Research Paper

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Comparative Evaluation of The Shear Bond Strength and Debonding Properties of a Conventional Composite and Flowable Composites Used for Orthodontic Bracket Bonding-An invitro study

Medical Science

KEYWORDS : Shear bond strength, Esthet -X Flow, Filtek Z-350, Flowable composites, Etching, Bonding, Brackets, Adhesives

Dr. Pradeep. S	Assistant professor, Dept. Of Orthodontics and Dentofacial Orthopaedics, J.S.S. Dental College and Hospital, Mysore, Karnataka, India.
Dr. Shivalinga. B. M.	Professor and H.O.D., Dept. Of Orthodontics and Dentofacial Orthopaedics, J.S.S. Dental College and Hospital, Mysore, Karnataka, India.
Dr. Ravi. S.	Associate professor, Dept. Of Orthodontics and Dentofacial Orthopaedics, J.S.S. Dental College and Hospital, Mysore, Karnataka, India.

ABSTRACT

AIM: To evaluate and compare sshear bond strength and debonding characters of the Transbond XT(BisGMA based composite), Esthet-X Flow(flowable composite) , Filtek Z-350(flowable composite) MATERIALS AND METHOD: A total of ninety human premolars were divided into group I,Transbond XT(n=30);group II, Esthet-X Flow(n=30) and group III, Filtek Z-350(n=30), the pre adjusted edgewise stainless steel premolar brackets were bonded to evaluate the shear bond and debonding properties. RESULT: The results of the statistical analysis comparing the three groups indicated no statistically significant differences between the groups. In general, the shear bond strength with group I and III exhibited similar bond strength with 11.58+/-1.3MPa and 11.07+/-1.0MPa respectively. Groups III exhibited least bond strength of 10.7+/-2MPa. In modified ARI the majority of bond failures occurred at enamel-adhesive interface or cohesive type failure in all the 3-groups. Group II and III showed increased frequency of score 2, 4 and 5 compared to Group I which showed increased frequency of score 0 and 1. CONCLUSION: when considering the SBS and ARI scores obtained, flowable composites can be effectively applied to orthodontic bracket bonding.

INTRODUCTION:

The introduction of acid etch technique by Buonocore1 in 1955 heralded a new era in adhesive dentistry, which has since initiated varied applications in the field of dentistry including bonding of orthodontic attachments.[2, 3]

Newman in 1965 introduced the novel concept of bonding orthodontic attachments to tooth surfaces by means of epoxy adhesive. This procedure improved the overall treatment results by eliminating band occupying interdental spaces, decreased gingival irritation, and easier removal of plaque and decreased risk of calcification[2]. Since then, various dental adhesives and methods of bonding orthodontic attachments have been reported to enhance the bond strength of the orthodontic attachments by pretreatment of enamel surfaces.[3,4, 5]

Previous generation bonding systems used conventional adhesives comprising of 3 different agents, an enamel conditioner, a primer solution, and an adhesive resin during the bonding of orthodontic brackets to enamel.[6]

Revolutionary advances in adhesive chemistry are changing the process of orthodontic bonding.[10] The constant quest for better bonding systems to reduce the technique sensitivity of the adhesion procedures, to improve the bond strength, to reduce the loss of enamel and to reduce the number of clinical application steps as well as chair side time has resulted in innovation of many bonding agents.[6, 7, 8, 9, 10] Fewer steps in the bonding process mean fewer human errors.

Though composite resin has wide clinical acceptance both for bonding of brackets or restorative purpose, several drawbacks have been reported which include loss of enamel during acid etching and debonding, enamel decalcification around brackets and lowered bond strength in the presence of water or moisture.

Incomplete polymerization.[8,11,12] even when mixed and cured according to manufacturer's instructions is another problem of composite resin resulting in residual monomer that is readily leached from the cured resin. Adverse reactions caused by leaching of residual monomer have also been reported based on the in vitro and in vivo studies on biocompatibility, potential mutagen city [13,14] and estrogenicity of various orthodontic adhesives. Recently it has been reported that Bisphenol A, a component in the structure of Bisphenol-A-glycidyl dimethacrylate (BisGMA) exhibits estrogenicity[15] and BisGMA itself has been found to be cytotoxic in a number of cell culture studies.[16,17] The presence of residual methacrylate monomer has been blamed for elution of toxic reactants.

As an alternative to traditional BisGMA based composite resins, newer bonding adhesives like Glass Ionomer Cement (GIC), Resin modified GIC; Compomers and Flowable composites have been developed and tried with varying degrees of success.

Thus, the flow property is an important feature for clinical consideration that influences both the penetration of the adhesive into retentive mechanism at the bracket base and the ability of an adhesive to resist bracket drift during direct bonding. Hence among the various innovations introduced in composite resins, a plethora of low viscous composite resins and flowable composites were marketed for restorative purpose and bonding orthodontic attachments which needs special mention. Flowable composites are low viscosity composite resins, created by retaining the same particle size of traditional hybrid composites , but reducing filler content and increasing resin content to reduce viscosity of resin.

Flowable composites were marketed for bonding of brackets during early 21st century. Flowable composite merits special attention because of their clinical handling characters of non-stickiness, fluid injectability[18] and shear bond strength comparable to that of traditional composite adhesives.[19]

Considering the merits and demerits of BisGMA based composite resin, and flowable composite the present in-vitro study was planned to evaluate Esthet x-flow, Filtek Z-350 flowable composites as an alternative orthodontic bonding agent by determining its shear bond strength and debonding characters and to compare it with that of conventionally used BisGMA based composite resin- Transbond XT composite.

MATERIALS AND METHOD:

The present invitro study was planned to evaluate and compare the shear bond strength of a conventional composite and flowable composites used for orthodontic bracket bonding.

Stainless steel metal brackets were bonded on extracted human premolar teeth using the above three mentioned adhesives. Shear bond strength and debonding characters of the 3 materials under study were determined and compared. The following materials and equipment were used for the above study:

I. Materials

➢ Adhesive system for evaluation:

1. ransbondXT (3M UNITEK, Monrovia, California) (Fig 1A)
2. Esthet –x flow (Densply) (Fig 1B)
3. Filtek Z-350 (3M UNITEK, Monrovia, California)

- Preadjusted edgewise upper premolar stainless steel brackets (Gemini, 3M Unitek, Monrovia, California.)
- Upper and lower premolar teeth-extracted for therauptic purpose
- Thymol solution for storing the teeth before bonding. (Fig 1F)

II. Bonding accessories
- Etchant- 37% phosphoric acid (Scotch bond 3M ESPE, MN).
- Applicator brush.
- 3-way syringe
- Bracket holder.
- Bracket positioner.
- Explorer.
- Light Emitting Diode curing unit –Starlight P (Monitex Bluelex).
- Polishing rubber cup and pumice powder

III. Color coded of the acrylic blocks
- Group 1 - Transbond XT: Green (Fig 1)
- Group II – Esthet-X flow : black (Fig 2)
- Group III – Filtek Z-350 : Blue (Fig 3)

Fig 1: Group I - Transbond XT (Green)

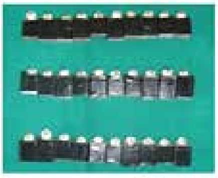


Fig 2: Group II – Esthet –X Flow (Black)

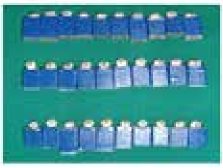


Fig 3: Group III – Filtek Z-350 (Blue)

IV. Equipments: Used to evaluate Shear bond strength

- Universal testing machine JJ LLOYD 20 KN (Fig 4)
- Custom made wooden jig.
- Aluminium block with Tooth embedded attached to lower jaw of testing machine with custom made zig and chiesel mounted to upper jaw
- Digital Vernier calipers.

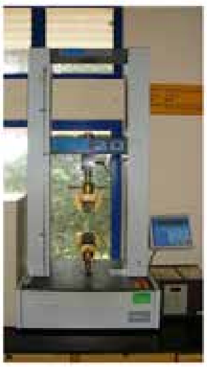
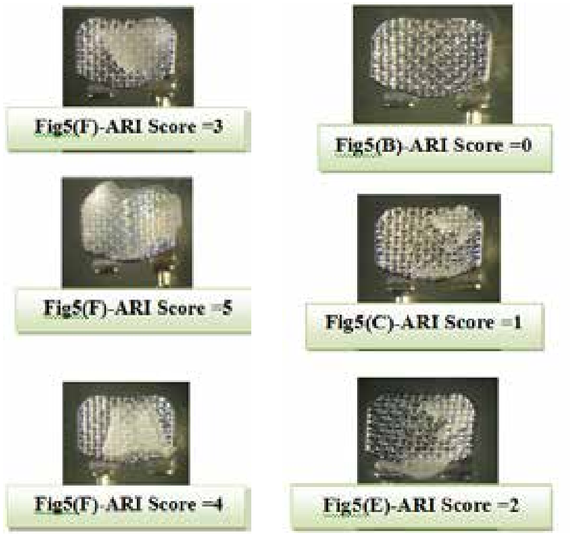


Fig 4: JJ LLOYD testing machine

V. Equipments: Used to evaluate debonding characters Optical microscope.(Fig 5A)Scanned bracket base. (Fig 5-B,C,D,E,F,G)



METHODOLOGY

A. Sample for the study

90 pre-adjusted edgewise upper premolar stainless steel brackets (Gemini 3M Unitek) and 90 freshly extracted premolar teeth were used in the study.

Ethical committee clearance was obtained from the Ethical committee, J.S.S University for the use of natural teeth for the study.

B. Inclusion criteria for the teeth to be evaluated in the study are
- Anatomically and morphologically well defined teeth
- Non caries maxillary and mandibular premolar teeth with intact buccal enamel, extracted for orthodontic purpose

Exclusion criteria for the sample are
- Teeth with heavy restorations
- Variations in crown morphology with enamel structural defect
- Teeth having surface cracks from extraction forceps
- Teeth treated with chemical agents
- Fluorosed teeth

C. Sample preparation and distribution:

The freshly extracted teeth were cleaned to remove blood or any tissue debris and stored in 0.1% wt/vol thymol solution to prevent bacterial contamination and dehydration.

The teeth were divided into 3 groups of 30 each to be bonded with stainless steel metal brackets using 3 different adhesives under study.

The teeth were then mounted on self cured, colored blocks of dimensions 25X10X10 mm such that the roots were completely embedded into the acrylic block up to cemento-enamel junction and the buccal surface of crown perpendicular to base of the block. The acrylic blocks were color coded to differentiate between different groups.

The teeth to be bonded with stainless steel metal brackets using three adhesives under study were grouped as given below

Color coding of Aluminium blocks	Adhesive used for bonding	No of metal brackets (sample size)
Green-Group I (Fig 3A)	Transbond XT	30
Black-Group II (Fig 3B)	Esthet-X Flow	30
Blue-Group III (Fig 3C)	Filtek Flow Z-350	30

BONDING PROCEDURE

Conditioning of the enamel surface

The buccal surface of the teeth was polished with pumice slurry using rubber cup mounted on low speed hand piece. After pol-

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ishing, the teeth were washed with distilled water and dried using oil free air from a three-way syringe. 37% ortho phosphoric acid was applied to the labial surface and left for a period of 15 seconds. The acid was then washed away with a spray of water for 10 seconds. The tooth surface was then air-dried using oil and moisture free three 3-way syringe until a dull frosty appearance was seen on the surface.

The above procedure was done for all the test specimens, to be bonded with three adhesives to be evaluated

Bonding procedure using Transbond XT : Group 1
The primer was applied to the etched surface with the help of an applicator brush and cured with LED for 10 seconds. The adhesive was then applied to the base of the metal bracket directly from the syringe. The bracket was held and carried to the tooth surface by a bracket holder. The bracket was then positioned on the tooth surface along the midline at a distance of 4 mm from the occlusal surface. The positioning was achieved with the help of a bracket positioner.

The bracket was pressed on the tooth surface using the reverse end of the bracket holder using uniform finger pressure. The flash around the bracket was then removed with an explorer.

The adhesive was cured using a LED (light emitting diode) curing unit. A radiometer was used to determine the intensity of the LED. The adhesive was cured from the occlusal, gingival, mesial and distal aspects for 10 seconds each The bonded teeth were then kept in distilled water at room temperature for 24 hours before debonding.

Bonding using Esthet – x flow and Filtek Z-350 : Group II and Group III
Bonding procedure for these adhesives was the same as that for group I,but after enamel etching primer step was eliminated.

EVALUATION OF BOND STRENGTH:
Shear bond strength was tested with a universal Testing Machine JJ LLOYD and was evaluated according to the following procedure for all the three samples. The machine has two vertically placed jaws.

- The aluminium block with the tooth embedded was placed in the lower jaw with custom made jig (Fixed head)
- A custom made chiesel was fitted to the upper jaw of the machine (Movable head)

At the start of the testing, the jaws are positioned such that the sharp edge of the chiesel from the upper block fits under the occlusal wings of the bracket bonded to the tooth. An occluso-gingival force was applied to each bracket producing a shear force at the bracket –tooth interface at a crosshead speed of 1mm/min

The JJ LLOYD unit was attached to an electronic console that displayed the debonding forces acting on the bracket tooth interface. Thus, the exact force at which the bracket debonded was noted from the console. This force was expressed in Newtons.

To evaluate the Shear Bond Strength in MPa, from the force value, the following formula was used ,

$$\text{Shear Bond Strength} = \frac{\text{Force in Newtons}}{\text{(MPa) Area of the bracket base (sq. mm.)}}$$

The area of the bracket base as measured by using Digital Vernier Calipers (8.68mm2). (Fig. 4C)

EVALUATION OF THE DEBONDING CHARACTERISTICS
The debonded tooth surface was examined under an optical microscope at 16X magnification to determine the bond failure interface. (Fig.5A, 5-B,C,D,E,F,G)

The adhesive remaining on the bracket base after debonding was scored according to the modified Adhesive Remnant Index (ARI) based on the following guidelines
Score 0 = no adhesive left on bracket
Score 1 = less than 25% of adhesive left on bracket
Score 2 = 25% of adhesive left on bracket
Score 3 = 50% of adhesive left on bracket
Score 4 = 75% of adhesive left on bracket Score 5 = 100% of adhesive left on bracket.
The values obtained from the Shear Bond Strength testing (SBS) and the modified ARI scores of the three adhesives were tabulated and the subjected to statistical analysis.

RESULTs :-
The results of the shear bond strength and modified ARI scores of the 3 adhesives-Group I-Transbond XT, Group II-Esthet-X Flow, Group III-Filtek Z-350 Flow with their interpretation are presented in Tables1,2 graphically and diagrammatically represented in Graphs 1,2-a,b,c

SHEAR BOND STRENGTH
Table 1: Mean and Standard deviation and test of significance of Shear Bond Strength (SBS) of the three adhesive groups

Group	Samples(N)	Mean S.B.S(MPa)	Std.dev	Range(MPa)	p-value	F statistic
I	30	11.58	1.39	9.5-14.9	0.0866	2.5172
II	30	10.70	2.00	8.6-19.9		
III	30	11.07	1.03	9.5-12.9		

- It is evident from the above table that Group I has the highest mean shear bond strength (11.58+/-1.3 MPa) followed by Group III (11.07+/-1.03 MPa) and the lowest in Group II (10.70+/-2.0 MPa)

- One-way Anova was used to calculate the p-value (<0.05 was considered significant). One–way Anova showed no significant difference in mean shear bond strength among three groups.

Graph: 1

ADHESIVE REMANENT INDEX

Table 2: Frequency distribution of modified ARI of the three adhesive groups:

Groups	Sample (N)	Score 0	Score1	Score 2	Score 3	Score 4	Score 5
		No %	No%	No %	No %	No %	No %
I	30	7 23%	6 20%	4 13%	8 27%	3 10%	2 7%
II	30	3 10%	4 13%	6 20%	10 34%	4 13%	3 10%
III	30	3 10%	3 10%	5 17%	10 33%	6 20%	3 10%

- From the above table it was observed that 60-70% of samples in all the 3 study groups showed score 3.
- Group II and III showed increased frequency of score 2,4 and 5 and lower in Group I but it was viceversa in score 0 and 1.

Summary of Results
Under the test conditions, Transbond XT showed highest shear bond strength followed by Filtek Z-350 and the least by Esthet-X Flow. However, the difference was not statistically significant when the means of all three study groups were compared and even One–way Anova showed no significant difference in mean shear bond strength among three groups.

Frequency distribution of modified Adhesive remanent index for the three adhesive groups showed. Group II and III showed increased frequency of score 2,4 and 5 and lower in Group I but it was viceversa in score 0 and 1. All the three groups had ARI score of 3 (60-70%), suggestive of cohesive type of failure.

DISCUSSION
The direct bonding of orthodontic brackets has revolutionized and advanced the clinical practice of orthodontics. Present day bonding makes use of acid etchants followed by primer materials as an essential part of the bonding procedure in order to allow good wetting and penetration of the sealant that bond the bracket to the enamel surface.20,21

The quality of orthodontic treatment is being constantly improved with increasing sophistication of techniques and orthodontic bonding materials that benefits both the patients and the clinician. Advances in material sciences have tried to improve the quality of bonding by refining the composition of bonding materials, dispensing systems and modes of curing, enhancing bond strength, handling characteristics and simplifying the procedure. The main requisite of an orthodontic adhesive is to produce a strong and durable bond to with stand both occlusal and orthodontic force during the course of treatment but at the same time permit bracket removal at the end of treatment without enamel damage and ease of cleaning.

Flowable composites are low viscosity composite resins, created by retaining the same particle size of traditional hybrid composites, but reducing filler content and increasing resin content to reduce viscosity of resin. Flowable composites were marketed for bonding of brackets during early 21st century. Flowable composite merits special attention because of their clinical handling characters of non-stickiness, fluid injectability and shear bond strength comparable to that of traditional composite adhesives.

This study, we therefore undertook which, compare and Evaluation of effectiveness of Esthet –X Flow , and Filtek Z-350 flowable composites will enable the clinician to consider as an alternative orthodontic bonding agent for orthodontics bracket bonding,[22]

The values of the shear bond strength and modified ARI scores obtained for Transbond XT, Esthet-X Flow and Filtek Z-350 in the present study were statistically analysed.

1. Comparison of Shear Bond Strength (SBS) of the three adhesive groups:

- Transbond XT has a slightly higher mean strength value of 11.58+/-1.3 MPa compared to Filtek Z-350 with a mean SBS of 11.07+/-1.03 MPa and Esthet –X Flow had the lowest SBS value 10.70+/-2.0 MPa. The differences noted in the mean SBS values of the three adhesives are not statistically significant (p=0.086). One-way Anova was used to calculate the p-value (<0.05 was considered significant). One–way Anova showed no significant difference in mean shear bond strength among three groups. (Table 1,Graph 1)

Thus the present study indicate Transbond XT and Filtek Z-350 have comparable bond strength followed by slightly lower bond strength for Esthet-X Flow.

At this juncture it is worthwhile to note that the bond strength of all the three adhesives are quite above the clinically acceptable level of 5.9-7.8 MPa as suggested by Reynolds.[23] Lopez[24] recommended a value of 7 MPa as minimum bond strength for succesful clinical bonding. According to Profit, [25] forces of mastication are highly variable which ranges upto 50 kgs and orthodontic forces in the range of 50-150 gms.

Among the various commercially available BisGMA based resins Transbond XT has been extensively evaluated for its own bond strength as well as a adhesive to evaluate other factors influencing bond strength namely enamel conditioning method, methods of polymerization, bracket types (metal or ceramic) and different debonding methods.

Olsen , Owens.Jr , Bishara.SE, Oesterle.LJ and Tecco.S et al to name a few have reported higher SBS values for Transbond XT when evaluated under different testing conditions as observed in the present study.[26]

Simona.T[27] and Michele.D.Attilio[28] have reported very high values of 23.23 MPa and 23.47 MPa for Transbond XT and 34.80 MPa and 24.98 MPa for Flowable composites compared to11.64 MPa and 11.0 MPa expressed in the present study. They suggested that Flowable composites can be used for orthodontic bonding.

Dong-Bum-Ryou[29] reported a lower SBS value for Flowable composites compared to that of Admira Flow in the present study and he concluded that Flowable composites with no intermediate bonding resin could be conveniently applied for orthodontic bracket

However, Tancan Uysal[30] reported a very low value for Flowable composites ranging from 6-8 Mpa compared to 17.10 MPa showed for Transbond XT and concluded that Flowable composites are not suitable for orthodontic bonding

The goal of current orthodontic research is to improve the bonding procedure by reducing chairside time during bonding and debonding without jeopradising the ability to maintain clinically acceptable bonds strength Clinicians are interested in determining the level at which the bond failure will take place with force application

According to Fox,[31] and Eliades [32] mean bond strength and standard deviation may not be the best indicators for evaluating the bond strength of the bonding materials. When considering the bond failure, weaker values (tail of the distribution) may be more important. Therfore it may be more appropriate to use a function that relates probability of failure to applied force. It is suggested that invitro and invivo bond strength testing should include some form of survival analysis. This gives the clinican a better idea of how the material or bracket is likely to perform in the clinical situation. Therfore in addition to Anova, which considers only mean and standard deviation, Kaplain-Meier survival analysis was also performed to analyse the data because it considers the entire spread of the data and thus helps to evaluate the clinial performance better

2. Frequency distribution of modified Adhesive Remanent Index scores of the three adhesive groups:
The frequency distribution of the modified ARI scores reveals that 60-70% of the samples in all the three study groups showed score 3 suggestive of a cohesive fracture. (Table 3)

Ideal ARI score is a subject of debate. Proponents of low score of modified ARI (score 1 and 2) claim that the tooth surface requires extensive cleaning of already damaged etched enamel surface.[33] Group-I had more percentage of score 1and 2 compare with that of Group II and III.

Proponents of high score of modified ARI (score 4 and 5) claims that there is no need of extensive cleaning, but there is a possibility of enamel crack or tear since entire adhesive comes out with bracket base. Group II and III showed increased frequency of score 2,4,and 5 compare to Group I.

It is suggested that bond failure at bracket adhesive interface is more desirable than adhesive enamel interface, because enamel fracture and cracking have been reported, though inherent weakness of the tooth surface can also cause tooth fracture.

The cohesive fracture noted in the present study is favorable and indicates moderate amount of bond strength at clinically acceptable level, and facilitate easy debonding after treatment. Further, it requires minimal clean up and less damage during debonding.

The above discussion on the present study reveals that Filtek Z-350 has comparable bond strength with that of Transbond XT and Esthet –X Flow has slightly lower bond strength values. However, the SBS values of all the three adhesives are within the clinically acceptable levels and they exhibit cohesive type of bond failure. Probability of failure rate is almost similar for all the 3 adhesives, the difference being not statistically significant.

Both Flowable composites on the other hand has a decreased filler particle i.e., it flows while being applied and contoured but remains firm when stationary. However, when this material was used for bonding in the present study drifting of the brackets was noticed due to its increased flowability and required extra care to position the brackets.

It is evident from the present study that flow property and viscosity of adhesive plays an important role. Within certain limits, thinner and flowable adhesive paste will facilitate better penetration of the adhesive into mesh of the bracket base and the micro porosities of the etched enamel surface and improve handling properties and bond strength. Therefore, a balance is required between the flow and viscosity to obtain optimal consistency to achieve optimal bond strength and improve handling property.

Though Transbond XT is a clinically efficient material as again confirmed from this study, Esthet- X Flow and Filtek Z-350 FLow, if their flow and viscosity are balanced to improve handling property can definetly be considered as an alternative bonding system due to its comparable bond strength and debonding characters and other reported properties of biocompatibility. Considering the invivo nature of the present study the findings should be interpreted with caution while applying it for clinical application. The efficacy of the flowable composites as a bonding agent needs invivo and clinical assesment through a survival analysis. Preliminary evaluation done in this study however will be a valuable guide for future in clinical use.

CONCLUSION

The following conclusions are drawn from this comparative in-vitro study on the shear bond strength and debonding characters of Transbond XT, Esthet-X Flow and Filtek Z-350 using metal brackets

- Filtek Z-350 has a comparable mean bond strength value (11.07+/-1.03 MPa) like that of Transbond XT (11.58+/-1.3 MPa).
- Esthet-X Flow has slightly lower mean bond strength value (10.70+/-2.0 MPa) compared Filtek Z-350 and Transbond XT.
- All the three adhesives exhibited clinically acceptable bond strength.
- 60-70% of all the three adhesives exhibited cohesive type of bond failure.
- The efficacy of the flowable composites as a bonding agent needs invivo and clinical assesment through a survival analysis.
- Filtek Z-350 and Esthet-X flow exhibited problems with handling properties and flowability. Drifting of brackets was noted and pressure was needed for positioning the bracket with Filtek Z-350 and Esthet-X flow .
- The flow property and viscosity should be balanced to obtain optimal consistency to achieve optimal bond strength and improve handling property for Filtek Z-350 and Esthet-X flow.
- Future research need to be focused towards the biocompatibility, rheological property and viscosity for Filtek Z-350 and Esthet-X flow to be used as orthodontic adhesive.

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