0.5 (millimeters), fa. filled area (square millimeters), ua. unfilled area (square millimeters), fa+ua. fissure area (square millimeters); penetration (%) = $\frac{\mathbf{fa}}{\mathbf{fa+ua}} \times 100$



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Statistical analysis

Fissure depth, fissure angle, and penetration were each analyzed using the Kruskal-Wallis test, as the data were not normally distributed. Post hoc testing, according to the degree of penetration, was performed using the Mann-Whitney U test with Bonferroni correction. Statistical analyses of three-point flexural strength data were performed using one-way ANOVA, as the data were normally distributed. IBM SPSS Statistics 23 (Armonk, NY, USA) was used for all statistical analyses. Statistical significance for all tests was regarded as $p<0.05$.

RESULTS

Fissure depth and fissure angle

Table 1 shows the mean and standard deviation values for fissure depth and angle in each group. There were no significant differences among the three groups ($p>0.05$).

Table 1. Mean and standard deviation values for fissure depth and fissure angle in the three groups

Group	Conventional group	Heat group	Sonic vibration group
Fissure depth (millimeters)	0.95 ± 0.41 ^{a}	0.93 ± 0.38 ^{a}	0.84 ± 0.23 ^{a}
Fissure angle (°)	33.13 ± 10.58 ^{b}	34.39± 12.95 ^{b}	35.42± 9.77 ^{b}

Values with the same letter in each row indicate no statistically significant differences among the three groups ($p > 0.05$).

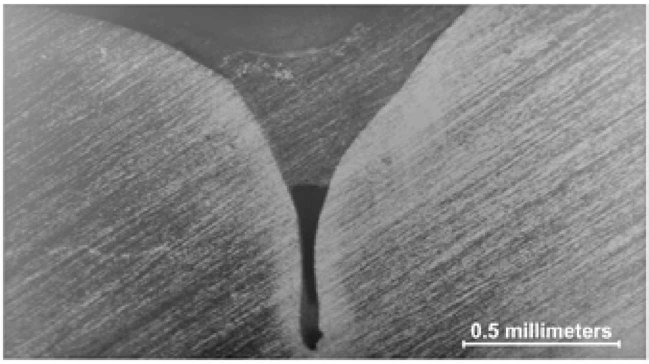
Penetration

Figure 4 depicts representative sections of penetration, according to the three different application groups (conventional group, heat group, and sonic vibration group). Penetration in the conventional group was insufficient and partially filled the fissures. Penetration was insufficient in the heat group; however, the heat group exhibited greater penetration compared with the conventional group. Fissures in the sonic vibration group were completely filled by flowable resin composite. Penetration in each group is summarized in Figure 5. The degree of penetration in the sonic vibration group was 98.27 ± 4.46% (mean ± standard deviations), compared with 73.92 ± 15.19% (mean ± standard deviations) in the conventional group and 86.47 ± 12.88% (mean ± standard deviations) in the heat group. Thus, the highest penetration occurred in the sonic vibration group, which was significantly greater than that in the other two groups ($p<0.001$). The heat application method exhibited significantly greater penetration compared with the conventional application method ($p=0.003$).

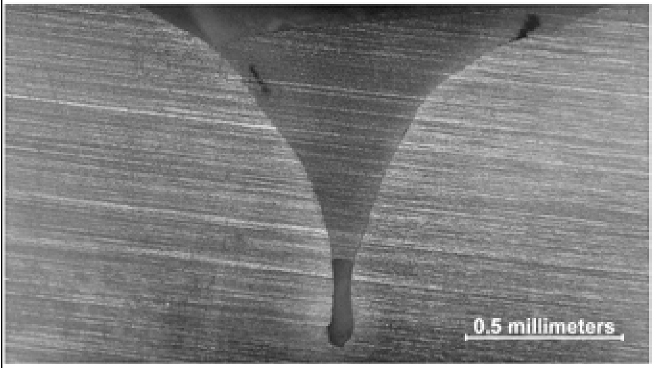
Three-point flexural strength

Three-point flexural strength was similar among all three groups ($p>0.05$) (Figure 6).

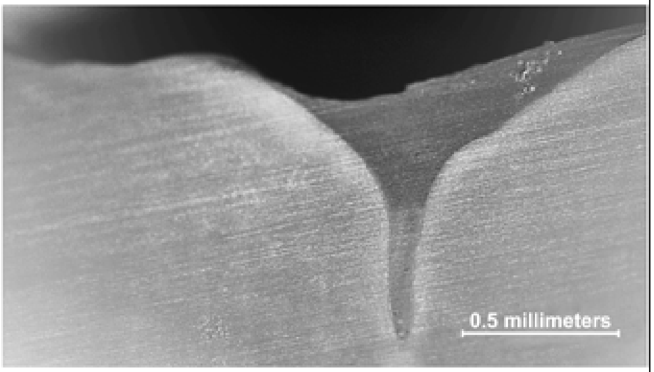
Figure 4. Sectioned images of fissures sealed by the flowable resin composite used as the pit and fissure sealant (50× magnification). Fissures were insufficiently filled with flowable resin composite in the conventional group and heat group. However, penetration in the sonic vibration group was complete.



Conventional group



Heat group



Sonic vibration group

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Figure 5. Box-whisker plot illustrating penetration for each application method. Penetration in the sonic vibration group was significantly greater than in other groups (p<0.001). Statistically significant differences (p=0.003) were found between the conventional and heat groups. The symbol "*" indicates a statistically significant difference among the three groups at P<0.05.

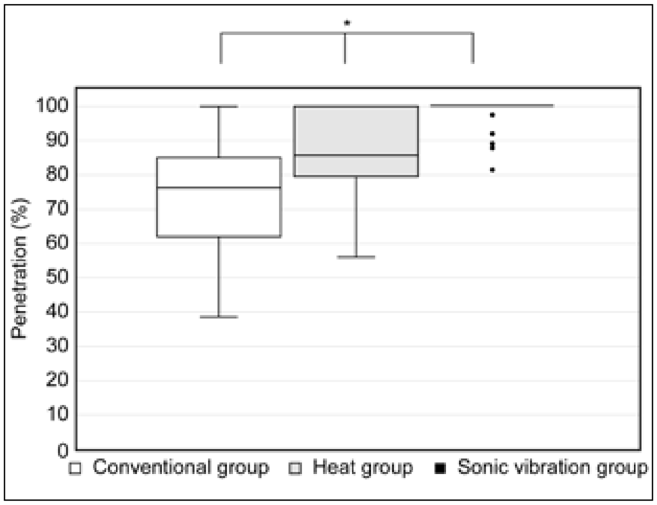
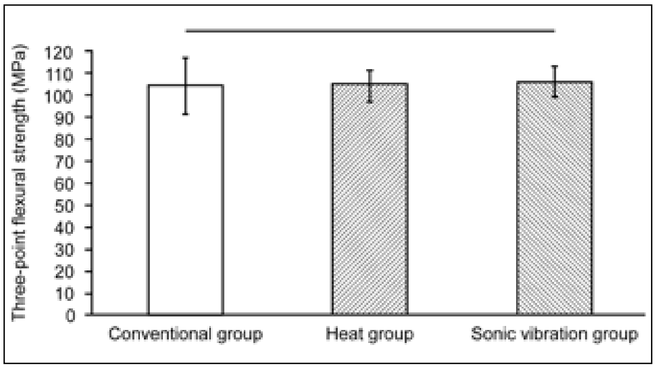


Figure 6. Three-point flexural strengths for each application method. Horizontal bar indicates no statistically significant differences among the three groups (p > 0.05).



DISCUSSION

Fissure depth and complexity influence sealant penetration within fissures.[14] In a study by Hosoya et al there were no significant differences in sealant penetration between the non-vibration groups and groups that underwent vibrating probe treatment; the degrees of sealant penetration were influenced by the diversity of shape and depth of the fissures.[11] Grewal et al reported that the liquid penetration into a crack was affected by the width and depth of the crack.[15] Sealants penetrated better into shallow fissures; these exhibited a wider entrance angle and increased occlusal width, relative to deep fissures. Fissures with a smaller entrance angle and shorter occlusal width exhibited reduced penetrativity.[3] Thus, to minimize variation among fissures in the present study, the occlusal width of fissures was defined as the location where the fissure width was 0.5 millimeters (Figure 2). As Table 1 shows, there was no significant difference in the average depth and angle of fissures among the three groups. This suggests that this study was performed under fair conditions that remain unaffected by variations among the fissures.

Another factor affecting sealant penetration is the viscosity of the sealant resin,[6] which is typically influenced by the content, shape, size, and volume of the filler particles scattered in a resin matrix.[16] The compositions of filler particles may also greatly affect mechanical properties, such as strength and wear resistance.[17-19] If filler particles are added, the viscosity and mechanical properties of resin (e.g., strength, wear, and abrasion resistance) are increased. Hence, a reduction in filler particles reduces the viscosity, which may improve penetration. However, this modification of filler particles negatively affects the mechanical properties, although the lowered viscosity increases overall penetration.[17,20] Therefore, under conditions that do not change the composition of the filler, the viscosity of the material can be influenced by changes in shear rate, temperature, pressure, and time of shearing.[21]

In the present work, sonic vibration was used to apply shearing within the material. The sonic vibration groups showed greatly increased penetration, compared with the penetration of the other groups (Figure 5); importantly, this penetration was nearly 100%. We suspect that the application of sonic vibration, which produces shearing, led to reductions in viscosity and improvements in the flowability of the flowable resin composites, enabling superior penetration into the fissure. Treatment with vibration transforms the thixotropic materials into a liquid-like state; the materials return to their original solid-like state when the vibration ceases. This thixotropic phenomenon alters the viscosity and increases the flow properties of materials, such as zinc phosphate cement or composite luting materials, when vibration is transferred through the restoration to underlying material during the seating of metal and composite inlays.[7] Tavas and Watts observed that some composite resins exhibited thixotropic behavior at high shear rates.[22] Similarly, Beun et al reported that the flowable composite resins decreased in viscosity and demonstrated thixotropy, as the shear rate increased. This suggests that flowable resin composites are better able to flow by themselves in small cavities and fissures according to an increase in the shear rate.[23] Generally, when the shear force is added to resin composites that exhibit weak molecular bonding and in which filler particles were packed, the molecules of the resin composites become repositioned or separated from each other, resulting in weakening and destruction of the molecular bond. This procedure leads to reduced viscosity, making the resin composites more readily able to flow.[16,24] Indeed, from a clinical perspective, resin-based sealants with a low viscosity can penetrate more effectively into the occlusal fissures and porous zones that are produced in the enamel by etching with a phosphoric acid solution.[25] Some previous clinical studies have investigated changes in the viscosity and flow properties of the material by vibration; these include the following studies. Lee et al revealed that ultrasonic vibration may improve the quality of resin infiltration and maximize dentin bonding strength in dentin tubes by optimizing the viscosity-decreasing effects of the vibration.[8] Kersten et al observed that ultrasonic vibration treatment of the tooth during the etching procedure increased the quality of the fissure sealing process, allowing the acid gel to penetrate into the enamel structure more deeply.[26]

The results of heat application of the flowable resin composite used as the pit and fissure sealant are also shown in Figure 5. Notably, the heat group exhibited greater penetration than the conventional group. However, the heat group exhibited less penetration than the

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sonic vibration group. Lee et al reported that viscosity markedly decreased, and that filler particles could easily be incorporated into the resin matrix, as the sealant temperature increased.[16] The viscosity varies with temperature: an increase in temperature decreases viscosity, which affects flowability.[27] Many studies have described the use of heat application.[28-32] However, the present study experienced difficulties in comparing the results shown; to our knowledge, no similar studies have evaluated the effect of heat application on penetration. Nevertheless, although it exhibited lower penetration than the sonic vibration application, it was evident that heat application reduced the viscosity and increased penetration into the fissure.

Lastly, sonic vibration and heat do not affect mechanical properties, such as three-point flexural strength (see Figure 6).

Ikejima et al revealed that mechanical properties, such as compressive strength, hardness, and flexural strength, improved progressively as the density of filler particles increased.[17] In contrast, Irinoda et al noted that the viscosity of pit and fissure sealant increased, while sealant penetration decreased, as filler particles were added.[20]

Based on the results of these studies, pit and fissure sealants with higher filler content than traditionally used sealants, such as flowable resin composites, may exhibit excellent mechanical properties; suitable use of sonic vibration and heat during sealing can improve greatly penetration into fissures, while mitigating the increased viscosity that was caused by adding filler. Accordingly, it can be presumed that it is possible to perform sealing that achieves both excellent penetration and mechanical characteristics by use of heat and sonic vibration. In addition, the use of an instrument specifically designed to generate sonic vibration and heat could help to conveniently apply sonic vibration and heat.

CONCLUSION

We rejected our primary null hypothesis that heat and sonic vibration would not significantly affect penetration of the flowable resin composite, and accepted our secondary null hypothesis. Overall, sonic vibration most strongly influenced penetration, exhibiting the greatest penetration among the three groups tested ($p<0.001$); heat resulted in higher penetration compared with the conventional application method ($p=0.003$), although it attained less penetration than did sonic vibration. Heat or sonic vibration did not affect the three-point flexural strength of the flowable resin composite.

REFERENCES

1. Waggoner W.F. and Siegal M. Pit and fissure sealant application: Updating the technique. J Am Dent Assoc; 127: 351-361. 1996.
2. Taylor C.L. and Gwinnett A.J. A study of the penetration of sealants into pits and fissures. J Am Dent Assoc; 87: 1181-1188. 1973.
3. Celiberti P. and Lussi A. Penetration ability and microleakage of a fissure sealant applied on artificial and natural enamel fissure caries. J Dent; 35: 59-67. 2007.
4. Beun S., Bailly C., Devaux J., and Leloup G. Physical, mechanical and rheological characterization of resin-based pit and fissure sealants compared to flowable resin composites. Dent Mater ; 28: 349-359. 2012.
5. Kakaboura A., Matthaiou L., and Papagiannoulis L. In vitro study of penetration of flowable resin composite and compomer into occlusal fissures. Eur J Paediatr Dent; 3: 205-209. 2002.
6. Brocklehurst P.R., Joshi R.I., and Northeast S.E. The effect of air polishing occlusal surfaces on the penetration of fissures by a sealant. Int J Paediatr Dent; 2: 157-162. 1992.
7. Walmsley A.D. and Lumley P.J. Applying composite luting agent ultrasonically: a successful alternative. J Am Dent Assoc ; 126: 1125-1129. 1995.
8. Lee J., Jang K.T., Kim J.W., Lee S.H., Hahn S.H., and Kim C.C. Effect of ultrasonic vibration on dentin bond strength and resin infiltration. Am J Dent 16; 404-408. 2003.
9. Tadokoro Y., Iwaku M., and Fusayama T. A laboratory report on vibration etching for fissure sealants. J Dent Res; 61: 780-785. 1982.
10. Beun S., Bailly C., Devaux J., and Leloup G. Rheological properties of flowable resin composites and pit and fissure sealants. Dent Mater ; 24; 548-555. 2008.
11. Hosoya Y., Garcia-Godoy F., and Summitt J.B. Microleakage and sealant penetration using a vibrating probe. Am J Dent; 17: 427-432. 2004.
12. Hevinga, M.A., Opdam, N.J., Frencken, J.E., Bronkhorst, E.M., and Truin, G.J. Microleakage and sealant penetration in contaminated carious fissures. J Dent ; 35: 909-914. 2007.
13. International Organization for Standardization. ISO 4049:2009(E): Dentistry-Polymer-based restorative materials. 4th ed. ISO, Geneva; 2009.
14. Symons A.L., Chu C.Y., and Meyers I.A. The effect of fissure morphology and pretreatment of the enamel surface on penetration and adhesion of fissure sealants. J Oral Rehabil; 23: 791-798. 1996.
15. Grewal N. and Chopra R. The effect of fissure morphology and eruption time on penetration and adaptation of pit and fissure sealants: An SEM study. J Indian Soc Pedod Prev Dent; 826: 59-63. 2009.
16. Lee J.H., Um C.M., and Lee I.B. Rheological properties of resin composites according to variations in monomer and filler composition. Dent Mater; 22: 515-526. 2006.
17. Ikejima I., Nomoto R., and McCabe J.F. Shear punch strength and flexural strength of model composites with varying filler volume fraction, particle size and silanation. Dent Mater; 19: 206-211. 2003.
18. Braem M., Finger W., Van Doren V.E., Lambrechts P., and Vanherle G. Mechanical properties and filler fraction of dental composites. Dent Mater; 5: 346-349. 1989.
19. Fu S.Y., Feng X.Q., Lauke B., and Mai Y.W. Effects of particle size, particle/matrix interface adhesion and particle loading on mechanical properties of particulate–polymer composites. Composite Part B 39: 933-961, 2008.
20. Irinoda Y., Matsumura Y., Kito H., Nakano T., Toyama T., Nakagaki H., and Tsuchiya T. Effect of sealant viscosity on the penetration of resin into etched human enamel. Oper Dent; 25: 274-282. 2000.
21. Barnes H.A., Hutton J.F., and Walters K. An introduction to rheology. Elsevier, New York; 12, 1989
22. Tavas M.A. and Watts D.C. The use of a cone and plate viscometer for determination of flow properties of unfilled resins and etching gels. J Oral Rehabil; 16: 185-192. 1989
23. Beun S., Bailly C., Devaux J., and Leloup G. Rheological properties of flowable resin composites and pit and fissure sealants. Dent Mater; 24; 548-555. 2008.
24. Lee I.B., Chang J., and Ferracane J. Slumping resistance and viscoelasticity prior to setting of dental composites. Dent Mater; 24: 1586-1593. 2008.
25. Percinoto C., Cunha R.F., Delbem A.C., and Aragones A. Penetration of a light-cured glass ionomer and a resin sealant into occlusal fissures and etched enamel. Am J Dent ; 1995:8: 20-22.
26. Kersten S., Lutz F., and Schüpbach P. Fissure sealing: optimization of sealant penetration and sealing properties. Am J Dent ; 14: 127-131. 2001.
27. Silikas N. and Watts D.C. Rheology of urethane dimethacrylate and diluent formulations. Dent Mater; 15: 257-261. 1999.
28. Gorseta K., Skrinjaric T., and Glavina D. The effect of heating and ultrasound on the shear bond strength of glass ionomer cement. Coll Antropol; 36: 1307-1312. 2012.
29. Dehurtevent M., Deveaux E., Hornez J.C., Robberecht L., Tabary N., and Chai F. Influence of heat and ultrasonic treatments on the setting and maturation of a glass-ionomer cement. Am J Dent; 28: 105-110. 2015.
30. Gorseta K., Glavina D., and Skrinjaric I. Influence of ultrasonic excitation and heat application on the microleakage of glass ionomer cements. Aust Dent J ; 57: 453-457. 2012.
31. Algera T.J., Kleverlaan C.J., de Gee A.J., Prahl-Andersen B., and Feilzer A.J. The influence of accelerating the setting rate by ultrasound or heat on the bond strength of glass ionomers used as orthodontic bracket cements. Eur J Orthod; 27: 472-476. 2009.
32. Kleverlaan C.J., van Duinen R.N.B., and Feilzer A.J. Mechanical properties of glass ionomer cements affected by curing methods. Dent Mater; 20: 45-50. 2004.

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