Sealant and resin viscosity and their influence on the formation of resin tags

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Gwinnett and Buonocore[1] were the first authors to describe resin tags inside the enamel as filamentous resin projections, similar to the enamel prisms and approximately 10 um in length. Many authors have described the role played by the resin tags as a factor responsible for the adhesive retention, but have reported different results as to the form, size and frequency of the tags. Some authors believe that charged particles in the composite resin would limit the free flow of adhesive into the enamel pores, inhibiting the formation of resin tags.[2-5] Others believe that the liquid phase of the composite is present in sufficient amount to flow into the conditioned enamel porosities, acting independently of the charged particles, and use this as an explanation for the equal size of resin tags obtained when the composite resin or the sealant is applied directly to the conditioned enamel.[6-9] Considering the existing controversy regarding resin viscosity for adequate tag formation, this study was designed to determine the influence on enamel penetration of resin viscosity and the presence or absence of a sealant. Three types of Concise (3M Brazil, Sumaré, São Paulo) resin—restorative, orthodontic, and diluted according to Artun and Zachrisson[10]—were applied with or without the previous application of a sealant.

Materials and methods

The sample consisted of 24 premolars, recently extracted for orthodontic reasons, divided randomly into six groups of four teeth each. The teeth were stored in a distilled water/thymol 0.5% solution, at room temperature. The buccal surface of each premolar was polished for 5 seconds with a rubber cup and an aqueous suspension of pumice, washed

Abstract

The ability of resin to penetrate tooth enamel during orthodontic bonding may be affected by the viscosity of the resin and the presence of a sealant. Twenty-four extracted molars were randomly divided into six groups of four. Three resin viscosities were applied with and without sealant and resin tag formation was studied with a scanning electron microscope. Statistically larger resin tags resulted in the group using the more fluid composite resin (orthodontic Concise) in combination with the sealant, although the frequency, regularity and form of the tags did not differ significantly among the various viscosities.

Key Words

Bonding • Resin • Sealant • Tags

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Table I
Number of tags in each group according to tag length

Tag Length (μm)	Groups 1	2	3	4	5	6
05I— 10	65	55	76	55	50	31
10I— 20	95	84	60	56	60	45
20I— 30	15	34	19	17	20	23
30I— 40	—	10	04	04	02	06
40I— 50	—	02	—	—	03	06
≥or = 50	—	03	—	02	03	02
Total	175	188	159	134	148	113
X (μm)	11.9	15.6	11.8	13.3	14.9	18.9

X (μm): average tag length of each group.

with water spray and dried with compressed air for 5 seconds. The labial surface was then conditioned with phosphoric acid solution for 1 minute, using the solution supplied with the Concise bonding kit. The etched surfaces were washed for 15 seconds and dried for an additional 15 seconds. The brackets were bonded to the enamel surfaces with the slot positioned 4 mm from the labial cusp tip. A new portion of resin was prepared for each bracket, according to the following scheme:

Group 1- Restorative Concise without previous sealant application;

Group 2- Restorative Concise with previous sealant application;

Group 3- Restorative Concise diluted according to Artun and Zachrisson[10], without previous sealant application;

Group 4- Restorative Concise diluted according to Artun and Zachrisson[10], with previous sealant application;

Group 5- Orthodontic Concise without previous sealant application;

Group 6- Orthodontic Concise with previous sealant application.

The sealant was applied to the teeth of groups 2, 4 and 6 with the brush supplied with the resin. After 24 hours, the teeth were sectioned in the labiOlingual dimension, following the long axis of the tooth and dividing the buccal surface and the bracket into halves. A handpiece fitted with carborundum disks (Dentorium, New York, NY) was used to section the teeth and intermittent cutting action was employed to avoid excess heat. The root was discarded and the two halves of the crown were inserted into epoxy resin, generating eight samples for each group. After the epoxy resin cured, the teeth were sanded with wet sandpaper, numbers 320, 400, and 600, and polished with abrasive diamond paste (Christensen Roder, Brazil) mounted in a polishing machine (Buehler) to obtain a smooth, flat surface. The sectioned samples were then refrigerated.

Concise phosphoric acid solution was used for 20 seconds to remove the enamel chaff from the cut surfaces of the samples in order to uncover the resin tags. The samples were washed with tap water for 15 seconds each, dried with hot air and placed in a mini-coater for dehydration and deposition of a thin layer of gold necessary for visualiZation in the SEM. The enamel field that best represented the resin tags 4 mm from the buccal cusp tip was photographed at 700X magnification (Figure 2A-B), using an SEM (JEOL, model JSM-25 S II, Japan) operating at 15 Kv. The field photographed corresponded to 0.158 mm of the enamel/resin interface. The negatives obtained with the Neopan 120 film were copied with Kodak Plus X Pan film and thus turned into positives. Projecting these positive images as slides allowed better evaluation and measurement of the resin tags. All the tags present were measured by means of a millimetric ruler (Figure 1) where 1 cm corresponded to 1 micrometer (0.001 mm). The magnification obtained by projecting the image was 10,000 times. Tags less than 5 μm long were excluded because they are related to the aprismatic enamel and are of little importance to the retention.[11,12]

Results

The total number of tags ≥5μm measured in each group, varied from 113 (group 6) to 188 (group 2) (Table I). The individual length of each tag was measured in order to calculate the average tag length (X in Table I); for the purpose of tabulation, the tags were divided into six classes according to size. The average number of tags per field (larger than or equal to 5 μm) was 20.1 in the groups without the sealant (1, 3 and 5) and 18.1 in the groups with the sealant (2, 4 and 6). The largest tag observed measured 89 μm and was found in group 5, where the orthodontic Concise was used without a previously applied sealant.

The analysis of variance and application of the F test and the Tukey test were used to compare the arithmetic averages, taking 5% as the probability level (P<0.05).

Table II
Analysis of variance

S.V.	D.F.	S.S.	M.S.	F.
Residual	5	4,093.41	818.68	10.90**(P<0.01)
Groups	901	67,668.36	75.10	
Total	906	71,761.77		

S.V. = source of variation
D.F. = degrees of freedom
S.S. = sum of squares
M.S.= mean square
F= F from Brieger

Table III
Tukey Test[†]

	X1	X2	X3	X4	X5
X2	3.7*	—	—	—	—
X3	0.1NS	3.8*	—	—	—
X4	1.4NS	2.3NS	1.5NS	—	—
X5	3.0*	0.7NS	3.1*	1.6NS	—
X6	6.2*	2.5NS	6.3*	4.8*	3.2*

† Minimal significant difference at 5% probability = 2.9
* Significant at 5% probability. NS: Not significant.
X = average tag length of each group from Table I

Discussion

There was a clear tendency for larger tag length when the sealant was applied. The differences between groups 1 and 2, 1 and 6, 2 and 3, 3 and 6, and 5 and 6 were statiscally significant (Table III). In the groups without sealant (groups 1, 3 and 5), orthodontic Concise (group 5) generated tags which were statiscally larger than those generated by the more viscous adhesives (groups 1 and 3). These data agree with the results obtained by other authors,[13-16] who observed that tag size depends on the viscosity of the adhesive used. Other authors, however, did not find such differences in tag lengths.[6-8,16-20] Even though the same technique was used in the preparation of the samples, it is possibile that a larger number of tag fractures and enamel losses ocurred when tags were longer. This may be due to the fact that the enamel layer, which varies in width from 20 μm to 30 μm,[21-24] turns out to be more porous by the acid conditioning. The next layer is thinner with more delicate pores and consequently is more subject to fractures during the process of preparation for the SEM.[25]

It is possible that the actual difference in tag lengths is larger than reported here. Many authors have found tags of similar lengths when applying adhesives of different viscosities. For Diedrich,[18] the controversy in the literature as to the size of the tags can be attributed to many causes: different methods of investigation, variations in the technique of acid conditioning, or the fragility of the long filaments of resin, which can fracture during the wash and dry process. In addition to the factors related by Diedrich,[18] at least three other studies can be cited:

a) Many authors do not clearly define the enamel area used in the study of the tag lengths, making a comparison of the results difficult. As demonstrated by Arakawa and coauthors,[27] and confirmed by data presented in this study, tag lengths can vary from zero to 50 μm, depending solely on where, incisocervically, the enamel was studied. More aprismatic enamel exists in the cervical region.[7,12,28-30]

b) Many references to tag lengths do not specify whether they are average lengths or whether they refer to the more pronounced projections. This observation can make a big difference. For example, the largest tag observed in the present study had a length of 89 μm, even though the average tag length values ranged from 11.8 μm to 18.9 μm.

c) The use of statistical analysis to compare tag lengths has been an exception more than the rule. Consequently, the meaning of possible differences cannot be evaluated, as has been pointed out by Jorgensen and Shimokobe[6]. Due to the previous application of sealant in groups 2, 4 and 6, in principle it would be expected that tag lengths would be similar. But the difference between groups 4 and 6 was also statiscally significant. Two possible explanations may account for this fact: First, the orthodontic Concise with its lower viscosity could have contributed to the deeper penetration of the resin into the enamel, resulting in greater average tag length of group 6. This seems unreasonable because the sealant

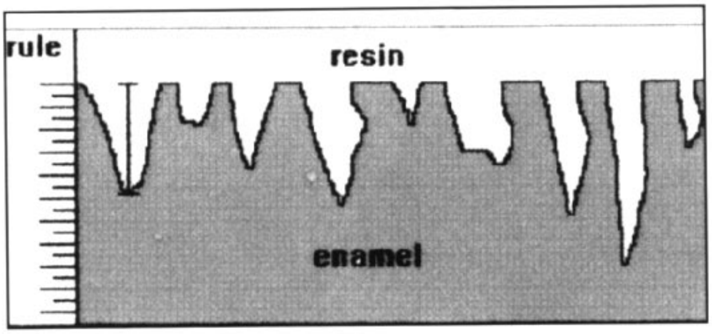

Figure 1

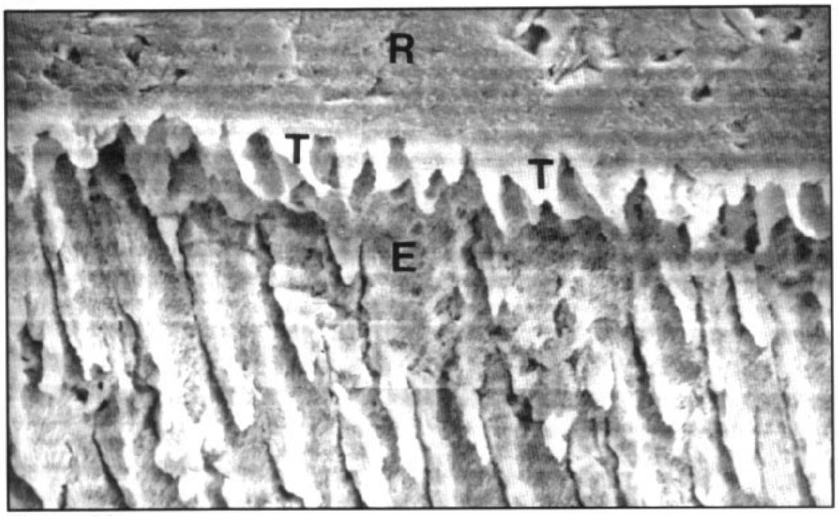

Figure 2A

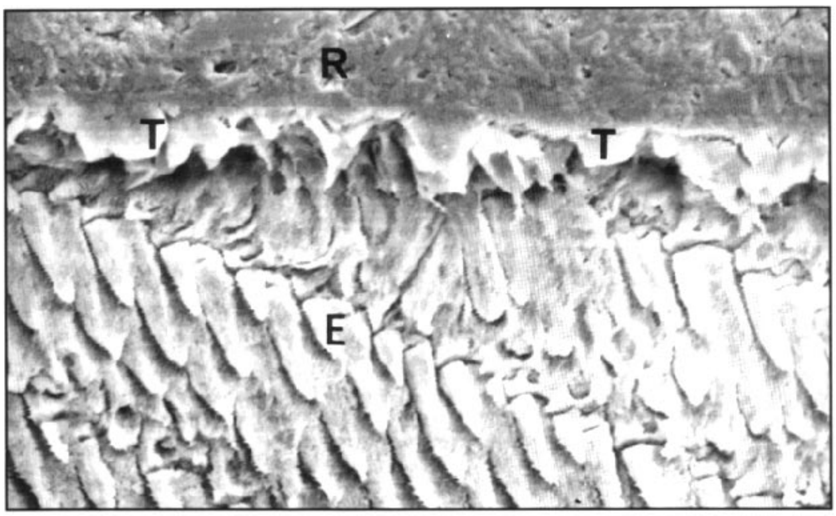

Figure 2B

Figure 1
Sketch showing how a rule was used to measure tag length.

Figure 2A-B
700x magnification electromicrographics showing the zone of tags (T) between resin (R) and enamel (E)
A. with previous sealant application and
B. without previous sealant application.

previously applied in groups 2, 4 and 6 should have been already polymerized and consequently obliterated the enamel pores making deeper penetrations unfeasible. Various authors have suggested that polymerization is inhibited by oxygen in the air.[25,29,31-35] If this is so, the sealant might not be already polymerized when the composite resin was applied, allowing a deeper resin penetration into the enamel, in the presence of an extra quantity of fluid resin from the orthodontic Concise.

Another possible explanation would be the differences that can occur in the enamel structure,[6,27,28,36-40], producing variations in tag lengths from tooth to tooth[13,15] or even from different areas of the same tooth.[6] This type of variation may explain why groups 4 and 6 demonstrated statistically different results. Some authors believe that there is an inhibiting effect on the resin penetration into the enamel pores caused by the particles of filler when the composite resin is used directly on the conditioned enamel.[2-5] But the particles of filler do not seem to inhibit penetration. The total number of tags, with or without the previous sealant application, was practically the same, and was even slightly higher in the groups where the union agent was not employed. This observation was also made by Asmussen[17] and Prévost and coauthors.[8] They did not find differences in the frequency or regularity of the tags, when comparing the use of the sealant with the direct application of the composite to the tooth (Figure 2A-B).

Certain variations in the extension and dimension of the tags from sample to sample have been observed by some authors.[13,15] Tag shape appears to be the most variable, according to Voss and Charbeneau,[20] and occurs independently of resin viscosity or presence of a sealant. It seems impossible to identify resin viscosity as the determining factor of tag dimension (Figure 2A-B).

Conclusions

Resin viscosity and the presence of a sealant affect the bonding of brackets to enamel. The presence of a sealant tends to increase the tag length for each resin viscosity applied. More fluid resin increases the tag length significantly. More fluid resin coupled with a previously applied sealant penetrates deeper into the enamel and forms larger tags. The frequency, regularity and shape of the tags are not affected by the resin viscosity or the presesence of a sealant.

References

1. Gwinnett AJ, Buonocore MG. Adhesives and caries prevention, a preliminary report. Br Dent J 1965; 119: 77-80.
2. Hocevar RA. Direct bonding metal brackets with the Concise-enamel system. J Clin Orthod 1977;11:473-482.
3. McLundie AC, Messer JG. Acid-etch incisal restorative materials. Br Dent J 1975;138:137-140.
4. Roberts MW, Moffa JP, Jenkins WA. Clinical evaluation of three acid-etch composite resin systems: two-year report. J Am Dent Assoc 1978;97:829-832.
5. Speiser AM, Kahn M. The etched butt-joint margin. J Dent Child 1977;44:42-45.
6. Jorgensen KD, Shimokobe H. Adaptation of resinous restorative materials to acid etched enamel surfaces. Scand J Dent Res 1975;83:31-36.
7. Low T, Lee KW, von Fraunhofer JA. The adaptation of composite materials to etched enamel surfaces. J Oral Rehabil 1978;5:349-355.
8. Prévost AP, Fuller JL, Peterson LC. Composite and intermediate resin tag formation in acid-etched enamel: A scanning electron microscopy evaluation. J Prosthet Dent 1984;52:204-207.
9. Soetopo, Beech DR, Hardwick JL. Mechanism of adhesion of polymers to acid-etched enamel. J Oral Rehabil 1978;5:69-80.
10. Artun J, Zachrisson B. Improving the handling properties of a composite resin for direct bonding. Am J Orthod 1982;81:269-276.
11. Gwinnett AJ. Human prismless enamel and its influence on sealant penetration. Arch Oral Biol 1973;18:441-444.
12. Sheykholeslam Z, Buonocore MG. Bonding of resins to phosphoric acid-etched surfaces of permanent and deciduous teeth. J Dent Res 1972;51:1572-1576.
13. Gwinnett AJ, Matsui A. A study of enamel adhesives. The physical relationship between enamel and adhesive. Arch Oral Biol 1967;12:1615-1620.
14. Silverstone LM, Snewin JM. Laboratory studies on fissure sealants: I. Effect of acid pretreatment of the enamel surface in vitro. J Dent Res 1972;51:1261.
15. Stewart G, Flynn M. Comparison of tag-like extensions at enamel-adhesive interface for 12 composite materials. J Dent Res 1976;55:B 143.
16. Pahlavan A, Dennison JB, Charbeneau GT. Penetration of restorative resins into acid-etched human enamel. J Am Dent Assoc 1976;93:1170-1176.
17. Asmussen E. Penetration of restorative resins into acid etched enamel. II. Acta Odontol Scand 1977;35: 183-189.
18. Diedrich P. Enamel alterations from bracket bonding and debonding: A study with the scanning electron microscope. Am J Orthod 1981;79:500-522.
19. Meurman JH, Nevaste M. The intermediate effect of low-viscous fissure sealants on the retention of resin restoratives in vitro. Proc Finn Dent Soc 1975;71: 96-101.
20. Voss JE, Charbeneau GT. A scanning electron microscope comparison of three methods of bonding resin to enamel rod ends and longitudinally cut enamel. J Am Dent Assoc 1979;98:384-389.
21. Gwinnett AJ. Histologic changes in human enamel following treatment with acidic adhesive conditioning agents. Arch Oral Biol 1971;16:731-738.
22. Kinch AP, Taylor H, Warltier R, Oliver RG, Newcombe RG. A clinical trial comparing the failure rates of directly bonded brackets using etch times of 15 or 60 seconds. Am J Orthod Dentofac Orthop 1988;94:476-483.
23. Silverstone LM. Fissure sealants. Caries Res 1974; 8:2-26.
24. Silverstone LM. State of the art on sealant research and priorities for further research. J Dent Educ 1984;48:107-118.
25. Maijer R. Bonding systems in orthodontics, In: Smith DC, Williams DF. Biocompatibility of dental materials. Boca Raton: CRC Press, 1982:51-76.
26. Ten Cate JM, Keizer S, Arends J. Polymer adhesion to enamel. The influence of viscosity and penetration. J Oral Rehabil 1977;4:149-156.
27. Arakawa Y, Takahashi Y, Sebata M. The effect of acid etching on the cervical region of the buccal surface of the human premolar, with special reference to direct bonding techniques. Am J Orthod 1979;76:201-208.
28. Gwinnett AJ. The ultrastructure of the "prismless" enamel of permanent human teeth. Arch Oral Biol 1967; 12:381-387.
29. Gwinnett AJ. Acid etching for composite resins. Dent Clin North Am 1981;25:271-289.
30. Ripa LW, Gwinnett AJ, Buonocore MG. The "prismless" outer layer of deciduous and permanent enamel. Arch Oral Biol 1966;11:41-48.
31. Brauer GM. Properties of sealants containing BIS-GMA and various diluents. J Dent Res 1978;57:597-607.
32. Ceen R, Gwinnett A, Caputo L. White spot formation associated with sealants used in orthodontics. J Dent Res 1980;59:509.
33. Coreil MN, McInnes-Ledoux P, Ledoux WR, Weinberg R. Shear bond strength of four orthodontic bonding systems. Am J Orthod Dentofac Orthop 1990;97:126-129.
34. Ruyter IE, Gyorosi PP. An infrared spectroscopic study of sealants. Scand J Dent Res 1976;84:396-400.
35. Zachrisson BU, Heimgard E, Ruyter IE, Mjor IA. Problems with sealants for bracket bonding. Am J Orthod 1979;75:641-649.
36. Aguirre MJ, King GJ, Waldron JM. Assessment of bracket placement and bond strength when comparing direct bonding to indirect bonding techniques. Am J Orthod 1982;82:269-276.
37. Bishara SE, Khowassah MA, Oesterle LJ. Effect of humidity and temperature changes on orthodontic direct bonding adhesive systems. J Dent Res 1975;54:751- 758.
38. Keizer S, Ten Cate JM, Arends J. Direct bonding of orthodontic brackets. Am J Orthod 1976;69:318-327.
39. Sheykholeslam Z, Brandt S. Some factors affecting the bonding of orthodontic attachments to tooth surface. J Clin Orthod 1977;11:734-743.
40. Williams B, von Fraunhofer JA. The influence of the time of etching and washing on the bond strength of fissure sealants applied to enamel. J Oral Rehabil 1977;4:139-143.

34. Ruyter IE, Gyorosi PP. An infrared spectroscopic study of sealants. Scand J Dent Res 1976;84:396-400.
35. Zachrisson BU, Heimgard E, Ruyter IE, Mjor IA. Problems with sealants for bracket bonding. Am J Orthod 1979;75:641-649.
36. Aguirre MJ, King GJ, Waldron JM. Assessment of bracket placement and bond strength when comparing direct bonding to indirect bonding techniques. Am J Orthod 1982;82:269-276.
37. Bishara SE, Khowassah MA, Oesterle LJ. Effect of humidity and temperature changes on orthodontic direct bonding adhesive systems. J Dent Res 1975;54:751- 758.
38. Keizer S, Ten Cate JM, Arends J. Direct bonding of orthodontic brackets. Am J Orthod 1976;69:318-327.
39. Sheykholeslam Z, Brandt S. Some factors affecting the bonding of orthodontic attachments to tooth surface. J Clin Orthod 1977;11:734-743.
40. Williams B, von Fraunhofer JA. The influence of the time of etching and washing on the bond strength of fissure sealants applied to enamel. J Oral Rehabil 1977;4:139-143.