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Analysis of mode of fracture and adhesive remnant index of self-adhesive composite resin on sound and bleached enamel surface

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Abstract

Introduction: Orthodontic bracket bonding with enamel surface of teeth is the fundamental procedure for orthodontic treatment and is directly related with an effective and successful teeth alignment. The objective of study was to analyze adhesive remnant index (ARI) of self-adhesive resin used for orthodontic brackets, to assess bond strength, and to determine the type of bond failure and its location.

Materials and Methods: This was an experimental study conducted at School of mechanical and chemical engineering SCME (NUST) with a duration of 6 months. Sixty premolar teeth between the age of 13-25 were randomly selected. The inclusion criteria were non dried, non-fractured teeth with intact buccal surface. All teeth were stored in normal saline. They were then divided into three equal groups. (n=20). Group one was a non-bleached (control group). Group two was bleached and bracket bonded on the same day. While group three was bleached two weeks prior to bracket bonding. Orthodontic brackets were bonded with RelyXU 200 self-adhesive on all respective groups. Mechanical de bonding was performed at Universal Testing Machine at the cross-head speed of 1 m m/sec. The (ARI) adhesive remnant index and fracture mode was determined with the stereo microscope having six-fold magnification and grading was carried out for given groups.

Results: For ARI, Pearson Chi Square test showed significance level of 0.01 which indicated significant difference among groups. The failure mode of self-adhesive was mainly adhesive at the enamo – adhesive interface.

Conclusions: The RelyX U200 showed the trend of adhesive failure for all groups with no adhesive on enamel surface or very minimal amount of adhesive on enamel. This enables the orthodontist to spend much less time on the post bonding cleanup. Iatrogenic damage to enamel due to rotary instrument is also reduced.

Keywords: ARI; bond failure; mode of fracture; self-adhesive composites

Introduction

Dental adhesives are contemporary resin monomers and are classified as etch and rinse adhesives, self-etch adhesive and self-adhesives.[1] Etch and rinse phenomenon is carried out by chemical etc hing with phosphoric acid and then applying priming and adhesive. This produces a hybrid layer which is a resin-tooth inter diffusion zone. Adhesive bonding is considered superior to mechanical bonds as they produce lesser stress concentration and can fully utilize the properties of adherend.[2] As adhesion is the surface phenomenon so properties of adhesive bond depends upon surface properties. Adhesive bonding presents many advantages over mechanical bonding like greater resistance to fatigue, vibration and corrosion.[3]

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The concept of adhesion in the field of dentistry was introduced in 1950 when the Swiss chemist Oskar Hagger developed a preliminary adhesive monomer, which was based upon glycerol phosphoric acid dimethacrylate.[4] Later on many investigators worked on enamel bonding with resin.[5,6] This revolution of adhesive dentistry had replaced the conventional method of tooth preparation for filling, based upon Blacks concept of extension for prevention by more conservative approaches. Current advent and development of resin-based adhesive materials have led to remarkable revolution in dental practice and expanded its application in orthodontic treatment, cementation of fixed prosthesis, porcelain laminates and tooth colored restorations in anterior and posterior teeth.[7]

Orthodontic bracket bonding with enamel surface of teeth is the fundamental procedure for orthodontic treatment and is directly related with an effective and successful teeth alignment.[8] There are two main regimes employed for this. The etch and rinse adhesive which are used through acid etching procedure followed by conditioning and priming leading to adhesive and self-adhesives having less filler content, less technique sensitive, dual cure composites that joins a bracket with dental substrate.[9] Newer self-adhesives have potential to simplify bracket bonding procedure from multi step to one step. RelyXU200 (3M ESPL St. Paul, MN 55144-1000 USA) is a single step self-adhesive, dual cure resin based material primarily introduced as luting materials, has proven to have many desirable properties.[10] The RelyX U200 is phosphoric acid based methacrylates which demineralize and infiltrate the tooth substrate producing micromechanical tags. They simply adhere to the tooth surface with distinct resin tags besides secondary chemical adhesion to hydroxyapatite. There is acid functionalized monomer to demineralize the tooth substrate and the proportion of inorganic filler to resin is about 43:67 by volume.[11,12]

The setting reaction involved radical polymerization producing cross-linking of methacrylate monomers that is further reinforced by silane treated fillers and hence gives high mechanical strength with minimal solubility and low water absorption.[13]

Regarding bond strength, the two different interfaces are considered, one established between enamel and the self-adhesive and the other between and self-adhesive and orthodontic bracket. The bond strength of the interfaces should be optimized as the weakest one will determine the cemented bracket strength.[14] In an oral cavity, tooth-bracket interface is exposed to diverse forces simultaneously. During setting, polymerization shrinkage puts stresses on the bond, and during function, different mechanical stresses due to chewing forces, thermal and chemical stress with variation in temperature and pH may effect bond integrity.[15]

In this study, RelyX U200 is investigated as the orthodontic cementing material and analyzed bonding potential and mode of fracture of RelyXU200 agent for sound (non-treated) and bleached (treated) enamel surface. The physical properties of self-adhesive resin, their bond strength, and micro leakage potential have been described by manufactures.[16] However, the scientific evidence on the adhesive properties of this cement is scarce along fewer data regarding the shear bond strength testing on bleached enamel.[17]

Material and Methods

This study was an experimental study. It was carried out at School of chemical and mechanical engineering (SCME) NUST Islamabad in six months' time duration. Sixty extracted human teeth (premolars and molars) of 13-25 years' age group were randomly selected. The inclusion criteria were

non dried, non-fractured with intact buccal surface. All teeth were stored in normal saline[18] and then divided into three groups (n =20).[19] Relyx U200 (3M ESPL St. Paul, MN 55144-1000 USA) self-adhesive was our material for testing. It was supplied in two paste system i.e. base paste and catalyst paste. Equal amount of both pastes were extruded and mixed over the mixing paper. For control group, self-adhesive was applied over whole bracket base and these brackets were attached with buccal surface of teeth and light cured.[20] Group two teeth were bleached with Ever Bright advanced tooth whitening system 1866E San Jose Ave city of industry, CA91748USA. After bleaching, bracket bonding was performed with above mentioned self-adhesive on same day. For group three, bleaching and bracket bonding were carried out with two weeks' time interval. Debonding was carried out with a shear blade attached to a Universal Testing Machine (Model AG20knx Plus Shimadzu Japan at the crosshead speed of 1mm/ sec.[21] Teeth and bracket were then examined under stereomicroscope at six fold magnification. Mode of failure were recorded according to following scale (Table I).[22]

Table I. :Adhesive remnant index ARI (according to adhesive present).

Grade 1	No adhesive left on the tooth and all the material was on the bracket.
Grade 2	Less than half of the material was left on the tooth.
Grade 3	Half of the material was on the tooth and half was on the bracket.
Grade 4	More than half material was present on tooth.
Grade 5	All of the material found on the tooth with an impression of mesh of bracket.

Score1 indicated fracture at the adhesive enamel interface and score2, 3 and 4 indicated mixed or cohesive mode of fracture. However, score 5 indicated all adhesive on the tooth. The bond strength of these interfaces were significant as the weakest link would give the final bond strength of bracket to tooth.[23] Using SPSS version 21, the data was statistically analyzed and interpreted. The variables were control, immediately bleached and bonded, and delayed bleached and bonded. To determine p value, the residual adhesive was compared with Pearson Chi Square test.

Results

The results of Chi Square test to compare the scores showed the presence of significant difference between the groups (p=0.01),(Table II,III).

Table II. Adhesive Remnant Index For Group of study

		Group of study			Total
		Control	Bleached	delayed	
Adhesive ramnant index	Grade1	11	14	5	30
	Grade2	3	6	3	12
	Grade3	1	0	3	4
	Graed4	1	0	5	6
	Grade5	4	0	4	8
Total		20	20	20	60

Table III: Chi Square Test

Chi-Square Tests			
	value	*df*	*asymp. sig. (2-sided)*
Pearson chi-square	20.200a	8	.010
n of valid cases	60		
a. 12 cells (80.0%) have expected count less than 5. The minimum expected count is 1.33.			

Coefficient of Contingency is a coefficient which shows whether two variables are independent or dependent of each other. As this value 0.502 is away from 0 and it is towards 1, showing the positive relationship between the variables. (Table IV).

Table IV: Coefficient of contingency

		Value	*Approx. Significance*
Nominal by Nominal	*Contingency Coefficient*	0.502	0.010
N of Valid Cases		60	

The predominant failure mode was adhesive at the enamel–adhesive phase (Figure 1).

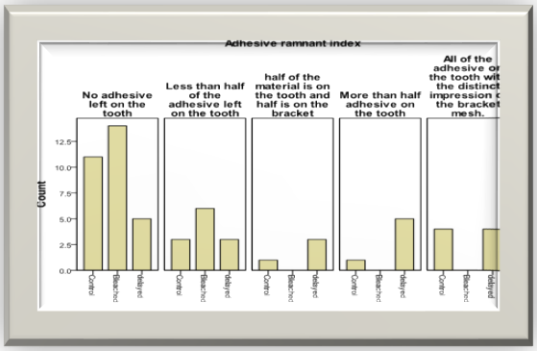

figure 1. Adhesive Remnant Index for all study groups

Discussion

The evolution of materials science demands simplification in material handling, manipulation and application. Over the years numerous adhesive materials have been introduced, a relatively recent advancement is one step self-adhesives.[11] In our study, there was mainly adhesive type of fracture with no adhesive or very few amount of adhesive over the tooth surface and grade 1 of ARI analysis.

The phenomenon of adhesion is regarded as the hierarchy of multiple forces. According to mechanical theories, adhesion is microscopic interlocking between two surfaces and an increase in contact surface area leads to an increased interlocking space and thus greater adhesion. Self-adhesives resin based composites infiltrates and produces micromechanical spaces.[24] Their primary adhesion with tooth structure was through distinct resin tags, while secondary adhesion was carried out by chemical bonding of phosphate group with hydroxyapatite crystals.[25] In 2019, Nagarkar et al studied different self-adhesive resins and discussed their chemistry, marginal adaptation, chemical adhesion and potential clinical advantages. The self-adhesive does not require separate acid etching, so significantly lower enamel loss is reported with the application of self-adhesives.[26] Fewer operatory steps, reduced chair- side time and easy manipulation eliminate the chances of error due to multiple steps and thus related to lower rate of post-operative sensitivity and debonding.[27]

The ARI analysis also helps to determine the location of bond failure. In 2017, Z Cai *et al* concluded that the ARI score is array of multiple factors including design of bracket base, adhesive composition, ratio, force type, location of applied force and bond strength at the interface and the bond failure would occur at the weakest link of bonding site.[28] Relyx U200 showed adhesive failure at tooth adhesive interface for all groups which is favorable preventing instrumental damage to enamel and reducing chair side time These findings are comparable to Zhang et al and Ferraz et al who found higher frequency of adhesive fracture in self-adhesives.[24,29] However clinical debonding could be different from in vitro results as a complex interplay of occlusal forces and cyclic fatigue at bracket adhesive interface. Furthermore, temperature and pH variation may affect bond strength.[30]

RelyxU200 is having relatively fluid consistancy as compared to conventional orthodontic adhesives which may cause bracket sliding and difficult to intially stabilizing the bracket on tooth surface. There fore, for orthodontic bracket place ment, it is recomanded to menufacturer to change the consistancy and to add more conditioner etchant to strengthen the adhesion at tooth adhesion interface and to increase the

durability of bonding. For immediately bleached and bonded group bond strength was significantly lower as compared to control and delayed group therefore bracket bonding immediately after bleaching is not recommended.[7,31]

Conclusions

RelyXU200 self-adhesive showed higher tendency of grade1 of ARI and has mainly adhesive type of mode of fracture which is favorable, time saving for post bonding cleanup and consequently less damaging to enamel. However there is need to change its consistency and composition to potentially increase its bonding strength. Long term clinical trials need to be carried out to prove their efficiency.

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