*Journal of Applied Dental and Medical Sciences*
*NLM ID: 101671413   ISSN:2454-2288*
*Volume 3 Issue1 January-March 2017*

**Review Article**

# Influence of Various Factors Affecting Shear Bond Strength: A Review

**Ankita Gupta[1], Amitabh Kallury[2], Kush Sahu[3]**

*[1] Post Graduate Student, Dept of Orthodontics, Peoples Dental Academy, Bhopal*
*[2] Prof & Head, Dept of Orthodontics, Peoples Dental Academy, Bhopal*
*[3]Consultant Prosthodontist,Jhansi*

A R T I C L E  I N F O

A B S T R A C T

Bond failures of brackets are one of the most frustrating occurrences during orthodontic practise resulting in prolonged treatment time , additional cost in materials and unexpected additional patient visits. Understanding various factors affecting bond strength assists the orthodontist in proper selection and application of appropriate orthodontic materials. Knowledge of location of bond failure allows the orthodontist to modify his or her bonding technique and helps in counselling of patients on care of their appliances. Thus, the article is aimed to aware clinician of how different variables affect shear bond strength and apply these principles in optimal bonding technique

Keywords:
Orthodontics,Bond Strength,Etch

## Introduction

Orthodontic bonding brackets have become a widely accepted clinical procedure.[1*]. The prevailing concepts of bonding are challenged continuously by new developments and technical improvements. Achieving a low bond failure rate should be a high priority objective, since replacing loose brackets is inefficient, time-consuming, and costly.

The shear bond strength can be defined as “amount of force required to break the connection between a bonded (dental)

* *Corresponding author:* ***Dr. Ankita Gupta,Post Graduate Student, Department of Orthodontics, Peoples Dental Acadmey,Bhopal.***
***Email : drankitagupta@gmail.com***

restoration and the tooth surface with the failure occurring in or near adhesive / adherens interface." Retief (1974)[1**] highlighted the different factors with respect to optimal bond strength. He showed that enamel fractures can occur with bond strengths as low as 13.53 MPa. It is comparable with the mean linear tensile bond strength (TBS) of 14.51 MPa for enamel reported by Bowen and Rodriguez (1962).[1***] The minimum clinically adequate TBS according to Reynolds (1975)[1] appears to be between 5.88-7.85 MPa. It was also shown by Bishara et al (1993)[2] that a mean safe debonding strength should be less than 11.28 MPa. The optimum range is thus between 5.88 and 13.53 MPa.[2] This article presents an overview of various factors affecting shear bond strength while bonding, from cleaning to curing.

## 1. Effect of Cleaning on Bond Strength

Preparing and cleaning the enamel surface is an integral part of the procedure for bonding orthodontic brackets on enamel surface. Gwinnett and Smith[3] reported that prophylaxis before acid etching is recommended to remove plaque and other required debris from tooth. Steven Lindauer [4] found that shear bond strength was not significantly affected by treating the enamel surface with pumice only, before the acid etching. Bishara et al concluded that that various concentrations of fluorides, fluoride pastes do not significantly affect bond strength.[5] They also found that chlorhexidine when applied on the teeth and over orthodontic appliances during treatment in order to reduce bacterial colonization, provide the bond strength of 9.6 Mpa, within the range of adequate bond strength.[6]

By eliminating the organic substances from the enamel surface before etching (deproteinization), using 5.25% sodium hypochlorite for 1 min, followed by a 30-second etching with 37% phosphoric acid, orthodontic bond strength can be increased because the resulting etch-pattern is predominantly type 1 and 2, instead of type 3. The mean SBS for brackets bonded using Transbond XT primer plus composite resin, with enamel deproteinization, was found 9.41 ± 4.46 MPa, and without enamel deproteinization was 8.12 ± 3.10 MPa.[7] The mean SBS for the brackets bonded using Fuji Ortho LC (Resin – Modified GIC), with enamel deproteinization, was 9.64 ± 5.01 MPa, and without enamel deproteinization was 5.71 ± 3.87 MPa.[7] The increased bond strength allows the orthodontist to use fluoride- releasing RMGIs (Resin –

Modified GIC) as bonding adhesives protecting enamel from developing white spot lesions, which is a major iatrogenic effect of orthodontic treatment.

**2. Effect of Enamel Conditioning on Bond Strength**

Air-Abrasion technology (50 $\mu$m or 90$\mu$m particles of Aluminium Oxide for 3 sec at 10mm distance) has been examined for potential applications within dentistry, including the field of orthodontics. Enamel surface preparation using air-abrasion results in significant lower bond strength of and should not be advocated for routine clinical use as an enamel conditioner.[8]

Laser etching (Neodymium-yttrium-aluminum garnet (Nd:YAG) laser) produces lower bond strengths than does acid etching.[9] Moreover, it had been claimed that different ion solutions containing sulfate induce crystal growth might be a better alternative than conventional acid etching for enamel pre-treatment in bracket bonding. But such solutions had shown 60 - 80 % of the bond strength_obtained with acid etching, so it is not yet considered a practical technique to achieve adequate bond strength.[10]

The modern bonding systems for resin-based materials are based on a micromechanical retention principle. To achieve this, an acid, generally a 37% orthophosphoric acid is used to clean the surface and dissolve the minerals. Buonocore[11] originally used an 85% phosphoric acid solution for 30 seconds for conditioning the enamel surface, which has by most manufactures been reduced to 35%. Many claim that concentrations for optimal strength vary between 35% and 50%. When enamel is etched with phosphoric acid of high percentage like 50%, it forms monocalcium phosphate monohydrate on the surface which is highly soluble in water and can be completely washed away leaving a roughness of larger surface area.[12] Similarly, whereas 30-60-seconds etching times are mostly recommended, lowering the etching time to as little as 10 seconds has been found to be effective.[13] In general, a 37% orthophosphoric acid concentration applied for 15-30 seconds is recommended by the manufacturers of various adhesive systems.

A 10% maleic acid solution has been used as an etchant, but resulted in lower bond strengths when compared with phosphoric acid[14]. Similarly, bond strength has been reduced using either a 10% (0.4 ± 1.0 MPa ) or 20% ( 3.3 ± 2.6 MPa ) polyacrylic acid instead of 37% phosphoric acid[15] .To minimize the damage of the sound enamel surface during the etching and debonding procedures, a mixture of phosphoric acid and an acidulated phosphate fluoride (APF) gel (50% and 67% APF fraction) can be used as an phosphoric acid etchant substitute with proper bracket bond strength of 7.26–8.57 MPa [16]

Clinically, a gel is easier to control than a solution of acid, which may damage the gingival tissue and induce uncontrolled bleeding, but no significant difference in bond strength between them.[17] Deciduous enamel may often show prismless enamel of the outer surface. Therefore, when bonding attachments to deciduous enamel, etching time should be increased to remove the outer prismless enamel. Since the etch depth increases dramatically between 60 and 120 sec, and there is no corresponding improvement in the bond strength, 60 seconds is adequate time for etching primary enamel.[18] Moreover, bond strength of permanent old teeth was stronger than that of younger teeth with either 15-or 60 –seconds etch time.[19]

Bleaching with 10% carbamide peroxide immediately before bonding reduces the bond strength of composite resin to enamel. Treating the bleached enamel surface with 10% sodium ascorbate or waiting 1 week reverses the reduction.[20] Fluorosed teeth manifest as an extensive outer acid-resistant hypermineralized layer which prevents conventional 37% phosphoric acid from effectively etching the surface, resulting in inconsistent etch patterns and an unreliable enamel surface for orthodontic bonding. Increased etchant concentrations and increased etching time, of up to 2 minutes, have provided inconclusive results with respect to improved bonding.[21]

Water and saliva contamination has a deleterious effect on the etched enamel. Blood contamination of enamel during the bonding procedure of conventional and hydrophilic primers significantly lowers their bond strength values and might produce a bond strength that is not clinically adequate.[22] A protective liquid polish (BisCover) layer can be applied to tooth surfaces before bracket bonding without affecting bond strength. It is composed of ethoxylated bisphenol diacrylate ,urethane acrylate ester and polyethyleneglycol diacrylate ,when applied to tooth surfaces, the negative effect of blood or saliva contamination on bond strength is prevented.[23] Sayinsu et al reported that the negative effect of contamination on bond strength in problem areas can be lessened by light curing the primer immediately after application.[24]

## 3. Effect of Primer on Bond Strength

### Self – etch Primer System

By reducing the number of steps during bonding, clinicians are able to save time and reduce the potential for error and contamination during the bonding procedure. It has been indicated that a self-etch primer (SEP), which contains both the enamel etchant and primer, has the potential to successfully bond orthodontic brackets.[25] Similarly, fluoride releasing SEP shows clinically acceptable shear bond strength.[26]

Kimura et al [27]determined that no difference occur in bond strength of orthodontic brackets to enamel treated either with fluoride varnish or not, with a self-etching primer or a conventional adhesive. Başaran and Ozer [28] claimed that, though conventional acid etching shows higher bond strength but no statistically significant difference in bond strength between the nanofiller self-etching primer adhesive with other self-etching primers.

### Moisture Insensitive Primer System

In situations in which moisture control is difficult, consideration should be given to using MIP (Moisture Insensitive Primer) with light-cured composite resins. Grandhi et al, [29] using bovine teeth, found similar bond strengths for both the conventional primer and the MIP primers in dry-etched conditions. Comparing saliva contamination after application of primer, MIP has significantly greater shear-peel bond strengths than when contamination occurred before the application of primer.[30]

## 4. Effect of Bonding Material on Bond Strength

Fajen et al[31] reported that bond strength of glass ionomer cements are significantly less than that of composite resin. Rix et al[32] determined that composite resin displayed significantly greater shear-peel bond strength than a resin modified glass ionomer cement and polyacid-modified composite resin under dry and saliva-contaminated conditions although the bond strengths for all 3 adhesives were clinically acceptable. No significant difference in bond strength is observed between compomer and a no-mix resin adhesive, as reported by Millett et al.[33]

Moreover, Ajlouni et al[34] reported that within the initial half an hour after bonding, ormocer can achieve SBS values that are similar to those obtained with composite orthodontic adhesive. Mccourt et al[35] concluded that fluoride-releasing, light-cured materials have low bond strengths after 30 days and are not acceptable as orthodontic bracket bonding agents. New materials that are introduced in operative dentistry can potentially have orthodontic applications. One such material is a nano-filled restorative material. With modifications in their flow characteristics, these materials can potentially be used to bond orthodontic brackets to teeth.[36, 37]

Bishara et al[38] reported that SBS of a traditional three-step adhesive system used for bonding orthodontic brackets is significantly greater than the SBS of the one-step universal self-adhesive. Similarly, shear bond strength of the two–step acid-etch primer/adhesive is greater than that of one-step system.[39] The cyanoacrylates have adequate bond strength at one-half hour and after 24 hours from initial bonding.[40]

## 5. Effect of Bracket material, Design on Bond Strength

### Bracket material

Since the introduction of ceramic brackets to orthodontic therapy, a need has arisen to test the manufacturer's claims regarding these brackets. Joseph and Rossouw (1990) reported that ceramic brackets (24.25 $mN/m^2$) exhibited significantly higher bond strength than that of the stainless steel (17.80 $mN/m^2$). The fracture of enamel is a real possibility during therapy or at debonding of the ceramic brackets, especially if the tooth is nonvital.[41] The incidence of partial bracket-base fracture in monocrystalline ceramic brackets is 15% whereas no bracket failure is reported in polycrystalline ceramic brackets. [42] Özcan et al studied that ceramic brackets show signifycantly higher bond strength values (11.5 ± 4.1 MPa) than polycarbonate brackets (6.3 ± 2.7 MPa)[43] Moreover, compared with conventional acid etching, SEPs significantly decreased the SBS of ceramic orthodontic brackets[44]

### Bracket bonding on Ceramic Surfaces

With the increase in adult orthodontic treatment comes the need to find a reliable method for bonding orthodontic brackets onto metal or ceramic crowns and fixed partial dentures. While bonding metal brackets on ceramic crowns, highest bond strength values are obtained with sandblasting and silicatization with silane or hydrofluoric acid without silane.

The use of silane after hydrofluoric acid etching did not increase the bond strength[45]

Kocadereli et al [46] reported that when ceramic brackets are to be bonded on porcelain surface, porcelain surface preparation with acid etching followed by silane application resulted in statistically significant higher tensile bond strength. Sandblasting the porcelain surface before silane treatment provides similar bond strengths, but sandblasting or acid etching alone are less effective.

**Bracket Designs**

Wang et al[47] compared bond strength of various metal bracket base designs named retention groove base (Dynalock, Unitek, Monrovia, Calif)circular concave base (Accuarch appliance Formula-R, Tomy, Tokyo, Japan), double mesh with 5.1 x $10^{-2}$ mm $^{2}$ mesh size (Ultratrimm, Dentaurum, Ispringen, Germany), double mesh, 3.1 x$10^{-2}$ $mm^2$ (Minidiagonali Roth, Leone, Florence, Italy), double mesh, 3.1 x$10^{-2}$ $mm^2$ (Tip-edge Rx-I, TP Orthodontics, LaPorte Ind), and double mesh, 2.9 x$10^{-2}$ $mm^2$ (Mini Diamond, Ormco, Glendora, Calif).They concluded that Tomy bracket, with its circular concave base, produced greater bond strength than did the mesh-based brackets; among the mesh-based brackets, Dentaurum, with the larger mesh size, produced greater bond strength than the brackets with smaller mesh sizes.

Samruajbenjakul and Kukiattrakoon compared shear bond strength of ceramic brackets with different base designs to feldspathic Porcelains (beads, large round pits, and irregular base) revealed that the beads base design had the greatest shear bond strength (24.7 $\pm$1.9 MPa) and was significantly different from the large round pits base (21.3 $\pm$ 2 MPa), irregular base (19.2 $\pm$ 2.0 MPa), and metal mesh base (15.2 $\pm$ 2.4 MPa).[48]

## 6. Effect of curing on bond strength Polymerization lamps

Wendl and Droschl reported that among various polymerization lamps (halogen, high performance halogen, xenon, and diode) halogen lamp achieved the highest bond strength with a curing time of 40 seconds.[49] Klocke et al determined that curing interval of 3 seconds with the plasma arc is recommended for both polycrystalline and monocrystalline ceramic brackets[50] Moreover, Talbot et al[51] concluded that lasing the enamel before or after bonding does not adversely affect bond

strength. Use of the argon laser to bond orthodontic brackets
can yield excellent bond strengths in significantly less time than conventional curing lights, while possibly making the enamel more resistant to demineralization. According to Shanthala and Munshi [52], no significant differences in bond strength are reported between curing with conventional light argon laser.

It is recommended that orthodontic brackets be photopolymerized for at least 20 seconds with the QTH (high-energy quartz tungsten- halogen) or the LED (light-emitting diode) before the arch wires are engaged.[53] At light-tip distances of three and six mm, no significant differences are present between the halogen and plasma arc lights, but both lights show significantly higher shear bond strengths than the LED light.[54] When evaluating the effect of light-tip distance on each light curing unit, the halogen light show no significant differences with different distances. However, the LED light produce significantly lower shear bond strengths at a greater light-tip distance, and the plasma arc lamp showed significantly higher shear bond strengths at a greater light-tip distance.[54]

## 7. Effect of recycled brackets on bond strength

Bahnasi et al [55] determined that sandblasted recycled metal orthodontic brackets can be used as an alternative to new brackets. In case of using repeated recycled brackets, better to apply bonding agent on bracket base for more bond strength. It is reported that industrial recycling obtained better results than sandblasting after three successive debondings.[56] The brackets' shear bond strength decreased as the size of the aluminium oxide particle used for sandblasting increased and as recycling is repeated.

Chung et al[57] studied bond strength of ceramic brackets and concluded that in the process of rebonding mechanically retentive ceramic brackets, (1) new brackets have the highest mean bond strength when compared with rebonded brackets, (2) the bond strength of sandblasted rebonded brackets with sealant is not significantly different from new brackets, (3) silane does not increase bond strength of rebonded brackets significantly, and (4) Hydrofluoric acid treatment on sandblasted rebonded brackets significantly decreases bond strength.

### 8. Effect of type of bonding on bond strength

Indirect bonding is considered to be a useful and efficient approach that improves the results of the treatment. Success with the technique requires attention to detail, but does not require excessive complexity. Milne et al[58] compared bond strength in direct and indirect bonding and found, no statistically significant differences in bond strength.

### Conclusion

Accordingly, the "ideal bond strength" is difficult to define, as every patient is unique with respect to the ability of their enamel to be etched and their individualized masticatory and intraoral factors that may affect bonding and bond strength. Stronger SBSs are not always better and bond strengths that are too high may do nothing more than create iatrogenic damage during bracket debonding. Thus these evidences on achieving adequate shear bond strength on various procedures from cleaning to curing will create awareness among clinicians that they might diminish the incidence of bracket failure rates.

## References

1. Reynolds JR: A review of direct orthodontic bonding. Br J Orthod 2:171-178, 1975)
2. Bishara SE, Fehr DE, Jakobsen JR: A comparative study of the debonding strengths of different ceramic brackets, enamel conditioners, and adhesives. Am J Orthod Dentofacial Orthop 104:170-179, 1993
3. Gwinnett AJ and Smith DC. Fissure sealant. In Smith DC, Williams DF editors. Biocompatibility of dental materials, Volume II.15-49, Boca Raton: CRC Press, 1982
4. Steven Lindauer Effect of pumice prophylaxis on the bond strength of orthodontic brackets. American Journal of Orthodontics and Dentofacial Orthopedics . 07/1997; 111(6):599-605
5. Damon, Bishara, Olsen, Jakobsen Effect of fluoride application on shear bond strength of orthodontic brackets, Angle Orthodontic 1996;66(1):61-64
6. Bishara ,Damon, Olsen, Jakobsen Effect of applying Chlorhexidine antibacterial Agents on shear bond strength of orthodontic brackets, Angle Orthodontic 1996;66(4):313-316

7. Roberto Justus, Tatiana Cubero, Ricardo Ondarza, and Fernando Morales Seminars in Orthodontics, Vol 16, No 1 (March), 2010: pp 66-75
8. Comparison of shear bond strength and surface structure between conventional acid etching and air-abrasion of human enamel Olsen, Bishara, Damon, Jakobsen Am J Orthod Dentofac Orthop 1997;112:502-6.)
9. 1993.Angle Orthodontist by J.A.Von Fraunhofer
10. 1997 AJO-DO), Volume Apr (333 - 340): Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment - Årtun and Bergland
11. Buonocore MG: A simple method of increasing the adhesion of acrylic filling materials to enamel surface. J Dent Res 34:849-853, 1955
12. Lehman and Davidson Am J Orthod. 1981 Jul;80(1):73-82.
13. Sadowsky PL, Retief DH, Cox PR, et al: Effects of etchant concentration and duration on the retention of orthodontic brackets: an in vivo study. Am J Orthod Dentofacial Orthop 98:417-421, 1990
14. Barkmeier WW, Erickson RL. Shear bond strength of composite to enamel and dentin using Scotchbond multi-purpose. Am J Dent 1994; 7:175-9.
15. Bishara, VonWald, Laffoon, Jakobsen, Am J Orthod Dentofacial Orthop 2000;118:288-94)
16. Kim ,Lim ,Changc;Leeb; Rhee; Yang Angle Orthod 2005;75:678–684
17. Angle Orthodontist Vol 69 No.3 1999 by Urabe et al
18. Redford, Clarkson, Mark Jensen, PEDIATRIC DENTISTRY: March 1986/ Vol. 8 No. 1
19. Sheen ,Wang , Hsiang Angle Orthodontist 1993:63:225-230
20. Bulut,Turku ,Kaya Effect of an antioxidizing agent on the shear bond strength of brackets bonded to bleached human enamel Am J Orthod Dentofacial Orthop 2006;129:266-72)
21. William A. Wiltshire and James Noble Clinical and Laboratory Perspectives of Improved Orthodontic Bonding to Normal Hypoplastic, and Fluorosed Enamel Semin Orthod 2010;16:55-65.)
22. Vittorio Cacciafesta Am J Orthod Dentofacial Orthop 2004; 126:207-12

23. Korkmaz Sayinsu,a Fulya Isik,a Serdar Sezen,b and Bulent Aydemirc Am J Orthod Dentofacial Orthop 2007;131:391-4
24. Sayinsua, Isikb, Sezenc ,Aydemird Angle Orthod 2006;76:310–313
25. Bishara, VonWald, Laffoon, Warren, Am J Orthod Dentofacial Orthop 2001;119:621-4
26. Bishara, Ajlouni, Laffoon, Warren Effect of a Fluoride-Releasing Self-Etch Acidic Primer on the Shear Bond Strength of Orthodontic Brackets Angle Orthod 2002;72:199–202.
27. Kimura, Dunn, Taloumis,Am J Orthod Dentofacial Orthop 2004;125:351-6
28. Başaran ,Ozer, Devecio Comparison of a recently developed nanofi ller self-etching primer adhesive with other self-etching primers an conventional acid etching European Journal of Orthodontics 31 (2009) 271–275
29. Grandhi RK, Combe EC, Speidel TM. Shear bond strength of stainless steel orthodontic brackets with a moisture-insensitive primer. Am J Orthod Dentofacial Orthop 2001; 119:251-5.
30. Shane Schaneveldt , Timothy F. Foley Bond strength comparison of moisture insensitive primers Am J Orthod Dentofacial Orthop 2002;122:267-73
31. Fajen et al AM J ORTHOD DENTOFAC ORTHOP 1990;97:316-22
32. Foley, Mamandras Comparison of bond strength of three adhesives: Composite resin, hybrid GIC, and glass-filled GIC (Am J Orthod Dentofacial Orthop 2001;119:36-42)
33. Millett, McCluskey, McAuley, S. L. Creanor, J. Newell, J. Love, A Comparative Clinical Trial of a Compomer and a Resin Adhesive for Orthodontic Bonding Angle Orthod 2000;70:233–240
34. Ajlouni et al Angle Orthod 2004;75:106–108
35. Mccourt, Cooley, Barnwell, Antonio, Bond strength of light-cure fluoride-releasing base-liners as orthodorntic bracket adhesives AM J ORTHOD DENTOFAC ORTHOP 1991;100:47-52
36. Bishara, Ajlouni, M. Soliman, Charuphan Oonsombat, Laffoon John Warren Evaluation Of A New Nano-Filled Restorative Material For Bonding Orthodontic Brackets World J Orthod 2007;8:8–12
37. Uysal , Yagci , Uysal ,Gülsen Are nano-composites and nano-ionomers suitable for orthodontic bracket bonding? European Journal of Orthodontics 32 (2010) 78–82
38. Bishara , Ostbyb; Raed Ajlounic; John F. Laffoond; John J. Warrene Early Shear Bond Strength of a One-step Self-adhesive on Orthodontic Brackets Angle Orthod 2006;76:689–693
39. Samir E. Bishara; Raed Ajlounib; John F. Laffoonc; John J. Warrend Comparison of Shear Bond Strength of Two Self-etch Primer/Adhesive Systems Angle Orthod 2006;76:123–126

40. Bishara F. Laffoon, Leigh VonWald, John Warren, Effect of time on the shear bond strength of cyanoacrylate and composite orthodontic adhesives Am J Orthod Dentofacial Orthop 2002;121:297-300

41. Joseph, Rossouw, The shear bond strengths of stainless steel and ceramic brackets used with chemically and light activated composite resins AM J ORTHOD DENTOFAC ORTHOP 1990;97:121-5

42. Theodorakopoulou, P. Lionel Sadowsky, Alex Jacobson and William Lacefield, Evaluation of the debonding characteristics of 2 ceramic brackets: An in vitro study Am J Orthod Dentofacial Orthop 2004;125:329-36)

43. Özcan ,Finnema Ybema Evaluation of failure characteristics and bond strength after ceramic and polycarbonate bracket debonding: effect of bracket base silanization European Journal of Orthodontics 30 (2008) 176–182

44. Tancan Uysal, Ayca Ustdal and Gokmen Kurt Evaluation of shear bond strength of metallic and ceramic brackets bonded to enamel prepared with self-etching primer European Journal of Orthodontics 32 (2010) 214–218

45. Schmage et al AJ Orthod Dentofacial Orthop 2003;123:540-6

46. Kocadereli Canay, Akça, Am J Orthod Dentofacial Orthop 2001;119:617-20

47. Wang et al Am J Orthod Dentofacial Orthop 2004;125:65-70

48. Samruajbenjakula, Kukiattrakoonb Angle Orthod. 2009;79:571–576

49. B. Wendl and H. Droschl European Journal of Orthodontics 26 (2004) 535–544

50. Klocke et al Am J Orthod Dentofacial Orthop 2003;124:309-15

51. Talbot Am J Orthod Dentofacial Orthop 2000;118:274-9

52. Shanthala BM, Munshi AK. Laser vs visible-light cured composite resin: an in vitro shear bond study. J Clin Pediatr Dent 1995; 19:121-5.

53. Y. Teresa Silta,a William J. Dunn,b and Charles B. Petersc Am J Orthod Dentofacial Orthop 2005;128:744-8)

54. Cacciafesta et al Angle Orthod 2005;75:386–391

55. Bahnasi ,Rahman ,Abu-Hassan J Clin Exp Dent. 2013;5(4):e197-202

56. Manuela M. Haro Montero, Ascensio´n Vicente, Noelia Alfonso-Herna´ndez, Manuel Jime´nez-Lo´ pez, Luis-Alberto Bravo-Gonza´ lez Comparison of shear bond strength of brackets recycled using microsandblasting and industrial methods Angle Orthod. 2015; 85:461–467

57. Chung, Friedman, and Mante Am J Orthod Dentofacial Orthop 2002;122:282-7)

58. Milne, Andreasen,Jakobsen, AM J ORTHOD DENTOFAC ORTHOP 1989;96:8-15