Leakage reduction with a surface-penetrating sealant around stainless-steel orthodontic brackets bonded with a light cured composite resin

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In this study a surface penetrating sealant was used around bonded stainless steel orthodontic brackets. The investigation attempted to identify the effect of surface penetrating sealants on the microleakage associated with orthodontic stainless steel brackets bonded with light cured composite resin.

A total of 58 bovine teeth were used for this study, orthodontic brackets were bonded with light cured orthodontic resin. The following groups were assigned: (I) Finished but unsealed, (II) Finished and sealed, and (III,) Un-finished but unsealed The brackets were activated using orthodontic elastics, stained, sectioned, and evaluated under magnification. The following statistical analysis was done Mann-Whitney U test for two independent samples, then confirmed with a Kruskai-Wallis One-Way analysis of variance by ranks. The second and third groups were statistically better in respect of marginal integrity as compared to the first.

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INTRODUCTION

With the introduction of composite bonding system the scope of orthodontic treatment has changed. The lengthy and uncomfortable procedure of placing bands on all the teeth can be avoided. However bonding the orthodontic brackets with composite resin comes with a few difficulties, one such difficulty is the sensitivity of the technique to moisture contamination. The second is enamel decalcification around the bracket resulting in permanent discoloration of the teeth.[24]

One of the major problems with composite resin restorations is marginal breakdown and microleakage. This concern has been addressed in several way, one such approach is the use of surface penetrating sealants.[13,14,17,18,30,44]

In this study the use of such a surface penetrating sealant was used around bonded stainless steel orthodontic brackets. The investigation will attempt to identify the effect of surface penetrating sealants on the leakage associated with orthodontic stainless steel brackets bonded with light cured composite resin.

The caries process, simply defined, occurs when specific bacteria within the plaque metabolize fermentable carbohydrates, and produce organic acids. These acids can dissolve the calcium phosphate mineral of the tooth enamel or dentin if exposed, and is know as demineralization. Dental caries of the enamel is first observed clinically as “white spot lesions.” The area beneath the dental plaque is demineralized, and the body of the enamel lesion may have lost as much as 50 percent of the original mineral content and is often covered by and “apparent intact surface.[35,39,49]

The two most important groups of bacteria that predominately produce acids; are the *Streptococci mutans* and lactobacilli. Each group contains several species; mutans streptococci include *Streptococcus mutans* and *S. sobrinus*. The acids that these microorganisms produce diffuse through the plaque and into the porous subsurface enamel, dissociating to produce hydrogen ions. The hydrogen ions readily dissolve the mineral, freeing calcium and phosphate into solution that diffuse out of the tooth. Lactic acid dissociates more readily than the other acids, producing hydrogen ions that rapidly lower the pH in the plaque. As the pH is lowered, acids diffuse rapidly into the underlying enamel or dentin.[35,39,49]

The bands, brackets, and all the other orthodontic elements that are used, make dental hygiene more difficult and the accumulation of plaque easier. In a

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study by Rosenbloom and Tinanoff the oral flora is altered, and an increase in *S. mutans* was noted. However this increase in count soon dropped after the removal of the all the bands and the bonded attachments. This increase in *S. mutans* may be a factor in the increase in enamel decalcification process. In a study by Ortendahi, Thilander, and Svanberg incipient caries developed only in the patients in whom *S. sobrinus* was detected in plaque. In a study by Fournier *et a!.* it was noted that the affinity of *S. mutans* was higher to porcelain and composite brackets as compared to metal, but with time, there was no significance in this affinity.[21]

Gorelick *et al.* reported that approximately 50% of the orthodontic patients experienced lesions during treatment.[24] While a study by Gaworski *et a!.* reported up to 77.1% of the teeth exhibited worse decalcification at the end of the study.[23]

However, the distribution of the decalcification within the dentition is irregular and not consistent between individuals. In a study by Wenderoth *et al.* the maxillary teeth have the highest decalcification rate, the maxillary lateral incisor had the highest rate while the mandibular central incisors had the least.[51,52]

The major cause of recurrent caries at margins of posterior esthetic restoration is marginal leakage. This is a slow and progressive procedure, which ultimately leads to a failed restoration. Secondary caries can be related to remnants of infected dental tissue, while preparing for the final restoration or when microleakage penetration occurs as a consequence of incomplete adaptation on the cavity walls and polymerization shrinkage of the material.[17,18]

Composite resins

Composite resins where first introduced during the 1950s as chemically cured methacrylate restoration, these restorations showed increased discoloration, recurrent caries and pulp reactions.[8] These were attributed to polymerization shrinkage and monomer leaching. Composite resins went through several changes in the hands of Bowen until the early 1960s; during which Bowen attached methyl methacrylat groups to the end groups of the epoxy resin, thereby creating the successful resin called bisphenol A glycidyl methacrylate, or BIS-GMA, or simply Bowen's resin.[4,5]

The composite resin evolved from being composed of large spherical particles (20—30 µm), to large irregular particles. These large particles were later replaced by microfine particles (0.04-0.2 µm), and fine particles (0.5-3 µm). These composites where further modified by blending mainly fine particle with microfine particles to improve wear resistance and better surface polishing.[11,33] The classification of the dental composite resin is determined by the: particle size, particle shape, and distribution of the filler.[11,33] The combination of the composite resin with the acid etching technique has opened the doors to new treatment opportunities. One such opportunity is bonding of orthodontic brackets.[8,33] The major causes of failed posterior composite restorations are marginal leakage. This is a slow and progressive procedure, which ultimately leads to a failed restoration. The polymerization and finishing procedure create micro-cracks at the margins and the surface of the restoration. Consequently, these microcracks can contribute to low wear resistance, marginal leakage, sensitivity, discoloration, and ultimately breakdown and failure of the restoration. Polymerization shrinkage occurs during the conversion of monomer to polymer. The resin matrix of all composite-based resin restorative materials shrinks volumetrically approximately 10 percent during polymerization, and up to 3 percent according to some authors. This also contributes to the stresses present and microcracks in resin cements. This may increase interfacial stresses and decrease the predictability of these resin cements.[10-12,15,17-20,31,32,50] In a study by Torstenson and Brannstrom they evaluated the composite resin contraction gap with a fluorescent resin technique, they found that the mean width of the cervical gap varied from 7 to 22 µm. They also emphasized that even the smallest gaps observed 7 µm, may allow not only bacterial invasion, but also growth of bacteria remaining on cavity walls.[48] In general, the more bonded area there is in a cavity, the greater the contraction stress will be at the bonded surface, since predominant flow is restricted to the free surface area of the material. The C-factor can be reduced if a restoration is built up in increments.[10,12]

In a study by Gwinnett 50% of the bracket samples evaluated by SEM had cracks evident in the resin with the presence of rod-shaped and spheroidal bodies. These were consistent with microorganisms.[25] While in a study by Matasa in which he evaluated the breakdown of the orthodontic resin adhesives, it was found that the resins were eaten away by aerobic and anaerobic microorganisms. Two hypotheses were advanced for this phenomenon:

1) The ingress of microbes in adhesive gaps possibly generated at the time of the bonding or wear,
2) The consumption of the adhesive by the microorganisms.

The author abandoned the first hypotheses due to the extent of the resin decay.[36]

In an attempt to resolve the problems associated with the microcracks on the composite restoration margins, several researchers have advocated the use of surface penetrating sealants, and noted significant improvement in wear resistance, microleakage and marginal integrity.[1,3,14,17-19,30] In a study by Shinkai *et al.* these surface penetrating sealants reduced the wear of composite inlay significantly, but had no significant effect on the wear of the inlay's different luting agents.[44]

However, one author has questioned the long-term effect of these penetrating sealants.[9]

There are three factors that may play a significant role in the bond strength of the bracket and tooth:

1. The bracket base retention mechanism: foil mesh [60-70] gauge seems to provide the strongest bond and is preferred over perforated bases; while ceramic brackets have exhibited higher bond strength than metal brackets.
2. The adhesive material: Filled and unfilled resins have been used for bonding orthodontic brackets to teeth. The filler particles may be large [macrofihled] or small [microfilled], and the resins may be photo-cured, auto-cured, or dual-cured. Recently fluoride releasing adhesive and photo-cured glass ionomer cements have been introduced.
3. The enamel preparation: Different concentrations of acid etching and at different time intervals have been suggested, in addition to air abrasion.

Intervention

Caries progression, as opposed to reversal, consists of a delicate balance between the pathological factors (i.e. bacteria, and carbohydrates) and the protective factors (i.e. saliva, calcium, phosphate, and fluoride). One critical point in reducing enamel decalcification is the establishment and maintenance of good oral hygiene and homecare routines. Due to the presence of the orthodontic components (i.e. bands, brackets, wires, and elastics) these act as plaque retentive factors, in addition make brushing and flossing very difficult *(pathological factor)*

The use of chlorhexidine mouthwashes on patients undergoing orthodontic treatment has been advocated as well. The data collected from a study by Anderson GB *et al.* indicated that the use of chlorhexidine mouthwashes, in addition to regular oral hygiene habits, was effective in reducing plaque and gingivitis in adolescent patients undergoing treatment *(pathological factor)*[1]

Preventive fluoride programs are beneficial as well, they may be office-applied or self-administered regimes [i.e. by patient] *(protective factor)*. To maintain fluoride in close approximation to the bracket-adhesive-enamel complex, fluoride-releasing adhesive have been attempted *(protective factor)*[6,7] from glass ionomer, resin reinforced glass ionomers, to fluoride releasing resins. The glass ionomer and the resin reinforced glass ionomers have proven to be effective in fluoride release.[16,23,47] In a study by Gaworski *et al.*, no statistical difference was found in the incidence of decalcification between glass ionomer adhesives and composite resin adhesives, however the glass ionomer adhesives had a higher failure rate then the resin adhesives.[23] In a laboratory study by Trimpeneers *et al.* the long term fluoride release of orthodontic bonding resins was evaluated: they noted that the amount of fluoride release decreased below the determination limit of the analytical method within half a year.[47]

Fluoride releasing pit and fissure sealants have successfully reduced the caries rate on the chewing surfaces. Application of these resin sealants on the enamel surface around and beneath the orthodontic brackets has been suggested as a method of preventing decalcification, but has had mixed results by different authors.[2,22,51,52]

To overcome the potential of recurrent caries and marginal discoloration associated with posterior composite restorations, the use of surface penetrating sealants has been very successful in the reduction of microleakage and surface wear.[1,3,14,17-19,30,44]

The purpose of this study is to determine if a surface penetrating sealant will reduce the marginal leakage associated with stainless steel orthodontic brackets bonded with light cured composite adhesives, thereby maintaining material and marginal integrity.

MATERIALS AND METHODS

Teeth preparation

Freshly extracted bovine[38] teeth were prepared according to ISO report:[27] The teeth were thoroughly washed under running water, the periodontal tissue was removed using a 4 inch stainless steal surgical grade knife, and washed under running tap water and a tooth brush. The teeth were then examined under magnification *(Surgitel loops at 2.5x)* and light for cracks and defects, the teeth were further evaluated for cracks with a caries-detecting die *(Snoop, Pulpdent Corp.);* all damaged teeth were disposed.

The pulp tissue was removed from the apical foramen using a barbed broach and headstrom files; some apecies were opened up with a high-speed hand-piece and a 330 bur to achieve this. Once the pulp tissue was removed to the best capability, few drops of normal saline were place in with a dropper and the apecies were then closed with wax. All the teeth were supported vertically on wax with the apecies facing up; the root surfaces were then coated with three coats of different colored nail polish. The apecies were further evaluated for flaws and an additional coat of nail polish was applied if any were noticed.

The teeth were mounted in lab yellow stone in 30 cc medicine cups, the entire root surface was submerged, the stone was trimmed to an approximated one by one inch blocks centering the tooth. During and following the teeth preparation the teeth were stored in water at 4˚C.till used.[46]

Bracket placement

The teeth were divided in three groups 30 teeth for each group. One sample from each group was disregarded at the end of the testing due to slippage of the sample during cutting which resulted in the damage of the cutting saw.

The teeth were pumiced, and were divided into two batches thirty each.[34,43]

Stainless steel brackets with mesh backings, and auxiliary hooks were used. The teeth were acid etched with 37% phosphoric acid for 30 seconds,[28] and 43 washed for 60 seconds, and dried with oil-free air. The light cured resin material used (Pulpdent Corp.) was cut into approximated 2 by 2 mm beads.

According to the manufacture's instructions the resin paste was placed on the brackets and the bonding liquid was placed on the tooth. The bracketing was done as follows:

The first batch: two brackets were placed on one tooth 5 mm apart, the excess material removed with a sharp explorer, and each bracket light cured for a total of 40 seconds as per the manufacture's instructions.

Based on a coin flip the margins of the brackets on the right side in this batch were re-etched for 30 seconds, washed, dried, and a surface sealer applied (Fortify) 2mm around the bracket. The sealer was thinned downed with a brush, it was not air thinned as not to contaminate the adjacent group. The sealer was then light cured for 20 seconds. A 2(m) orthodontic elastic was placed around the brackets and the auxiliary hooks engaged. This was done in order to place a comparable load to the bracket as would be expected *in vivo*.

The second batch: one bracket was placed but the excess material was not removed, light cured for 40 seconds. A paper clip bent and secured to the stone block with an elastic 5mm away from the bracket. The same 2(m) orthodontic elastic was placed from the paper clip to the bracket and hook.

This provided three groups:

Group 1: Excess material removed with a sharp explorer, then light cured.

Group 2: Excess material removed as group 1, cured, and then the margins sealed.

Group 3: Excess material is not removed after curing.

The groups were stored for 24 hours in a humidor at room temperature. The samples were placed in medicine cups upside down with the crowns submerged in fuchin die for approximately 24 hours.[17,18]

The samples were sectioned using a slow cutting saw (Isomat) mesio-distally through the brackets.

Samples were evaluated under magnification (Surgitel loops at 2.5x) for leakage and voids at the mesial and distal bracket margin:

L_0 = no leakage,

L_1 = any evidence of leakage, and/or marginal defects

While sectioning the specimens some brackets detached, this was added as an additional criterion. This was not part of the original study, but was noted incidentally during the experiment:

D_0= no detachment,

D_1= bracket detached.

The following statistical analysis were performed for evaluating the marginal integrating:

- Mann-Whitney U test for two independent samples:

Comparing Group I (finished/unsealed) versus Group II (finished/sealed)

Comparing Group II (finished/sealed) versus Group III (unfinished)

Comparing Group I (finished/unsealed) versus Group III (unfinished)

- Kruskal-Wallis One-Way analysis of variance by ranks was performed to confirm the results

An additional statistical analysis was done for the bracket detachment:

Generalized Chi-square for degrees of freedom (df) >1

RESULTS

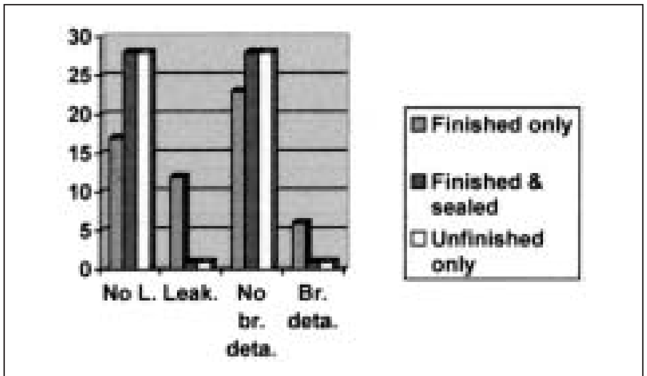
Total number of teeth used this study was 29 per group; this was due the elimination of one sample from each of the groups. Table (1) summarizes the results of the study for both the test criteria.

Table 1. Study results

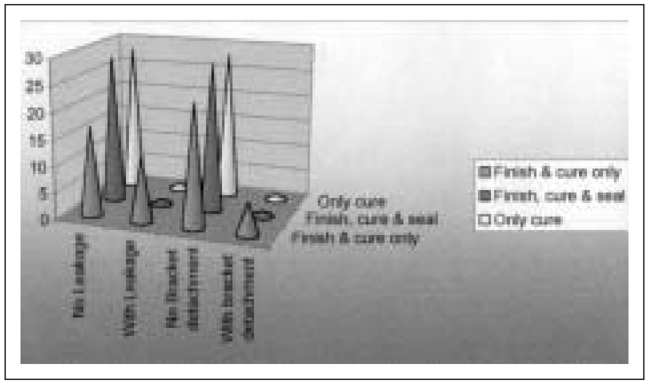
Test criteria Sample	Leakage Lo	L_1	Bracket detachment Do	D_1
Finished / cured / no fortify (1)	17	12	23	6
Finished / cured / fortified (2)	28	1	28	1
Unfinished! cured (3)	28	L 1	28	1

Lo = no leakage, Li = any evidence of leakage,
Do = no detachment, D_1 = bracket detached

There was significant statistical difference between the (Finished only) group to both (Finished & sealed) and (Unfinished) groups, and no difference between (Finished & sealed) and (Unfinished) groups in respect of leakage.



Graph (1). Graphical representation of statistical significance of the different groups, in the different criteria.



Graph (2). Graphical representation of statistical significance of the different groups, in the different criteria.

Kruskal-WaIlis One-Way analysis of variance by ranks was performed to confirm the results.

This confirmed the statistical significance of the leakage of group I versus group II and II, with no significant difference between groups II and III. There was statistical difference between group I to group II and III in respect of bracket detachment.

DISCUSSION

Looking at the results from this study, the significant difference in the marginal leakage/defects between the first group (finished and unsealed) to the other two groups (finished and sealed, and unfinished and unsealed) may be related to the two possible situations: First, the resin materials may be pulled out from underneath the bracket while removing the excess with an explorer from the first and second group, however this was not a concern with the unfinished brackets (third group). Secondly, the shrinkage of the resin during the polymerization may have an effect on this situation. In general, the more bonded area there is, the greater the contraction stress will be at the bonded surface, since predominant flow is restricted to the free surface area of the material, hence the material may pull away from the bracket, and the margins may be regarded as the weakest area and hence it pulls away from the bracket as seen in this study. Furthermore, the combination of both the pulling of the resin while finishing the bracket and the polymerization shrinkage of the resin provided the defects on the margins, that facilitate the ingress of the bacteria below the brackets. Furthermore the presence of voids within the resin provides areas for these bacteria to flourish, and this will provide the bases for natural tooth and resin breakdown. The effect of the surface sealer extended to approximately 2 mm from the bracket.

The unfinished group had the additional concern of the overhang material around the bracket, which may pose as an addition to the plaque retention concern around the bracket

However, the reason behind the bracket detachment is not clear, it might be related to the presence of voids and defects at the margin which may hypothetically act as an areas for the saw to grab on while sectioning, and thereby pulling the bracket off. Presence of bias during the placement of the two brackets can be ruled out, because the selection of the bracket for sealing was done blindly based on a coin flip.

The relevance of this technique has to be evaluated clinically and compare it with the results achieved with pit and fissure sealants. The longevity of the sealants can be questioned around the brackets, however being out of direct occlusion may play a role in improving the permanence of the surface sealer.

CONCLUSION

In conclusion the following clinical implications may be drawn:

1. The mariginal leakage/defects associated with the finished, but unsealed group may contribute to the bacterial attack to the tooth and resin around and below the bracket.
2. The overhang material evident with the non-finished group may be an addition to the plaque retention concern.
3. The smooth beveled area around the bracket may help reduce plaque retention.

REFERENCES

1. Anderson GB, Bowden J, Marrison EC, Caffesse RG. Clinical effects of chlorhexidine mouthwashes on patients undergoing orthodontic treatment. Am J Orthod Dentofac Orthop 11: 606-612, 1997.
2. Banks PA, Richmond S. Enamel sealants: a clinical evaluation of their value during fixed appliance therapy. Euro J Ortho 16: 19-25, 1994.
3. Belanger G. Effect of tacking time on bond strength of light-cured adhesives. JCO 31: 449-453, 1997.
4. Bowen RL, inventor. Method of preparing a monomer having phenoxy and methacrylate groups linked by hydroxy glycerol groups. U.S. patent 3179623. April 1965.

5. Bowen RL. Properties of a silica-resin-forced polymer for dental restoration. JADA 66: 57-64, 1963
6. Boyd R, Chun YS, Eighteen month evaluation of the effects of a 04% stannous fluoride gel on gingivitis in orthodontic patients, Am J Orthod Dentofac Orthop 105: 35-41, 1994
7. Boyd R. Longitudinal evaluation of a system for self monitoring plaque control effectiveness in the orthodontic patient. J Clin Periodontol 10: 380-388, 1983.
8. Buonocore MG. A simple method of increasing the adhesion of acrylic filling materials to enamel surface. J Dent Res 34: 849-853, 1955.
9. Christensen GJ. Sorting out the confusing array of resin-based composites in dentistry. JADA 130: 275-277, 1999.
10. Choi K, Condon J, Ferracane J. The effects of adhesive thickness on polymerization contraction stress of composite. J Dent Res 79: 812-817, 2000.
11. Craig GR. Restorative dental materials. CV Mosby, St Louis, Chap 10, 284-276, 1993.
12. Dauvillier B, Feilzer A, DeGee A, Davidson C. Visco-elastic parameters of dental restorative materials during setting. J Dent Res 79: 818-823, 2000.
13. Dickinson GL, Leinfelder KF, Mazer RB, Russel CM. Effect of surface penetrating sealant on wear rate of posterior composite resins. JADA 121: 231-2522, 1990.
14. Dickinson GL, Leinfelder KF. Assessing the long-term effect of a surface penetrating sealant. JADA 124: 68-72, 1993.
15. Ericson D, Paulsson L, Sowiak H, Derand T. Reduction of cusp deflection resulting from composite polymerization shrinkage, using a light-transmitting cone. Scand J Dent Re 102: 244-248, 1994
16. Evrenol B, Kucukkeles N, Arun T, Yarat A. Fluoride release capacities of four different orthodontic adhesives. J Clin Pediatr Dent 23: 315-319, 1999.
17. Ferdianakis K, White G. Newer class I cavity preparation for permanent teeth using air abrasion and composite restoration. J Clin Pediatr Dent 23: 201-216, 1999.
18. Ferdinakis K. Microleakage reduction from newer esthetic restorative materials in permanent molars. J Clin Pediatr Dent 22: 22 1-229, 1998.
19. Ferracane IL. Current trends in dental composites. Crit Rev Oral Biol Med 6: 302-318, 1995.
20. Fortin D, Vargas M. The spectrum of composites: new techniques and materials. JADA 131(supp): 26s-30s, 2000.
21. Fournier A, Payant L, Bouclin F. Adherence of streptococcus mutans to orthodontic brackets. Am J Orthod Dentofac Orthop 114: 414-417, 1998.
22. Frazier MC, Southard TE, Doster PM. Prevention of enamel demineralization during orthodontic treatment: an in vitro study using pit and fissure sealants. Am J Orthod Dentofac Orthop 110: 459-465, 1996.
23. Gaworski M, Weinstein M, Bonslow A, Braitman L. Decalcification and bond failure: Acomparison of a glass ionome and a composite resin bonding system in vivo. Am J Orthod Dentofac Orthop 116: 518-521, 1999.
24. Gorelick L, Geiger AM, Gwinnett AJ. Incidence of white spot formation after bonding and banding. Am J Orthod Dentofac Orthop 81: 93-98, 1982.
25. Gwinnett AJ. Corrosion of resin-bonded orthodontic brackets. Am J Orthod 82: 441-446, 1982.
26. Haligren A, Oliveby A, Twetman S. Caries associated microflora in plaque from orthodontic appliances retained with glass ionomer cement. Scand J Dent Res 100: 140-143, 1992.
27. ISO/TC 106/SC 1/WG 11, 1991. Dental materials. Guidance on testing of adhesion to tooth structures. Adhesion test methods and accepted as a committee draft at the ISO/TC meeting in Trieste October, 1991.
28. Johnston C, Burden D, Hussey D, Mitchell C. Bonding to molars-the effect of etch time (an in vitro study). Am J Orthod Dentofac Orthop 20: 195-199, 1998.
29. Joseph Vp, Rossouw PE, Basson NJ. Some “sealants” seal—a scanning electron mictoscopy (SEM) investigation. Am J Orthod Dentofac Orthop 105: 362-368, 1994.
30. Kawai K, Leinfelder KF. Effect of surface-penetrating sealants on composite wear. Dent Mater 9: 108-113, 1993.
31. Kemp-Scholte C, Davidson C. Complete marginal seal of class V resin composite restoration effected by increased flexibility. J Dent Res 69: 1240-1243, 1990.
32. Kemp-Scholte C, Davidson C. Marginal integrity related to bond strength and strain capacity of composite resin restorative systems. J Prosthet Dent 64: 658-664, 1990
33. Kugel G, Ferrari M. The science of bonding: From first to sixth generation. JADA 131: 20s-25s, 2000.
34. Lindauer S, Browning H, Shroff B, Marshall F, Anderson R, Moon P. Effect of pumice prophylaxis on the bond strength of orthodontic brackets. Am J Orthod Dentofac Orthop 111: 599-605, 1997.
35. Lingstrom P, van Ruyven F, van Houte J, Kent R. The pH of dental plaque in itrs attack of orthodontic adhesives. Am J Orthod Dentofac Orthop 108: 132-141, 1995.
36. Newman relation to early enamel cavities and dental plaque flora in humans. J Dent Res 79: 770-777, 2000.
37. Matasa C. Microbial R. Adhesion and orthodontic plastic attachment: progress report. American journal of orthodontics 51: 901-912, 1965.
38. Oesterle L, Shelihart W, Belanger G. The use of bovine enamel in bonding studies. Am J Orthod Dentofac Orthop 114: 514-519, 1998.
39. Ogaard B, Rolla G, Arends J. Orthodontic appliances and enamel demineralization: Part 1. Lesion development. Am J Orthod Dentofac Orthop 94: 68-73, 1988.
40. Ogaard B, Rolla G, Arends J, Cate M. Orthodontic appliances and enamel demineralization: Part 2. Prevention and treatment of lesions. Am J Orthod Dentofac Orthop 94: 123-128, 1988.
41. Olea N, Pulgar R, Peres P. et al. Estrogenicity of resin-based composites and sealants used in dentistry. Environ Health Prespect 104: 298-305, 1996.
42. Platt Jeffuey. Resin cements: Into the 21st century. Compendium 20: 1173-1181, 1999.
43. Reisner K, Levitt HL, Mante F. Enamel preparation for orthodontic bonding: A comparison between the use of a sandblaster and current techniques. Am J Orthod Dentofac Orthop 111: 366-373, 1997.
44. Shinkai K, Suzuki 5, Leinfelder KF, Katoh Y. Effect of surface-penetrating sealants on wear resistance or luting agents. Quintessence Int 25: 767-771, 1994.
45. Soderhoim K, Phil M, Mariotti A, BTS-GMA- Based resins in dentistry: are they safe? JADA 130: 201-208, 1999.
46. Titley K, Chernecky R, Rossouw P. Kulkarni G. The effect of various storage methods and media on shear-bond strength of dental composite resin to bovine dentine. Arch Oral Biol 43: 305-311, 1998.
47. Trimpeneers L, Verbeeck R, Dermaut L. Long-term fluoride release of some orthodontic bonding resins: A laboratory study. Dent Mater 14: 142-149, 1998.
48. Torstenson B, Brannstrom M. Composite resin contraction gaps measured with a fluorescent resin technique. Dent Mater 4: 238-242, 1988.
49. Von Ruyven F, Lingstrom P, von Houte, Kent R. Relationship among mutans streptococci, “low-pH” bacteria, and lodophilic polysaccharide-producing bacteria in dental plaque and early enamel caries in humans. J Dent Res 79: 778-784, 2000.
50. Walls AWG, McCabe JF, Murray JJ. The polymerization contraction of visible-light activated composite resins. J Dent 16: 177-181, 1988.
51. Wenderoth C, Weinstein M, and Borislow A. Effectiveness of a fluoride-releasing sealnt in reducing decalcification during orthodontic treatment. Am J Orthod Dentofac Orthop 116: 518-521, 1999.
52. Wenderoth CJ, Weinstein M, Borislow AJ. Effectiveness of a fluoride-releasing sealant in reducing decalcification during orthodontic treatment. Am J Orthod Dentofac Orthop 116: 629-634, 1999.
53. Yap AU, Tan S, The TY. The effect of polishing systems on microleakage of tooth colored restoratives: Part 1. Conventional and resin-modified glass-ionomer cements. J Oral Rehab 27: 117-123, 2000.