ASSESSMENT OF ENAMEL LOSS AFTER DEBONDING OF CERAMIC, COMPOSITE AND METAL BRACKETS-

AN IN VITRO STUDY

Dissertation Submitted to

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MASTER OF DENTAL SURGERY

BRANCH - V
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CERTIFICATE

This is to certify that the dissertation titled “Assessment of enamel loss after debonding of ceramic, composite and metal brackets- an in-vitro study” done by Dr.G.INDUMADHI, Post graduate student (M.D.S), Orthodontics (branch V), Tamil Nadu Govt. Dental College and Hospital, Chennai, submitted to the Tamil Nadu Dr. M.G.R. Medical University in partial fulfillment for the M.D.S. degree examination (April 2013) is a bonafide research work carried out by her under my supervision and guidance.

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DECLARATION

I, Dr. G.Indumadhi, do hereby declare that the dissertation titled "Assessment of enamel loss after debonding of ceramic, composite and metal brackets" was done in the Department of Orthodontics, Tamil Nadu Government Dental College & Hospital, Chennai 600 003. I have utilized the facilities provided in the Government Dental College for the study in partial fulfillment of the requirements for the degree of Master of Dental Surgery in the speciality of Orthodontics and Dento-facial Orthopaedics (Branch V) during the course period 2010-2013 under the conceptualization and guidance of my dissertation guide, **Professor Dr.S.Premkumar, M.D.S**. I declare that no part of the dissertation will be utilized for gaining financial assistance for research or other promotions without obtaining prior permission from the Tamil Nadu Government Dental College & Hospital. I also declare that no part of this work will be published either in the print or electronic media except with those who have been actively involved in this dissertation work and I firmly affirm that the right to preserve or publish this work rests solely with the prior permission of the Principal, Tamil Nadu Government Dental College & Hospital, Chennai 600 003, but with the vested right that I shall be cited as the author(s).

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And
Mr. Dr.S.Premkumar aged 43 years working as **Professor** in Department of Orthodontics and Dento-facial Orthopedics at the college, having residence address at B-3,Block 2,Jains ashraya Phase III, Arcot road,Virugambakkam, Chennai 600092 (herein after referred to as the “Principal Investigator”)
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Miss. Indumadhi aged 31 years currently studying as **Post Graduate student** in Department of Orthodontics and Dento-facial Orthopedics, Tamilnadu Government Dental College and Hospital, Chennai - 3 (herein after referred to as the “PG student and co- investigator”).

Whereas the PG student as part of her curriculum undertakes to research on “**ASSESSMENT OF ENAMEL LOSS AFTER DEBONDING OF CERAMIC, COMPOSITE AND METAL BRACKETS- AN IN-VITRO STUDY**” for which purpose the Principal Investigator shall act as principal investigator and the college shall provide the requisite infrastructure based on availability and also provide facility to the PG student as to the extent possible as a Co- investigator.

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College represented by its

Principal **PG Student**

Witnesses **Student Guide**
1.

2.

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LIST OF COLOUR PHOTOS

LIST OF ABBREVIATIONS

1)ARI-Adhesive Remnant Index

2)mARI-Modified Adhesive Remnant Index

3)EDS-Energy dispersive spectroscopy

4)SEM-Scanning electron microscope

5)Ca^{++} -Calcium ion

6)$ARI_{BRACKET}$ Modified Adhesive remnant index score on bracket surface

7)ARI_{TOOTH} Adhesive remnant index score on tooth surface

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ASSESSMENT OF ENAMEL LOSS AFTER DEBONDING OF CERAMIC, COMPOSITE AND METAL BRACKETS

BACK GROUND: As more adult patients started seeking orthodontic treatment, this lead to the development and improvisation of newer esthetically superior bracket materials but still the disadvantages of these materials remain unresolved. One such aspect of concern is enamel loss and cracks after debonding of ceramic brackets. The amount of enamel lost during the removal of adhesive may be of clinical significance because of the removal of a major part of the protective fluoride-rich layer of enamel. Debonding consists of Debracketing and adhesive removal. This study is about enamel loss after debracketing of ceramic, composite plastic and metal (stainless steel) brackets.

AIMS:-To assess the enamel loss after debonding of ceramic, composite and metal brackets (Stainless steel) and to compare them.

METHODOLOGY: - The sample consisted of 90 maxillary I premolars (both right and left side) that were extracted for orthodontic purpose. The teeth were randomly assigned into three equal groups of 30 teeth each. Group I were bonded with ceramic brackets (Virage), Group II were bonded with composite plastic brackets (Silkon Plus) and Group III were bonded with stainless steel (Mini master series) brackets. The teeth were then stored for 48 hours in distilled water at 37°C before debonding All the brackets were debonded according to manufacturers' instructions. After debonding all the tooth surfaces were evaluated by ARI index. Tooth surfaces are examined by scanning electron microscope in order to verify the presence and sites of the enamel cracks. All the bracket surfaces were examined under a stereomicroscope and scored according to the Modified Adhesive Remnant Index (m ARI). In addition, energy dispersive spectroscopy attached to High Resolution Scanning Electron Microscope was used to detect calcium (Ca) on the adhesive material removed during debonding of the brackets. All the results obtained were tabulated and analyzed using Pearson's Chi-square test.

RESULTS:- Adhesive Remnant Index on tooth surface bonded with ceramic brackets showed least amount of lower $\text{ARI}_{\text{TOOTH}}$ score which implies more damage to enamel surface and composite plastic and stainless steel brackets showed mostly higher $\text{ARI}_{\text{TOOTH}}$ Score indicating less damage to tooth surface. On scanning electron microscopic examination, the enamel surfaces bonded with ceramic bracket resulted in more enamel cracks; composite plastic bracket showed negligible amount of enamel crack and stainless steel brackets showed no enamel cracks. Ceramic brackets showed higher $\text{ARI}_{\text{BRACKET}}$ score indicating more damage to enamel surface, composite plastic bracket and stainless brackets showed lesser values indicating least amount of enamel damage. Energy Dispersive Spectroscopy analysis proved that the loss of elemental calcium is more evident in tooth surface bonded with ceramic bracket.

SUMMARY AND CONCLUSION:-Enamel loss after debonding was assessed by both quantitative and qualitative methods in this study. The results indicate that after debonding of ceramic bracket enamel loss is more, when compared to that of composite plastic and metal brackets. This implies that debonding of ceramic bracket needs meticulous attention and strict adherence to manufacturer's instructions is recommended.

KEY WORDS:-Adhesive remnant index, scanning electron microscope, Energy dispersive spectroscopy.

INTRODUCTION

The earlier fixed appliances attached brackets and tubes to the patient’s teeth with bands, and significant limitations existed in the degree of accuracy possible with cemented bands. Bonding of attachments, eliminating the need for bands, was a dream for many years before rather abruptly becoming a routine clinical procedure in the 1980s. Bonding is based on the mechanical locking of an adhesive to irregularities in the enamel surface of the tooth and to mechanical locks formed in the base of the orthodontic attachment.

Michael G Buonocore (1955)[18] revolutionized dentistry with his historical paper: “A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces” depicting the advantage of etching and bonding of acrylic to enamel. It forever changed the practice of dentistry. Newman (1965)[57] introduced direct bonding as a viable clinical technique in the field of Orthodontics as an excellent alternative to banding, and its popularity increased significantly over the next years.

The advantages of direct bonding are conservation of arch length, ease of placement and esthetic superiority. Direct bonding procedure requires debonding at the end of active treatment. Great consideration should be given to de-bonding procedures and the effect that these procedures have on the enamel surface underlying the bonded attachments.

The term debonding refers to removal of orthodontic attachments and all the residual adhesive from the enamel surfaces and restore as closely as possible to its pretreatment condition without inducing iatrogenic damage[30]. The color similarity between adhesives used and enamel does not allow for complete removal of remaining adhesive which discolors with time and creates an esthetic problem.

Hosein[32] et al pointed out that more surface enamel is lost during the debonding and clean up procedures than during bonding.

The amount of enamel lost during the removal of adhesive may be of clinical significance because of the removal of a major part of the protective fluoride-rich layer of enamel. The highest fluoride concentration is at the surface, and a rapid decline in concentration is in the first 20 µm of enamel[16,45,46,64]. It would therefore seem undesirable to remove that much enamel in any procedure.

Debonding may cause considerable abrasion of enamel. Tooth surfaces microscopically manifested many scratches and surface irregularities in varying degrees. The rougher surfaces could potentially contribute to plaque accumulation, stain, odor, and demineralization through microbial activity. Calcium loss from the enamel surface particularly can result in dental erosion, which is a localized loss of dental hard tissues.

As more adult patients started seeking orthodontic treatment, esthetic brackets were wanted. So in 1963, Morton Cohen and Elliott Silverman brought out the first commercially available plastic brackets. They had drawbacks like distortion and color absorption.

In the mid 1980s, ceramic brackets were introduced into the field of orthodontics, as an esthetic alternative to plastic brackets, which could withstand most orthodontic forces and resist staining. Debonding of these brackets has caused more enamel fractures and cracks than metal brackets. The lack of ductility of these brackets may generate stress in the adhesive–enamel interface that may produce enamel cracks at debonding.

Ceramic brackets using chemical retention cause enamel damage more often than those using mechanical retention[9,12]. This damage occurs probably because the location of the bond breakage is at the enamel–adhesive interface rather than at the adhesive–bracket interface.

Bishara et al reported that 18% of teeth had an increase in the number or severity of enamel cracks following the debonding of ceramic bracket[75].

With the wide array of bracket materials available today, it becomes the duty of the orthodontist to select the best material that is esthetically pleasing, clinically effective, and at the same time causing least amount of enamel damage. So it is necessary to assess the amount of enamel loss after debonding of various bracket materials. Scanning electron microscope and Energy dispersive spectroscopy were used in this study to assess the enamel loss.

This study aims to take a further step forward in our understanding of enamel loss after debonding in orthodontic treatment.

AIMS AND OBJECTIVES

AIMS OF THE STUDY:

The aims of the present investigation were to assess enamel loss after debonding of ceramic, composite and metal brackets and to compare them.

OBJECTIVES:

1. To assess the amount of residual adhesive on the tooth surface after debonding of three different bracket materials.
2. To examine the enamel surface structure for enamel cracks after debonding of different types of brackets using the Scanning Electron Microscope.
3. To assess the amount of residual adhesive on the bracket surface after debonding.
4. Examination of brackets by energy dispersive spectroscopy for elemental calcium lost from the enamel surface.

REVIEW OF LITERATURE:

1) ENAMEL LOSS AFTER DEBONDING

The mean linear tensile strength of enamel is 14.5MPa. Thus, when the force required to remove the bracket from the enamel exceeds the mean linear tensile strength of the enamel or the bracket itself, fracture of the enamel surface or the bracket takes place.

Retief [69] (J Oral Rehabil 1974) reported that enamel fracture can occur with bond strengths as low as 13.5MPa which was comparable to the linear tensile strength of the enamel. Therefore, a debonding technique that reduces the required forces for debracketing reduces the risk of enamel fracture.

The study by **Fitzpatrick** and **Way**[27] (AJO 1977) showed enamel loss during etching, bonding, and debonding of an ultraviolet light-polymerized adhesive to be 55.6 µm.

Zachrisson[97] (AJO 1977) however, making reference to his own studies and to the reports of **Mannerberg**[50], suggests that total loss in bonding and debonding procedures is less than 5 µm. He measured the height of perikymata at 5 µm and by demonstrating their presence on scanning electron micrographs after debonding, had concluded that virtually no enamel had been lost. The difference could be at least partially accounted for as a result of the entirely different measuring technique employed. Another experimental difference between the two studies was that Zachrisson used a low-speed, six-fluted tungsten carbide bur for clean-up, whereas Fitzpatrick and Way used a high-speed, twelve-fluted tungsten carbide finishing bur.

Brown and **Way**[15] in their article published in AJO 1978 mentioned that the techniques required in the removal of highly filled composite adhesives at the end of orthodontic treatment on an average cause more loss of enamel than removal of an unfilled polymethylmethacrylate adhesive and the amount of enamel lost during the removal of either adhesive may be of clinical significance because of the removal of a major part of the protective fluoride-rich layer of enamel and the use of zirconium silicate on a rotating bristle brush may cause considerable abrasion of enamel.

John Gwinnett, Gorelick [36](1977) mentioned that Enamel is a heterogeneous tissue composed of submicroscopic crystallites embedded in a sparse organic matrix. Its special biophysical and micromorphologic characteristics predispose it to many and varied abrasion anomalies. Enamel may frequently show gouging in addition to scratching and grooving. In order that these abrasion anomalies produced in enamel can be eliminated, it is necessary to decrease the size of the anomaly progressively by the sequential use of abrasives of decreasing particle size .For unfilled and lightly filled resins, the simplest, most conservative method and least traumatic to enamel in debonding, consisted of the judicious use of hand instruments and pumice. Where necessary, this may be augmented with a cooled, medium, green rubber wheel. In the case of heavily filled resins, the use of the cooled green rubber wheel always appeared indicated because it rapidly abrades away the composite and very little enamel while producing fine scratches that are readily removed with pumice.

Zachrisson and **Artun**[98] (1979) investigated about the enamel surface and mentioned that the quality of enamel surfaces after debonding of orthodontic brackets was assessed under clinical and experimental conditions by means of stereomicroscopy and scanning electron microscopy. The most adequate results were obtained with the Tungsten Carbide bur. This tool, operated at low speed, produced the finest scratch pattern and the least enamel loss, and it was superior in accessibility to developmental grooves and other difficult-to-reach areas.

Peter Diedrich[22], (1981)did a study on enamel alterations from bracket bonding and debonding using scanning electron microscope and he mentioned that plastic brackets displayed more torn-off fragments of superficial enamel layers than metal brackets in which fracture occurred mostly at the interface adhesive/mesh pad.

Swartz[92] (JCO 1988)recommends applying a slow peeling force at the base of the ceramic bracket with mechanical interlock and slow gradual compression mesio-distal to the base of the brackets with chemical adhesion. He speculates that the crack propagation occurs within the adhesive rather than in the enamel. Crack lines, heavy caries, large restorations, hypoplasia and hypocalcification should be contraindications to bonding with ceramic brackets.

Samir E. Bishara and **Timothy S. Trulove**[13,14] (1990)did an investigation using three debonding techniques--conventional, ultrasonic, and electrothermal-- to remove three types of ceramic brackets .They mentioned that there was no evidence of enamel damage in their study but combination bond failures occurred with significantly greater frequency for the brackets debonded by the recommended conventional techniques. Their results point to the need for a careful approach to bracket removal by the clinician, to minimize the potential for enamel damage.

Joseph and Russouw [47] (AJO 1990) speculated that the use of ceramic brackets on non-vital teeth could cause a higher incidence of enamel fracture at debonding.

Bishara and **Trulove**[13](AJO 1990) reported that ultrasonic and electro thermal debonding of ceramic brackets resulted in lower incidences of bracket fracture, higher frequency of failure at the bracket/adhesive interface, and decreased chances of enamel damage. However the ultrasonic technique required significantly increased debonding time, excessive wear of the expensive ultrasonic tips, the need to apply force levels possibly uncomfortable to the patients with sensitive tooth, the potential for soft tissue injury, and the need for a water spray to avoid pulpal damage from heat build up.

M. Toufic Jeiroudi[36] et al(1991)presented a case report-" Enamel fracture caused by ceramic brackets" .He said accidentally debonded bracket surfaces showed evidence of enamel debris. There was no sign of pulpal damage.

Thomas B.Redd,Shivapuja [68] et al (1991) in their study on debonding Ceramic Brackets and its effects on enamel. They concluded that enamel damage is more likely from debonding ceramic brackets than from debonding metal brackets, although it may only be apparent microscopically and ceramic brackets using mechanical retention appear to cause enamel damage less often than those using chemical retention and the pistol-type debonding instrument is more comfortable for the patient and appears to have less potential for damage to the enamel than other instruments.

Joseph Ghafari [28] et al (angle 1992) mentioned that small teeth may pose higher risk of tooth fracture than larger tooth. If the load application tends to fracture ceramic brackets, breaking the adhesive-bracket interface would probably minimize damage to enamel surface.

Winchester[95]*(BJO 1992)* suggested an agent that can contribute to easier debonding - a derivative of peppermint oil(Post-debonding agent, GAC International Inc.) that is applied around the bracket base and is left for 2 minutes before debonding. According to this method, ceramic bracket removal can be facilitated and failure at the adhesive/enamel interface, without damaging the tooth surface, can be promoted. Laboratory studies had shown that a 60-second application of peppermint oil facilitated ceramic bracket removal and promoted failure at the adhesive-enamel interface, without damaging the tooth surface[89].

Ghafari, Skanchy [29] (JCO1992) suggested that increasing the resin space between the bracket base and the tooth through grooves or recesses might reduce the debonding force by favoring bond failure within the adhesive itself. Storm found it more difficult to debond ceramic brackets bonded with heavily filled resins than those bonded with a hybrid filled resin which produced more failures at the bracket –resin interface.

Failure mode analysis of ceramic brackets bonded to enamel was evaluated by **Theodore Eliades, Anthony D.Viazis and Lekka**[24] (1993).According to them the effect of the debonding procedure on enamel structure was significantly affected by the various bonding mechanisms of the bracket bases. Cohesive enamel fractures were detected from brackets that provided a bonding mechanism of micromechanical retention and chemical adhesion. The brackets that combined mechanical retention and chemical adhesion, presented both cohesive resin fractures and fractures located at the bracket resin or the resin enamel interface. The higher frequency of cohesive bracket fracture was obtained from mono-crystalline bracket.

Keith V.Krell, James M.Courey, Samir E.Bishara [47](AJO 1993) in their investigation about orthodontic bracket removal using conventional and ultrasonic debonding techniques and enamel loss proved that enamel loss as a result of orthodontic bracket removal is minimized by first removing the bracket with the debonding pliers, followed by ultrasonic removal of the residual composite .

Bishara, Fehr, and Jacobson[13] (AJO 1993) in their comparative study of the debonding strengths of different ceramic brackets, observed that enamel damage after debonding occurred with only one molar tooth. The tooth was etched with phosphoric acid and bonded to a chemically/mechanically retained ceramic bracket (Allure) with a highly filled adhesive (Phase II).In this study, the enamel damage was evaluated visually with a magnifying loop.

Joseph M. Bordeaux, Robert N. Moore [40] (AJO 1994) discussed about the base designs that have been modified to reduce tooth damage during debonding of ceramic brackets. They compared fracture sites of four second-generation ceramic brackets (base designs have been modified). The ceramic brackets tested did not cause enamel damage during debonding.

Joseph & Rossouw [41] (1994) demonstrated that the Transcend Bracket caused fracture within the enamel. They concluded that increased mechanical retention in the base of the bracket reduces enamel damage during debonding while maintaining adequate bond strength.

Campbell[20] (A0 1994) examined the enamel surfaces after debonding and said that scarring of enamel following debonding was inevitable.

Pramod K. Sinha, Ram S. Nanda[65] (AJO1995) published an article about bond strengths and remnant adhesive resin on debonding for orthodontic bonding techniques .The direct method comprised bonding the attachments directly to the incisors with the composite resin. The indirect-1 method comprised securing attachments to die-stone models of the teeth with a water soluble glue, making silicone positioners to transfer the brackets from the models to the teeth, and bonding to the teeth with the use of the two-paste composite resin system. The indirect-2 method comprised bonding the attachments to die-stone models of the teeth with composite resin, making silicone positioners to transfer the brackets from the models to the teeth, and bonding to the teeth with the use of unfilled sealant resin. The bonding technique has an influence on the ARI score. The indirect-2 technique had significantly lower ARI scores compared with the direct and indirect-1 techniques, therefore requiring little or no cleanup after debonding. The direct technique had significantly lower ARI scores compared with the indirect-1 technique.

According to **Sinha, Michael and Nanda**[66] (1995)the indirect bonding techniques, create a resin interlayer when used with ceramic brackets eased problems related to bracket fracture on debracketing.

Tsun Ma, Roy D. Marangoni[86] in 1997(AJO) observed during their in vitro study on comparison of debonding force and intrapulpal temperature changes during ceramic orthodontic bracket removal using a carbon dioxide laser and mentioned that Lasers thermally soften the bonding resin, which reduces the tensile debonding force. Thermal effects of lasers may create adverse effects to the dental pulp. It is feasible to use a laser for the debonding of ceramic brackets while keeping the intrapulpal temperature rise below the threshold of pulpal damage.

R.G.Oliver[59] et al(1998)studied the effect of different methods of bracket removal on the amount of residual adhesive. He mentioned that a shear force applied with the blades of debonding pliers or ligature cutters positioned at the enamel/composite interface leads to enamel damage together with reports of enamel being removed with the composite, militate against use of this method.

Sergio J.Weinberg, Timothy F.Foley[93] (Angle 1997)compared the bond strengths of two ceramic brackets using Argon laser, light and chemically cured resin systems. Debonded surfaces are examined under stereomicroscope.No enamel fractures were found on debonding the chemically cured brackets while the laser and light cured exhibited a 10% rate of enamel fracture on debonding.

Karina.S.Mundstock, P.Lionel Sadowsky[43] (AJO1999) did an in vitro evaluation of a metal reinforced orthodontic ceramic bracket. They measured and compared the bond strength and failure sites of an already available ceramic bracket with the new metal reinforced ceramic bracket and evaluated the amount of composite left on the tooth using the Adhesive Remnant Index in the teeth that were debonded with pliers recommended for this purpose. In addition, the presence or absence of enamel damage after debonding was also assessed. Both brackets failed mostly at the bracket-adhesive interface (75%), indicating a possible reduction of the chances of enamel damage. Six of the premolars, bonded with Transcend 6000 brackets and debonded with the plier, showed an increase in the number or length of enamel cracks as evaluated by an optical microscope (Micro-Vu); one premolar, bonded with Clarity brackets and debonded with the pliers, showed an increased enamel crack length. Gross enamel damage, assessed by enamel dislodgment, was not evident in any specimen. Results of this study suggest that the new metal reinforced ceramic bracket (Clarity) may be recommended for clinical use because of its acceptable shear bond strength and possible reduced chances of enamel damage during bracket removal.

Theodorakopoulou LP, Sadowsky PL[84] in 2004 evaluated and compared the shear bond strengths and bond failure locations of polycrystalline and monocrystalline orthodontic ceramic brackets. No enamel damage was evident in any specimen when the brackets were removed with the appropriate pliers. Their results indicate that the safest way to remove ceramic brackets with respect to reducing the chance of enamel damage is to use the debonding technique specifically designed for each ceramic bracket.

Tufekci E, Mirrill TE, Pintado MR[87](AJO 2004) mentioned that the White spot lesions is considered to be a precursor of enamel caries by making the area slightly softer than surrounding sound enamel. These incipient carious lesions demonstrated about 10% reduction in the mineral content of enamel. This reduction in the inorganic content of WSL is an important contributing factor to their increased abrasion in vivo making it more prone to enamel loss during debonding procedures.

A. J. Ireland, I. Hosein[35] (2005) during their study on enamel loss at bond-up, debond and clean-up following the use of a conventional light-cured composite and a resin-modified glass polyalkenoate cement, observed that the least enamel loss occurred following the use of the slow-speed tungsten carbide bur and the greatest loss was seen with the ultrasonic scaler or high-speed tungsten carbide bur. Overall, the lowest enamel loss was observed with the poly(acrylic acid) conditioner and Fuji Ortho LC.

J. S. Russell[74] (Journal of Orthod, 2005) on a review paper about aesthetic orthodontic brackets said that rigid ceramic brackets present a debonding challenge, with enamel damage more likely. The sudden nature and the degree of force required to achieve mechanical bond failure of the early chemically bonded ceramic bracket, often resulted in enamel fractures and delamination. Alternatively, the brackets shattered leaving the base still attached to the enamel surface. Removal of the residual ceramic, using a diamond bur in a high-speed handpiece is both difficult and time consuming.

Neslihan Eminkahyagil, Arman A[25] (AO 2006) in his study on effect of resin-removal methods on enamel found that the high-speed TCB was found to be the most hazardous to the enamel. The scarring of enamel after the debonding is inevitable but it can be reduced.

Scott A. Soderquist, James L. Drummond[79] in 2006 evaluated the bond strength of ceramic and stainless steel bracket bases subjected to cyclic tensile loading. All brackets performed without enamel fracture, but the high bond strength brackets displayed increased risk of enamel fracture. In this study, cyclic fatigue did not show clinically unacceptable bond strengths or an increased incidence of enamel fracture for the ceramic brackets used. Out of all, stainless steel bracket has excellent fatigue resistance and moderate bond strength because of metal deformation that prevents enamel fracture.

Hsing-Yu Chen,a Ming-Zen Su[33](AJO2007)investigated the effects of different debonding techniques on the debonding forces and failure modes of ceramic brackets in simulated clinical set-ups . The Clarity ceramic brackets were debonded with Howe pliers. The Inspire and the Inspire Ice ceramic brackets were debonded with the specifically designed plastic pliers recommended by the manufacturer

(Ormco). No enamel damage was found in this study. The results indicate that it is safe to remove ceramic brackets with the pliers recommended by the manufacturers.

Maryam Habibi, Tahereh Hossein zadeh Nik[51], (2007)in their in-vitro study on comparison of debonding characteristics of metal and ceramic orthodontic brackets to enamel used three types of orthodontic brackets (metal, ceramic with chemical retention, and ceramic with mechanical retention) that were bonded to the teeth with a luting resin composite. The brackets were debonded with a sharp-edged debonding pliers in a universal testing machine. Enamel cracks were evaluated with a stereomicroscope. It shows that, the increases in the numbers of enamel cracks were 25% for metal and chemically retained ceramic brackets and 33.3% for mechanically retained ceramic brackets, but these differences were not significant. In addition, no significant difference for increased crack length was found in the 3 groups. No enamel or bracket fracture occurred during debonding any of these brackets. They stated that the relatively smaller contact area of the narrow blades of the debonding pliers was sufficient to start and propagate a crack in the adhesive. This was claimed to reduce the trauma of debonding because of the reduced stress on the enamel surface. The risk of enamel damage when debonding ceramic brackets is not greater than the risk when debonding metal brackets.

Neslihan Arhun, Ayca Arman[56] in a review paper (Seminars in Ortho 2007) on effects of orthodontic mechanics on tooth enamel mentioned that the maximum bond strength should be less than the cohesive strength of enamel, which is approximately 14 MPa, to allow for the removal of the bracket without causing damage to the enamel. Bond strengths lower than 12.75 MPa would be safe for the enamel. The process of debonding a bracket from the tooth has the potential to result in iatrogenic damage to the surface of the enamel. The sites of failure can be between the bracket and the adhesive, within the adhesive itself, or between the tooth surface and the adhesive. There are two schools of thought regarding the amount of adhesive remaining on the teeth surface after debonding. One favours the failure at bracket-adhesive interface leaving the adhesive resin on the enamel surface and the second at the enamel-adhesive resin interface leaving much less adhesive left on the enamel surface. It should be kept in mind that whenever debonding forces exceed the enamel strength, the result will be enamel fracture and crazing. Increased bond strength with ceramic brackets resulted in bond failure at the enamel surface, rather than at the bracket adhesive interface, resulting in more enamel fractures. Two particular properties of ceramics—hardness and brittleness—have necessitated the use of special debonding instruments to prevent both the enamel and bracket fracture. The earliest type of debonding instruments used on ceramic brackets, which applied heavy shear-torsion forces, resulted in enamel fracture or cracks. Referring to Swartz they recommended a sharp-edged debonding instrument placed at the enamel-adhesive interface for ceramic brackets. Applying the load to the 2 sides of the bracket simultaneously with the pliers increases the chance of creating a crack in the brittle adhesive. Referring to Storm they suggested that a rotational motion with a specially designed ceramic bracket debonding instrument would be safer for the enamel surface. Alternative methods of debonding ceramic brackets have been proposed such as ultrasonic, electrothermal, and laser techniques**.** Increasing the bond strength may increase the susceptibility to enamel fracture during debonding. Minimal thickness of the adhesive helps in reducing the debonding forces markedly, thereby preventing enamel cracks as well as surface irregularities.

Rihito Kawabata[71](Ortho Waves 2007) in a research paper about bonding and debonding characteristics of orthodontic brackets to human enamel using modified4-META/MMA-TBB resin, mentioned that Phosphoric acid etched specimens showed enamel fracture upon debonding of orthodontic bracket. On the contrary, no enamel fracture was recognized in self-etching primed specimens. The addition of TCP/CaF2(A mixture of a-tricalcium phosphate (a-TCP) and calcium fluoride (CaF2) (1:1, w/w) was added to the polymer powder of resin) tended to be associated with more residual resin on the tooth surface after debonding, which suggests a lower risk of enamel fracture. TCP/CaF2-modified resin used with self-etching primer appears to allow easy and safe debonding of orthodontic brackets without loss of adequate bracket bond strength.

Samir E. Bishara; Adam Wade Ostbyb[77] et al (Angle 2008) conducted a study on enamel cracks and ceramic bracket failure during debonding in vitro. Enamel surfaces were visualized with transillumination prior to bonding and after removal of the residual adhesive, so the effect of the debonding forces could be determined. The new debonding instrument left relatively less adhesive on the tooth after debonding than was left by conventional Utility pliers. The present results also reveal that changes in the enamel surface following debonding were essentially the same between the two types of pliers. Most teeth showed no increase in the frequency or severity of cracks. The new pliers produced a lower incidence of bracket fracture.

Flávia Mitiko Fernandes Kitahara[26] (AJO2008) in their study on assessment of enamel damage after removal of ceramic brackets used different type of brackets in each group: mechanical retention, mechanical retention with a polymer base, and chemical retention. After debonding, the surfaces were again photographed. The photographs were evaluated for quality of enamel surface according to a predetermined scale. The results showed no significant statistical difference between the mechanical retention group and the polymer base retention group. There was a significant statistical difference (P _0.05) for the chemical adhesion ceramic bracket group. Bonding and debonding these brackets resulted in enamel damage.

Adam W. Ostby Samir E. Bishara,John F. Laffoon,John J. Warren[1](sem in orthodontics MAR 2010)states that enamel damage is more likely to take place during debonding of ceramic than metallic brackets, and monocrystalline ceramic brackets display more enamel loss than polycrystalline. Also, ceramic brackets with chemical retention appear to cause enamel damage more often than those with mechanical retention.

The probability of damaging the tooth structure by applying mechanical debonding methods would be even higher, if the integrity of the tooth structure was already compromised by the presence of developmental defects, enamel cracks and large restorations, or the ceramic bracket was bonded on a nonvital tooth.

ADHESIVE REMOVAL METHODS: Removal of attachments and all resin remnants from tooth surfaces is the final procedure required to return the enamel surface as closely as possible to the original pretreatment condition. Therefore, many researchers have introduced different techniques for resin removal and subsequent enamel polishing without causing iatrogenic damage; these include scraping with a scaler or a band-removing plier and removal with a tungsten carbide bur in a contra angle handpiece, as well as the use of Sof-Lex discs (3M ESPE).Ultrasonic applications and air abrasion techniques with aluminum oxide particles have been investigated as alternative methods for removing adhesive remnants. In addition, studies have demonstrated that laser energy degrades the bonding resin, and that lower force is used for bracket removal, suggesting that it could be used for resin removal as well. The commonly preferred method is to use a suitable bur in conjunction with a polishing disc and subsequently a polishing paste. If the normal enamel surface is seen after all adhesive has been removed,polishing with pumice or prophylaxis paste may be optional.

Zachrisson and Bu¨yu¨kyılmaz[97] (AJO 1977) reported that about 30,000 rpm is optimal speed for resin removal without enamel damage. Clinical and laboratory studies have revealed that rotary instruments may alter the enamel surface irreversibly by causing deep scratches or lost enamel. Frequently, adhesive remnant has been found on the enamel surface, even after cleaning and polishing with rotary instruments.

K. Zarrinnia, N.M. Eid, M.J. Kehoe[96] did a study **in 1994**.The purpose of their in vitro study was to evaluate the enamel surface structure subjected to various techniques of debonding orthodontic attachments and to develop a technique for residual adhesive removal that restores the enamel surface as closely as possible to its pretreatment condition without introducing iatrogenic damage. Enamel surface structure was examined with a scanning electron microscope. Results of this study show the bracket removing plier produced the most consistent separation at the bracket-adhesive interface, leaving the enamel surface intact. Carbide burs at high speed and air coolant proved to be efficient in residual resin removal, but when used alone, failed to produce a satisfactory enamel surface. After the removal of residual resin, graded medium, fine, and superfine Sof-Lex finishing disks (Unitek Corp., Monrovia, Calif.) produced surfaces that could be readily restored satisfactorily after receiving a final polish with a rubber cup and Zircate paste.

Amna Hassan Al Shamsi, J. Leo Cunningham[2](AJO 2007) evaluated 3-dimensionally the changes on tooth surfaces by using 3-dimensional laser scanning technology after debonding orthodontic brackets and after removing residual adhesive and finishing. The mean (_ SD) enamel loss after cleaning and finishing the enamel surface of the teeth bonded with Fuji Ortho LC adhesive was 22.8 µm, and the maximum loss was 70µm. The mean enamel loss for the Adhesive PreCoated brackets was 50.5µm, and the maximum loss was 120µm.

Sevinc Karan &Beyza[80] (Angle 2010) published an article on enamel surface roughness after debonding. They compared two different burs eight-bladed tungsten carbidebur and a fiber-reinforced composite bur. After resin removal, evaluation of the smoothness of enamel surfaces via Atomic force microscopy (AFM) analysis that uses multiple mechanical scans in high resolution was done. They concluded composite bur used creates smoother surfaces compared with the carbide bur—even smoother than original surfaces.

STUDIES ON DIFFERENT METHODS OF DEBONDING OF CERAMIC BRACKETS:

Ceramic brackets are nine times harder than stainless steel brackets or enamel. Tensile strength is much stronger in monocrystalline alumina than in polycrystalline alumina, which in turn is significantly stronger than stainless steel. Fracture toughness in ceramics is 20 to 40 times less than in stainless steel, making it much easier to fracture a ceramic bracket than a metallic one[73].Among ceramic materials polycrystalline alumina presents higher fracture toughness than Single crystal alumina. The brittle nature of ceramic brackets has resulted in a higher incidence of bracket failure (fracture) during debonding. Recently developed ceramic brackets have incorporated silane coupling agents required significantly greater shear bond strength to cause debonding and pure adhesive failure. As the properties of ceramic brackets differ significantly from those of metal brackets, techniques for removing bonded metallic orthodontic attachments are not as effective as with ceramic brackets and thus special Debracketing techniques are recommended.

Conventional technique: The first technique used for debonding ceramic brackets was mechanical. Manufacturers have produced special instruments or pliers for debonding their own ceramic brackets, although the A-Company Starfire debonding pliers may be used to remove any bracket according to **Birnie**[7] et al(BJO 1992). **Bishara SE, Fehr DE**[8] (AJO 1993) stated that pliers cause either deformation of the bracket, thus breaking the bond at the bracket-adhesive interface or by stressing the adhesive to its ultimate strength causing cohesive failure within the composite resin. Sometimes failure may occur at the adhesive-enamel interface. The force required for mechanical bond failure is very high and thus leads to enamel and bracket fracture. **Swartz**[81] (JCO 1988) recommended that ceramic brackets should be debonded with a sharp-edged instrument (ligature cutter) placed at the enamel adhesive interface, and a "slow gradual squeezing" force should be applied until bracket failure occurs.

ELECTRO-THERMAL DEBONDING :

Jost-Brinkmann, Harald Stein[42] (AJO 1992) on their histologic investigation of the human pulp after electrothermal debonding of metal and ceramic brackets mentioned that the thermodebonding of metal brackets worked properly and without any obvious pulp damage, there were problems related to the thermodebonding of ceramic brackets, if more than one heating cycle was necessary, several teeth showed localized damage of the pulp with slight infiltration of inflammatory cells, bracket fractures occurred frequently, and enamel damage could be shown, and often with Transbond (Unitek/3M, Monrovia, Calif.) as the adhesive, more than one heating cycle was necessary for bracket removal, and thus patients complained about pain.

Joseph S. Dovgan,Richard E. Walton, Samir E. Bishara[39,23](AJO 1995) mentioned that patient acceptance was generally positive after electro thermal debracketing. Pulpal necrosis was not observed but, in a number of specimens, slight inflammation and odontoblastic disruption occurred at both observation periods.

John J. Sheridan, Glenn Brawley, Joe Hastings[37,38](AJO 1986) mentioned that All electrothermal procedures in the sample elicited pulpal wall temperatures that were significantly below the primate baseline. When water spray was used in conjunction with ETD, the mean ultimate increase in pulpal wall temperature was less than 1° C and ETD is a physiologically acceptable alternative to conventional debracketing techniques.

Bishara and Trulove[13] (AJO 1990) found the electrothermal technique to be quick, effective, and devoid of either bracket or enamel fracture. One concern with this method was related to the potential for pulp damage, because a signifcant rise in pulp temperature may result in tooth necrosis. However, subsequent investigations found that the heating temperature during electrothermal debonding was too low and the heating time was too short for pulp damage. Bond failure at the bracket-adhesive interface was observed mainly when the Starfire brackets were debonded with the ETD instrument. The obvious advantage is a reduction in the probability of enamel damage during debonding, since all of the adhesive remains on the tooth surface.

ULTRA SONIC TIPS:

Bishara S. Trulove T [13,14] (AJO 1990) mentioned that the ultrasonic debonding technique has been used to create a purchase point within the adhesive between the bracket base and the enamel surface. In this technique, the brackets are debonded with KJS ultrasonic tips and the Cavitron 2002 ultrasonic unit (Dentsply International). The advantages of the ultrasonic debonding approach include a decreased chance of enamel damage, a decreased likelihood of bracket failure and the ability for the removal of the residual adhesive with the same instrument after debracketing. Many authors found bond failures at the enamel-adhesive interface with this approach However, there are a number of disadvantages associated with the ultrasonic technique, including a significantly increased debonding time, excessive wear of the expensive ultrasonic tips, the need to apply moderate force levels, which could create some discomfort to sensitive teeth, the potential for soft tissue injury by a careless operator, and the need for a water spray to reduce the heat build-up and to minimize any possibility of pulpal damage. Since the ultrasonic method is effective but time consuming, its use might be indicated when a ceramic bracket fractures while the conventional method is being used and part of it remains attached to the tooth.

The use of lasers (Nd:YAG and CO2)for debonding ceramic brackets has been investigated by **Strobl K, Bahns TL, Willham L**[48](AJO 1992). The proposed laser-aided debonding technique was found to significantly reduce the residual debonding force, the risk of enamel damage and the incidence of bracket fracture as compared with the conventional methods, and the method can be used for removal of various types of ceramic brackets, regardless of their design. This technique has the potential to be less traumatic and painful for the patients. According to **Tocchio RM, Williams PT, Mayer FJ**[85] (AJO 1993), it was found to favor bond failure at the bracket adhesive interface with no bracket or enamel damage. After CO2 laser illumination for 2 seconds the average torque force necessary to break the adhesive between the polycrystalline ceramic brackets and the tooth was lowered by a factor of 25. Similarly the average torque force needed to debond monocrystalline brackets was lowered by a factor of 5.2. Strobl et al concluded that the debonding mechanism was thermal softening of the resin adhesive by the laser induced heat which transmitted through the bracket to the resin. Actually laser-initiated resin degradation can occur as the result of either thermal softening or thermal ablation or photoablation.

NATURE OF BOND FAILURE DURING DEBRACKETING OF METAL BRACKETS:-Bond failure at the bracket resin interface was considered preferable to the resin enamel interface. If fracture occurs heterogeneously at the resin-enamel interface, it may lead to uncontrolled fracture within the enamel. **Bennett**[5] et al (JCO 1984) in their extensive study with photo elastic stress analysis to determine stress areas in the enamel during bracket removal found that forces applied to the outer wings of bracket transferred the least amount of stress to the enamel, whereas forces applied to the base of the bracket and to the adhesive zone created stress concentration regions within the enamel surface that caused separation at the enamel-adhesive interface.

Yapel and **Quick**[54] (Angle 1994) reported that a rapidly applied force was associated with a relatively high risk of enamel damage. Accidental impacts to an orthodontic appliance could cause debracketing of brackets with secondary damage to enamel surface. Ceramic brackets offered a margin of safety over metal brackets because they were more prone to breakage and dispersed the force of an impact , and were less likely to be associated with enamel damage. According to **Katona TR**[44] (Angle 1997) tension during Debracketing was less likely to cause enamel damage than sheer peel loading.

NATURE OF BOND FAILURE DURING DEBRACKETING OF CERAMIC BRACKETS:-The adhesion between the resin and ceramic bracket bases has increased to a point where the most common site of bond failure during debonding has shifted from the bracket base interface to the enamel-adhesive interface, a less desirable site. This shift has lead to an increase in the incidence of bond failures within the enamel surface. Nevertheless there is some controversy about the site of bond failure for ceramic brackets.

Odegard and Segner[58] (AJO 1988) found bond failure in ceramic brackets to be more prevalent at the enamel-adhesive interface, in contrast to metal brackets, where bond failure occurred predominantly at the bracket-adhesive interface. According to them the bond strength between ceramic brackets and adhesive was more than bond strength between adhesive and enamel in the shear mode.

Ripley[13] (1990) found different sites of bond failure with different types of retention in ceramic brackets. A ceramic bracket employing a combination of chemical and mechanical retention had significantly less shear bond strength but significantly higher tensile bond strength than one retained by chemical methods only. The analysis showed that the predominant site of bond failure for the combination of chemical and mechanical retentive system was at the enamel-adhesive interface, while bond failure for chemically retained brackets occurred primarily at the bracket-adhesive interface .Therefore, the increase in bond strength of bonded ceramic brackets and the greater incidence of bond failure at the enamel-adhesive interface could increase the risk of enamel damage.

Bishara SE, Olsen ME, Von Wald L[12] (AJO1997) conducted a study on evaluation of debonding characteristics of a new collapsible ceramic bracket. They state that although all types of ceramic brackets present a challenge during debonding, mechanically retained brackets have adequate bond strength and cause minimal enamel damage. The main advantage of the Clarity collapsible ceramic bracket was that it can be debonded in the same manner as metal bracket. When the new ceramic brackets were debonded with the Weingart pliers, most of the residual adhesive remained on the enamel surface, a pattern that is similar to the one observed with metal brackets. The failure at the bracket-adhesive interface decreases the probability of enamel damage but necessitates the removal of more residual adhesive after debonding.

Samir E. Bishara, Marc E. Olsen, Leigh VonWald[76] (AJO 1999) compared the debonding characteristics of two innovative ceramic bracket designs i.e., one designed with a metal-lined arch wire slot and the other with an epoxy resin base. The new brackets are thought to combine the esthetic advantages of ceramics and the functional advantages of debonding metal brackets. The failure occurred at the bracket-adhesive interface that decreases the probability of enamel damage but necessitates the removal of more residual adhesive after debonding. Bishara et al concluded that the site of bond failure of an epoxy resin base ceramic bracket debonding by mechanical method was at bracket-adhesive interface.

Pramod K. Sinha, Ram.S.Nanda[66] (1995) in their study to determine the effect of the interlayer on conventional debonding techniques for polycrystalline ceramic orthodontic brackets, used 3 different techniques (direct, indirect (modified Thomas), and an indirect technique that used a thermal-cured resin). No enamel damage was observed in any of the groups evaluated under a stereomicroscope and a scanning electron microscope. Interlayer formation in the indirect bonding techniques significantly affects the debonding of polycrystalline orthodontic brackets by reducing bracket failure and causing no enamel damage.

Samir E. Bishara, Juanita M. Fonseca[75] (1995) published an article about debonding pliers in the removal of ceramic brackets and found that the ARI scores were found to range between 2 and 4 indicating a cohesive type of bond failure. Transillumination was used to evaluate minute enamel damage, and the results indicated that most of the teeth (82.02%) experienced no increase in enamel cracks after debonding. The teeth that showed an increase in the number of cracks after debonding had significantly higher mean bond strength (113 Kg/cm 2) than those with no increase in the number of cracks.

IN VITRO ASSESSMENT OF ENAMEL SURFACES

Studies assessing tooth surface conditions following debonding have used linear contact measuring devices. Quantitative measurements were made for visualising enamel surfaces before and after debonding with a miniaturized Boley gauge (**Brown** and **Way**[15], 1978), or by optical profilometric techniques. Both techniques allowed only a few measurements per tooth surface and thus may have created less accurate final results. Digital scanning and associated software has improved the accuracy of assessment. **Quick**[54] *et al.* (1992) developed a scanning ruby laser digitizer to scan and measure dental impressions and casts. The accuracy of this system needs to be enough to measure differences of up to 40µm. **Van Waes**[89] *et al.* (1997) assessed loss of enamel caused by orthodontic bracket bonding and debonding using a mechanical computerized 3D scanner with resolution of 1µm.

Al Shamsi[2] *et al.* (2007) describe the use of a fast, non-contacting laser probe which scans 8000 to 14,000 measured points per second, depending on surface topography, allowing enhanced visualisation of the enamel surface. The accuracy of the laser was found to be up to 8µm with reproducibility of 2µm.

Lee and Lim[49] (2008) reported on the use of a 3D laser profilometer to measure the amount of residual adhesive following removal of orthodontic brackets cemented using three different adhesives. The use of the Adhesive Remnant Index (ARI) has provided rank scores, but not a true numerical value. It is also a surface area assessment, and not 3-dimensional volumetric measure.

ENERGY DISPERSIVE SPECTROSCOPY: **Peter Diedrich**[22], (1981)discussed about enamel alterations from bracket bonding and debonding with the scanning electron microscope and in this study torn-off particles of enamel which adhered to the bracket's lower surface were proved by the differing micromorphology and material contrast and by the energy dispersive spectroscopy.

U. Stratmann, K. Schaarschmidt[88] (EJO 1996) in their study compared thermally debonded ceramic and mechanically debonded metal brackets and evaluated the extent of enamel surface fractures by energy dispersive micro- and image-analysis. They proved the mineral-like particles attached to the adhesive fracture surfaces belong to enamel surface.

Wei Nan Wang, Ching Liang Meng[90] (AJO1997) mentioned that the greater bond strength with a chemically coated base of ceramic brackets had a greater debonded interface between enamel and resin, and the weaker bond strength of mechanical interlock base of ceramic and metal brackets had a greater debonded interface between bracket and resin. They examined the debonded interface and enamel detachment with scanning electron microscope and energy dispersive x-ray spectrometer. The enamel detachment was found on only the stronger bond strength in which there was a chemically coated base on the ceramic bracket. They concluded that the mechanical interlock base of the ceramic bracket combines the strength, durability and retention of a metal bracket along with an aesthetic advantage and no enamel detachment after debonding.

Ponts[34](AJO 2010)in his study on performed elemental analysis on the debonded bracket bases by using energy dispersive x-ray spectrometry mean area scanning analysis. The incidence of Ca% from the scanned brackets showed significant differences between the maxillary and mandibular teeth, especially for the canines and second premolars. With more remnants on the bracket base, the Ca% was higher. Iatrogenic damage to the enamel surface after bracket debonding was inevitable.

G. Merone[53] et al (EJO2010) in his research analysed debonded surfaces using scanning electron microscopy (SEM) and electron dispersion spectrometry (EDS). EDS showed that the conventional brackets demonstrated less damage to the enamel surface.

Uma H.L., B. Chandralekha[88](AOSR 2012) in their invitro study on scanning electron microscopic evaluation of the enamel surface subsequent to various debonding procedures –mentioned that Tungsten carbide bur produced the smoothest enamel surface followed by ultrasonic scaler and hand scaler respectively.

MATERIALS

MATERIALS USED

1) 90 maxillary first premolars that were extracted for orthodontic purpose.

2) Virage ceramic brackets – Maxillary I premolar 022” slot Roth series brackets

3) Silkon plus composite plastic brackets- Maxillary I premolar 022” slot Roth series brackets

4) Mini master series stainless steel brackets- Maxillary I premolar 022” slot Roth series Brackets.

5) 3M ESPE SCOTCHBOND Multipurpose Etchant

6) 3M Unite adhesive primer

7) 3M Unite Bonding Adhesive

8) Pumice

9) Two tone disclosing solution-FDC No.3 Red.

INSTRUMENTS USED

1) Bracket holder

2) Applicator tip for Primer

3) Contra angle hand piece

4) Rubber cup

5) Sickle probe

6) Chip blower

7) #001-343 Ceramic debonding pliers (Fig 6)

8) 001-001E Ligature cutter (Fig 1)

9) 001-346E Direct Bond Bracket Remover (Fig 1)

10)Magnifying lens

EQUIPMENTS USED IN THIS STUDY:

SCANNING ELECTRON MICROSCOPE (SEM): It is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. The beam of electrons interact with electrons in the sample, producing various signals that can be detected and that contain information about the sample's surface topography and composition. In the most common or standard detection mode, secondary electron imaging or SEI, the SEM can produce very high-resolution images of a sample surface, revealing details less than 1 nm in size. Due to the very narrow electron beam, SEM micrographs have a large depth of field yielding a characteristic three-dimensional appearance useful for understanding the surface structure of a sample. (Fig 10)

OPTICAL STEREO MICROSCOPE: The stereo or dissecting microscope is an optical microscope variant designed for low magnification observation of a sample using incident light illumination rather than transillumination. It uses two separate optical paths with two objectives and two eyepieces to provide slightly different viewing angles to the left and right eyes. In this way it produces a three-dimensional visualization of the sample being examined. Use of reflected light from the object allows examination of specimens that would be too thick or otherwise opaque for compound microscopy. The large working distance at low magnification is useful in examining large solid objects such as fracture surfaces, especially using fibre-optic illumination. Such samples can also be manipulated easily so as to determine the points of interest. (Fig 11)

ENERGY-DISPERSIVE X-RAY SPECTROSCOPY (EDS OR EDX): It is an analytical technique used for the elemental analysis or chemical characterization of a sample. It relies on the investigation of an interaction of some source of X-ray excitation and a sample. Its characterization capabilities are due in large part to the fundamental principle that each element has a unique atomic structure allowing unique set of peaks on its X-ray spectrum. To stimulate the emission of characteristic X-rays from a specimen, a high-energy beam of charged particles such as electrons or protons, or a beam of X-rays, is focused into the sample being studied. At rest, an atom within the sample contains ground state (or unexcited) electrons in discrete energy levels or electron shells bound to the nucleus. The incident beam may excite an electron in an inner shell, ejecting it from the shell while creating an electron hole where the electron was. An electron from an outer, higher-energy shell then fills the hole, and the difference in energy between the higher-energy shell and the lower energy shell may be released in the form of an X-ray. The number and energy of the X-rays emitted from a specimen can be measured by an energy-dispersive spectrometer. As the energy of the X-rays are characteristic of the difference in energy between the two shells, and of the atomic structure of the element from which they were emitted, this allows the elemental composition of the specimen to be measured.(Fig 12)

METHODOLOGY

SAMPLE SELECTION:

The sample consisted of 90 maxillary I premolars (both right and left side) that were extracted for orthodontic purpose. Since Hobson[71] *et al.* (2001), noted significant differences in bond strength between upper and lower premolars and Bora Ozturk[60] in his report in EJO 2008 says that to obtain reliable results in enamel bond strength studies, the same tooth type from the upper or lower arch should be used and Ponts[34] (AJO 2010) reported that calcium loss was different between maxillary and mandibular teeth, only maxillary premolars were included for this study.

INCLUSION CRITERIA:

1) All teeth had intact buccal enamel and were free of carious lesions and large restorations.

2) No evidence of enamel decalcification.

3) No history of fracture while extracting by forceps.

4) No evidence of enamel cracks as examined by fibre-optic transillumination.

5) Not treated with any chemical agents.

6) All teeth were obtained from 14-23 years age group

All the samples were cleaned and stored in distilled water at room temperature (Fig 2). Prior to the start of the experiment, the teeth were rinsed and randomly assigned to three equal groups of 30 teeth. Group I were bonded with ceramic brackets (Virage), Group II were bonded with composite plastic brackets (Silkon Plus) and Group III were bonded with stainless steel (Mini master series) brackets.

All the brackets were examined by scanning electron microscope before bonding. (Fig 4)

BONDING PROCEDURE:

Prophylaxis was done with water and pumice without fluoride with a rubber cup for 5 seconds under low rotation (Fig 3).Each rubber cup was replaced after 5 prophylactic procedures[26]. The surfaces were then rinsed for 15 seconds and dried with an oil-free air compressor.

All teeth were then bonded according to the manufacturers' instructions.

ETCHING:

The buccal enamel was etched for 15 seconds with a 35 per cent phosphoric acid gel(3M ESPE SCOTCHBOND MULTIPURPOSE ETCHANT) , rinsed with water spray for 15 seconds, air-dried for 2 seconds (with oil-free compressed air).

APPLYING ADHESIVE PRIMER: After etching buccal tooth surface was sealed with 3M Unite adhesive primer (3M Unitek, Monrovia, California, USA).The adhesive primer was applied on the bracket base also.

APPLYING BONDING ADHESIVE:3M Unite adhesive- a no mix adhesive for direct bonding (3M Unitek) was placed onto the bracket base over the primer, and the bracket was firmly pressed on the prepared enamel; the excess adhesive was then removed with an explorer. Due to the transparent nature of ceramic brackets, it is possible to achieve a higher degree of polymerization of the resin adhesive (Özcan[59] *et al.* , 2004) compared to other groups if light cure adhesive used.So, to avoid any bias, chemical cure adhesive was used in this study. The teeth were then stored for 48 hours in distilled water at 37°C before debonding[51].

DEBONDING: All brackets were debonded according to manufacturer's instructions.

CERAMIC BRACKET: Virage brackets used in this study were debonded by using the recommended #001-343 debonding pliers by placing the opposing tips of the pliers occlusal and gingival under the tie wings of the bracket, while applying constant pressure to the handles. (Fig 7)

COMPOSITE PLASTIC BRACKET:Silkon plus composite brackets used in this study were debonded by using 001-001E ligature cutter by placing the beaks of the plier mesio-distally and applying constant pressure.(Fig 8)

STAINLESS STEEL BRACKET:Mini master series brackets used in this study were debonded by 001-346E Direct Bond Bracket Remover by applying pressure from the gingival to occlusal aspect at 45° angulation.(Fig 9)

ASSESSMENT OF ENAMEL SURFACE AFTER DEBONDING:

1) QUALITATIVE ASSESSMENT METHODS

a) EVALUATION OF THE RESIDUAL ADHESIVE ON TOOTH SURFACE by ADHESIVE REMNANT INDEX

After debonding all the tooth surfaces were examined by a magnifying hand lens after applying disclosing solution and evaluated by ARI index by a single observer. To avoid intra-observer bias scoring was done twice. The ARI scores also were used as a more complex means of defining the sites of bond failure between the enamel, the adhesive, and the bracket base.

b) SCANNING ELECTRON MICROSCOPIC EXAMININATION OF THE TOOTH SURFACE FOR ENAMEL CRACKS. Tooth surfaces corresponding to lower ARI scores are examined by scanning electron microscope(HITACHI-3400 N,Japan) and Gold ion sputtering machine, (HITACHI E 1010 Ion Sputter) in order to verify the presence and sites of the enamel cracks.

c) EVALUATION OF THE RESIDUAL ADHESIVE ON BRACKET SURFACE by MODIFIED ADHESIVE REMNANT INDEX

All the bracket surfaces were examined under a stereomicroscope with 20×magnification and scored according to the Modified Adhesive Remnant Index (mARI) with respect to the amount of resin material that adhered to the bracket surface. Scores were given by a single observer. To avoid intra-observer bias scoring was repeated again.(Fig 11)

2) QUANTITATIVE ASSESSMENT METHOD

In addition, energy dispersive spectroscopy (EDAX ^{TSL}-AMETEK,Advanced Micro analysis solutions) attached to FEI Quanta FEG 200-High Resolution Scanning Electron Microscope was used to detect calcium (Ca) on the adhesive material removed during debonding of the brackets. Morphologically notable mineral-like particles attached to the adhesive fracture surface as well as the particle-free adhesive fracture surfaces were analysed for their elemental composition by an energy dispersive X-ray microprobe. (Fig 12)

STATISTICAL ANALYSIS:All the results obtained were tabulated and analysed using Pearson’s Chi-square test. It is a nonparametric test that is used to determine the significance of the difference between independent groups, when the data consists of frequencies in discrete categories.

FIGURE 1-ARMAMENTARIUM

FIGURE 2-Teeth sample stored in distilled water

FIGURE 3-Prophylaxis with rubber cup and pumice

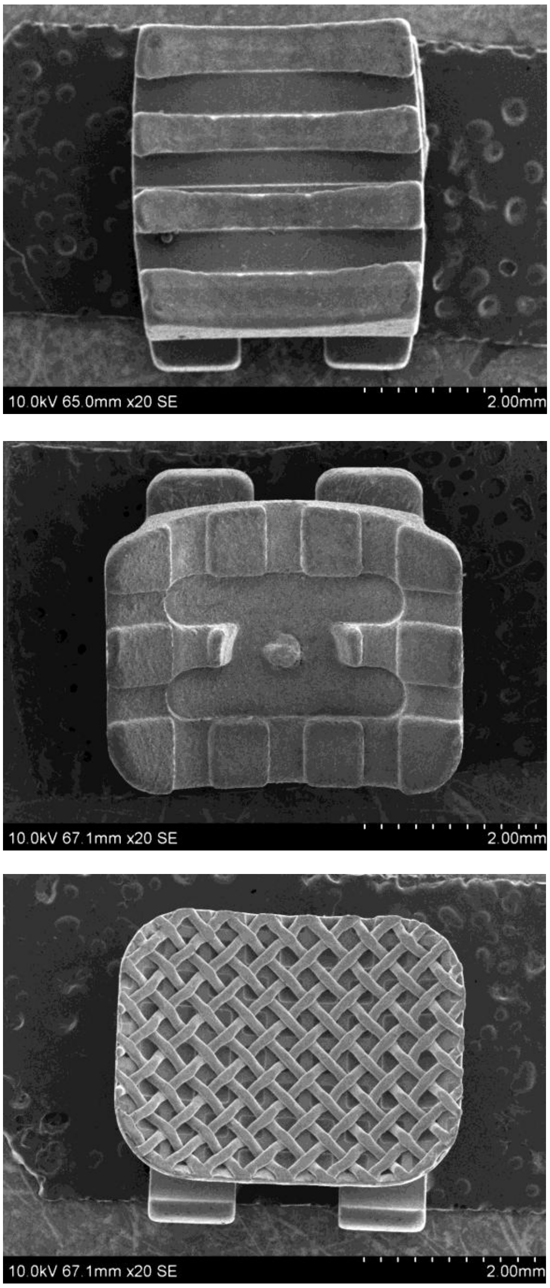


FIGURE 4 -Bracket surfaces examined before bonding using scanning electron microscope

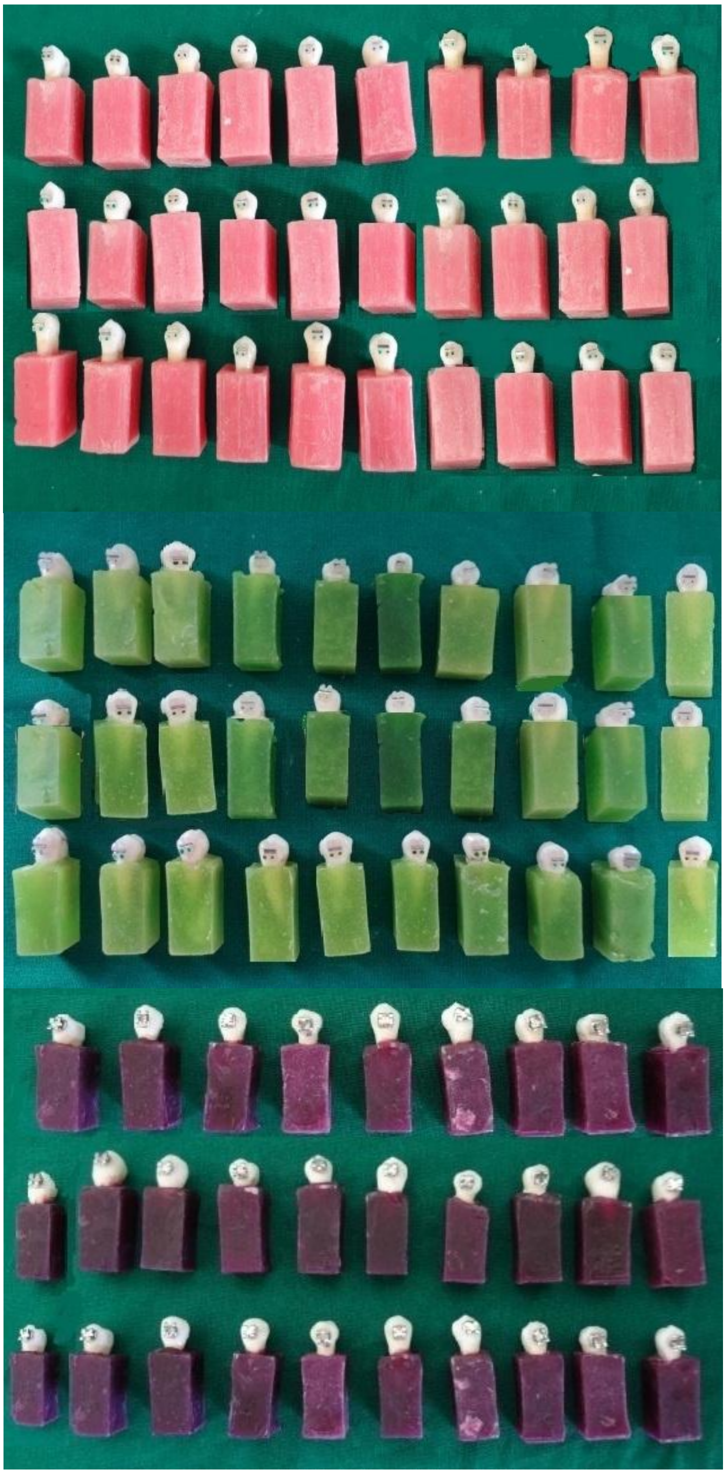


FIGURE 5-BONDED TEETH SAMPLES

PINK-Ceramic bracket

GREEN-Composite Plastic bracket

PURPLE-Stainless steel bracket

FIGURE 6--#001-343 debonding pliers for ceramic bracket

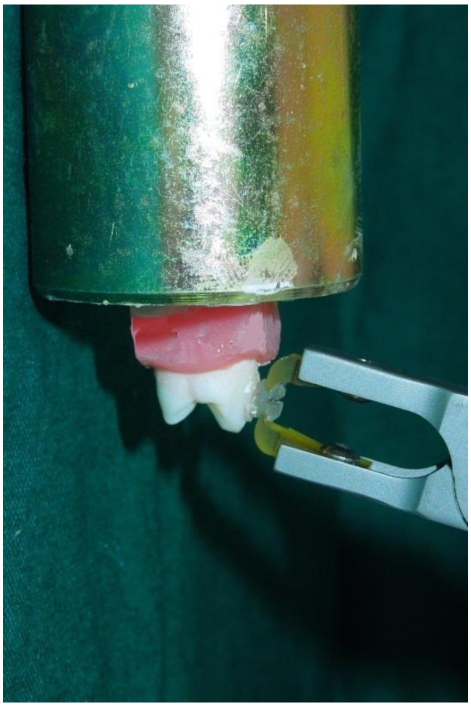


FIGURE 7- Debonding of ceramic bracket

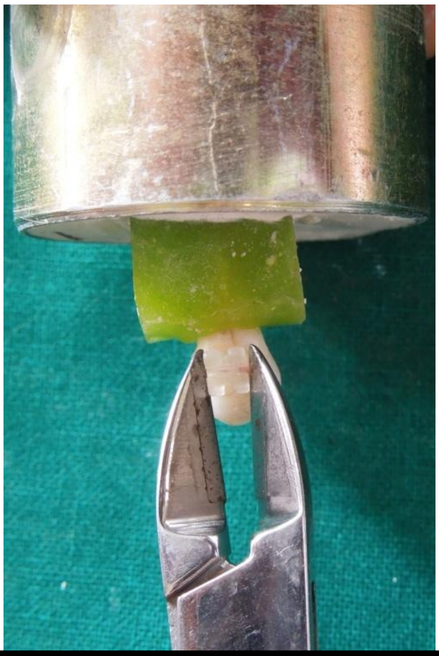


FIGURE 8-Debonding of composite Bracket

FIGURE 9-Debonding of stainless steel bracket

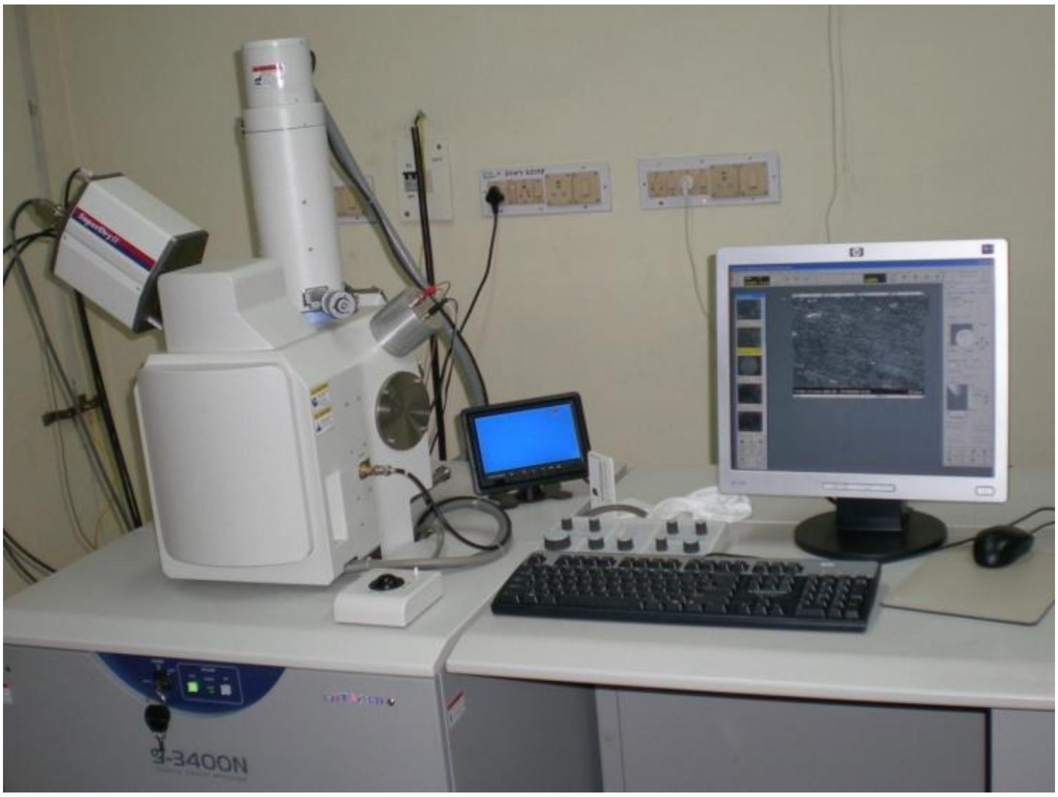


FIGURE 10-SCANNING ELECTRON MICROSCOPE-Used for examining tooth surfaces after debonding

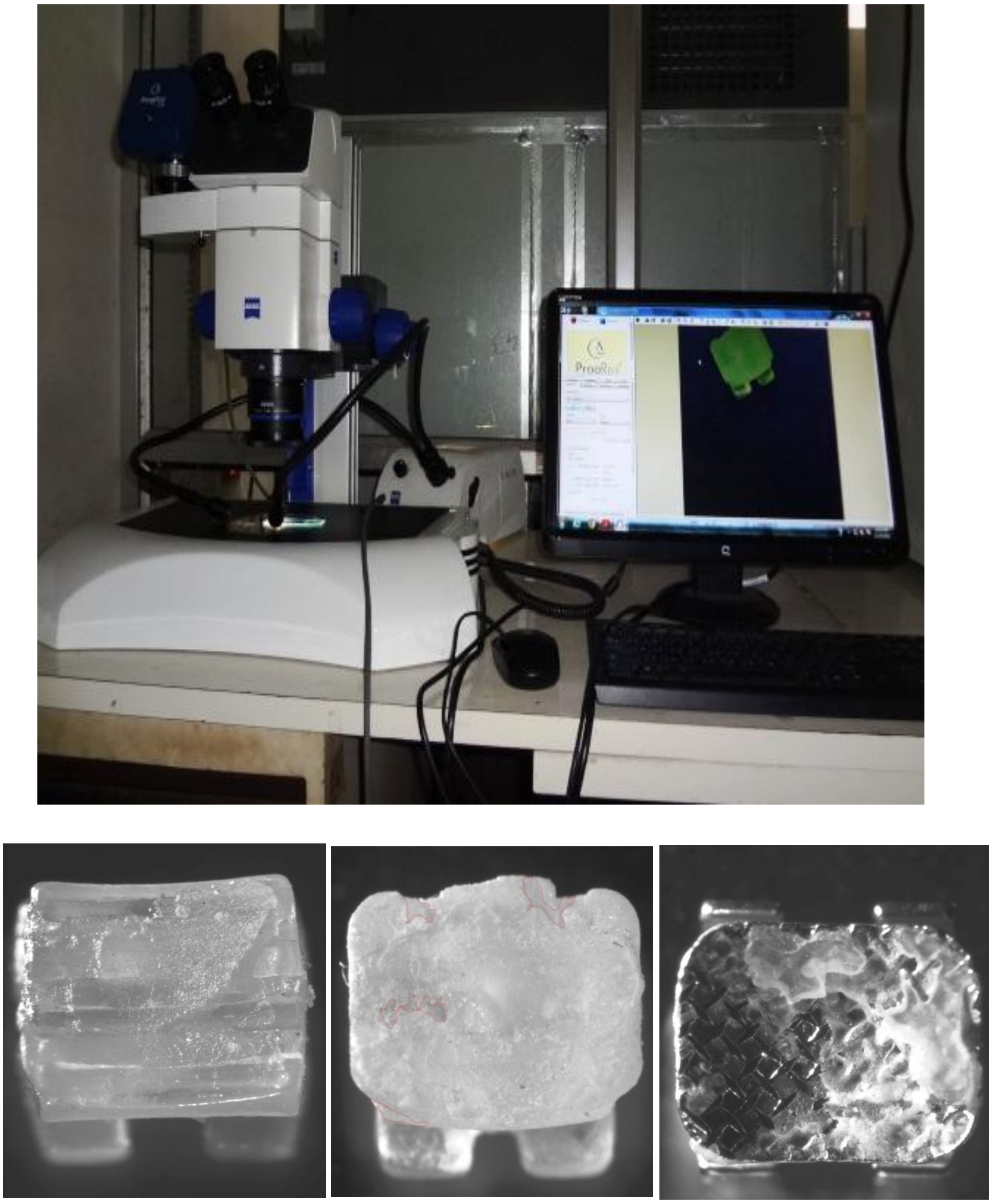


FIGURE 11-STEREOMICROSCOPE used for bracket surface evaluation after debonding by Modified Adhesive Remnant Index.

Ceramic Bracket- m ARI Score 3

Composite Bracket- m ARIScore 4

Stainless steel bracket – m ARI Score 3

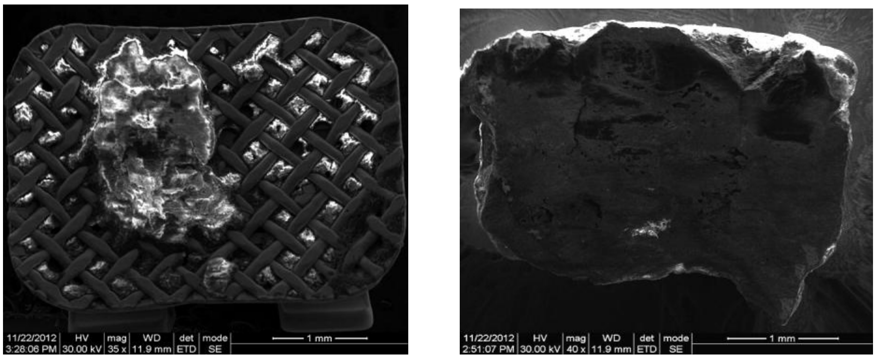


FIGURE 12-Energy dispersive spectroscopy (EDAX ^{TSL}-AMETEK,Advanced Micro analysis solutions) attached to FEI Quanta FEG 200-High Resolution Scanning Electron Microscope used for Bracket surface examination after debonding for elemental calcium loss

RESULTS

Debonded tooth surfaces were examined using Two tone disclosing solution and magnifying lens. The amount of composite adhering to tooth surfaces was evaluated using 4-point ARI score.Recorded scores are given below.

TABLE 1- ARI Score on Tooth Surface

			ARI Score on Tooth surface				Total	
			0	1	2	3		
Surface	Ceramic	Count	0	13	15	2	30	
		% within Surface	0%	43.3%	50.0%	6.7%	100.0%	
	Composite	Count	0	12	12	6	30	**P value** **0.049**
		% within Surface	.0%	40.0%	40.0%	20.0%	100.0%	
	Metal	Count	0	6	13	11	30	
		% within Surface	.0%	20.0%	43.3%	36.7%	100.0%	
Total		Count	3	30	40	17	90	
		% within Surface	3.3%	33.3%	44.4%	18.9%	100.0%	

0-No adhesive left on the tooth.

1-Less than half of the adhesive left on the tooth.

2-More than half of the adhesive left on the tooth.

3-All adhesive left on the tooth, with distinct impression of the bracket mesh.

TABLE 2- Bond Failure Pattern

			Type of failure			Total	
			ENAMEL-ADHESIVE	BRACKET-ADHESIVE	COMBINATION		
Bracket	Ceramic	Count	12	3	15	30	
		% within Bracket	40.0%	10.0%	50.0%	100.0%	
	Composite	Count	0	17	13	30	**P Value**
		% within Bracket	.0%	56.7%	43.3%	100.0%	**0.000**
	Metal	Count	0	18	12	30	
		% within Bracket	.0%	60.0%	40.0%	100.0%	df=4
Total		Count	3	55	32	90	
		% within Bracket	3.3%	61.1%	35.6%	100.0%	

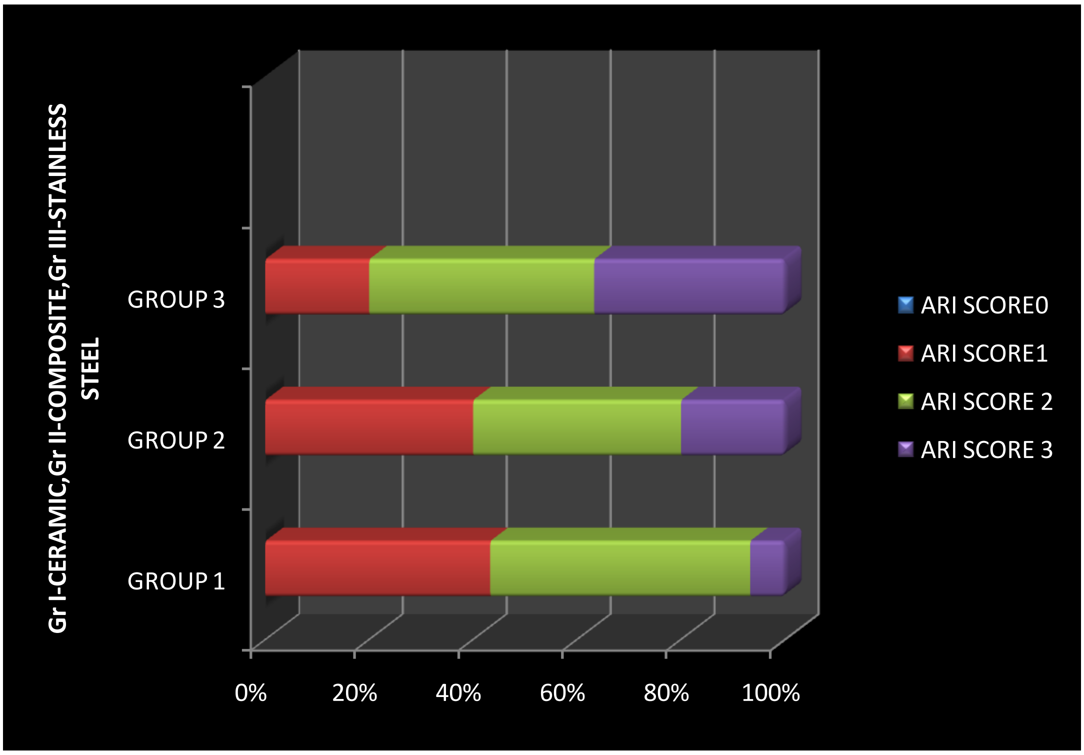


CHART No.1 -ARI score on tooth surface

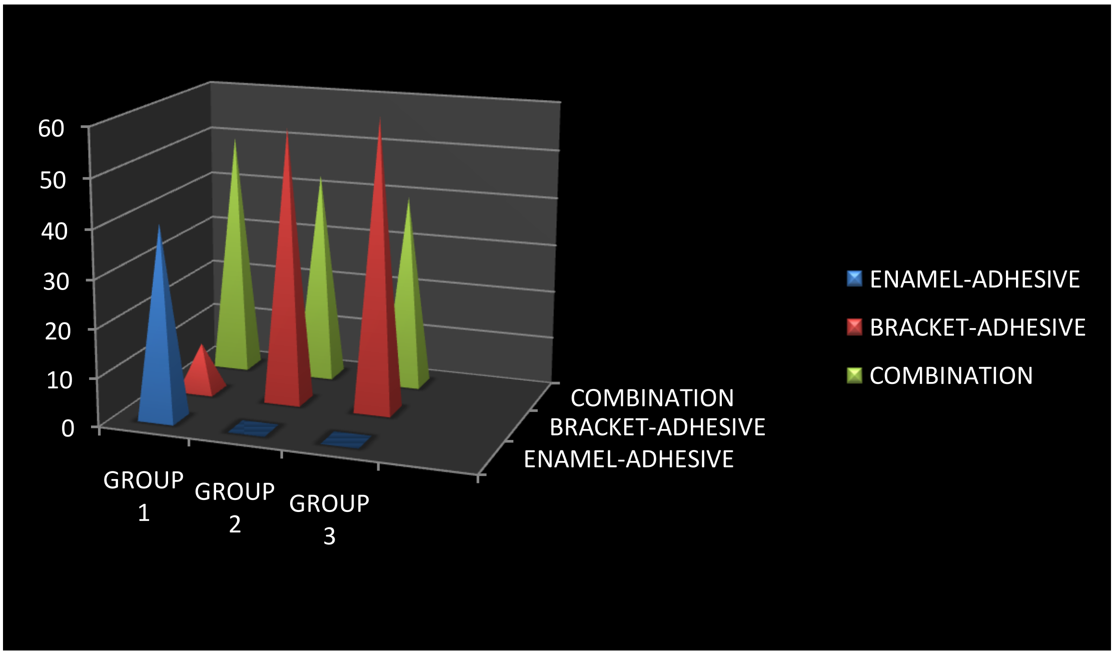


CHART No.2-Bond failure pattern

SCANNING ELECTRON MICROSCOPIC EXAMINATION OF TOOTH SURFACE AFTER DEBONDING

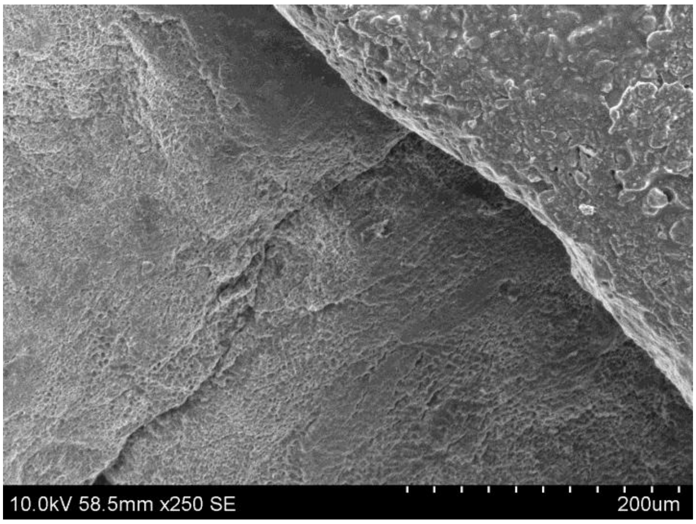


FIGURE I3-Tooth surface after debonding of ceramic bracket under x250 Magnification showing an enamel crack

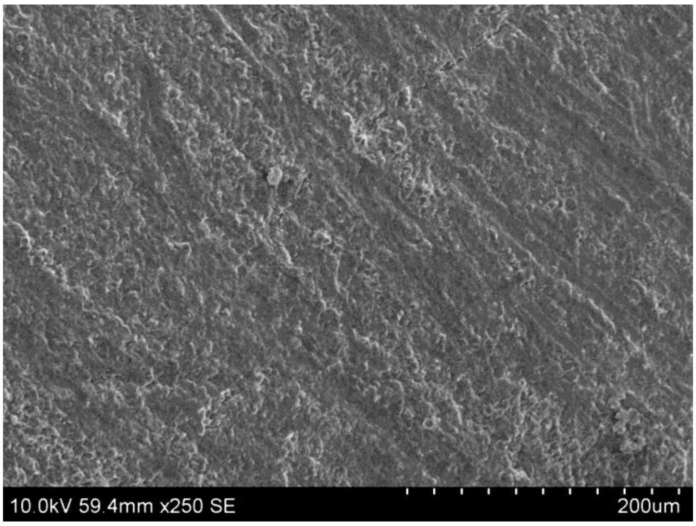


FIGURE 14-Tooth surface after debonding of composite bracket under x250 Magnification showing a minute enamel crack

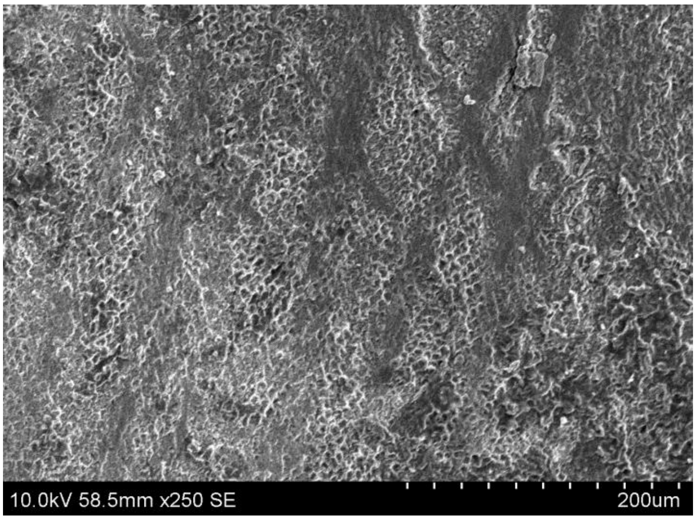


FIGURE 15-Tooth surface after debonding of stainless steel bracket under x250 Magnification -no enamel crack seen

TABLE 3- MODIFIED ARI Score on Bracket surface

			MODIFIED ARI Score on Bracket surface					Total
			1	2	3	4	5	
Surface	Ceramic	Count	0	1	21	5	3	30
		% within Surface	.0%	3.3%	70.0%	16.7%	10.0%	100.0%
	Composite	Count	6	0	17	7	0	30
		% within Surface	20.0%	.0%	56.7%	23.3%	.0%	100.0%
	Metal	Count	9	2	15	4	0	30
		% within Surface	30.0%	6.7%	50.0%	13.3%	.0%	100.0%
Total		Count	15	3	53	16	3	90
		% within Surface	16.7%	3.3%	58.9%	17.8%	3.3%	100.0%

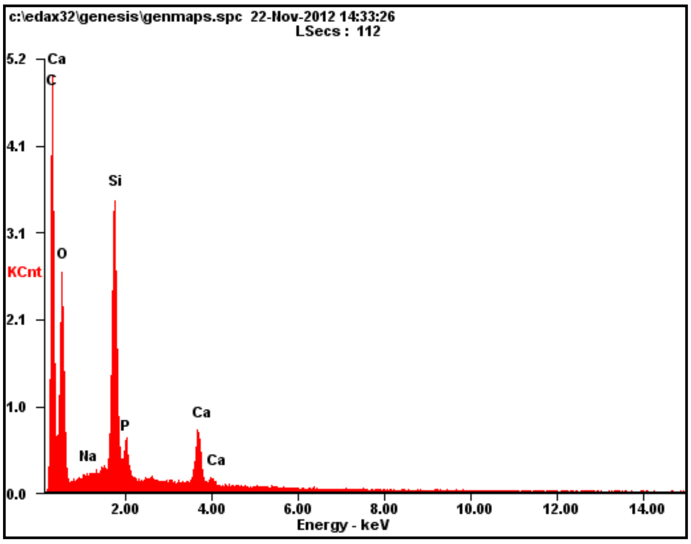
1. All adhesive remained on the tooth
2. More than 90% of the adhesive remained on the tooth
3. More than 10% but less than 90% of the adhesive remained on the tooth
4. Less than 10% of the adhesive remained on the tooth.
5. No adhesive remained on the tooth.

Statistical analysis by Chi –square test gives the P value of .019.(df-8)

QUANTITATIVE ASSESSMENT OF ENAMEL LOSS BY ENERGY DISPERSIVE SPECTROSCOPY;

EDS analysis showed a minimal amount of calcium (Ca++) on the composite attached to the base of metal bracket, while a high amount of Calcium (Ca++) was observed in ceramic brackets.

Ceramic brackets showed many points of elemental Calcium (Ca++) loss,where as composite bracket showed few points of Calcium loss and metal bracket showed one point of Calcium loss.



Element	*Wt%*	*At%*
CK	22.86	30.93
OK	57.19	58.08
NaK	00.42	00.30
SiK	14.57	08.43
PK	02.15	01.13
CaK	02.80	01.14
Matrix	Correction	ZAF

FIGURE 16-EDS Analysis for evaluation of the presence of Ca^{++} on the ceramic bracket base after debonding showing the elements by peaks derived from the *k* shell of atoms.

TABLE 4-Amount of elements on the ceramic bracket base (Group I sample no.1)

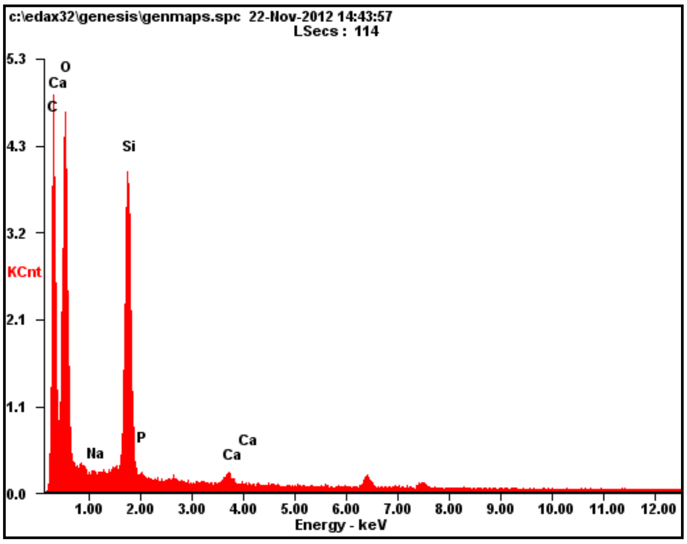


FIGURE 17-EDS Analysis for evaluation of the presence of Ca^{++} on the ceramic bracket base after debonding showing the elements by peaks derived from the *k* shell of atoms.

Element	*Wt%*	*At%*
CK	16.79	22.66
OK	67.36	68.24
NaK	00.34	00.24
SiK	14.87	08.58
PK	00.12	00.06
CaK	00.51	00.21
Matrix	Correction	ZAF

TABLE 5-Amount of elements on the ceramic bracket base (Group I sample no.1)

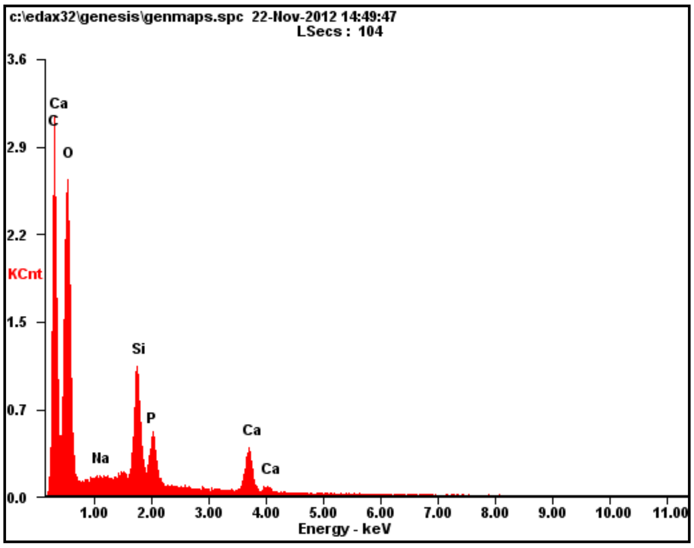


FIGURE 18-EDS Analysis for evaluation of the presence of Ca^{++} on the composite bracket base after debonding showing the elements by peaks derived from the *k* shell of atoms.

Element	*Wt%*	*At%*
CK	22.82	29.58
OK	66.86	65.07
NaK	00.52	00.35
SiK	05.44	03.02
PK	02.45	01.23
CaK	01.91	00.74
Matrix	Correction	ZAF

TABLE 6-Amount of elements on the composite bracket base (Group II sample no.1)

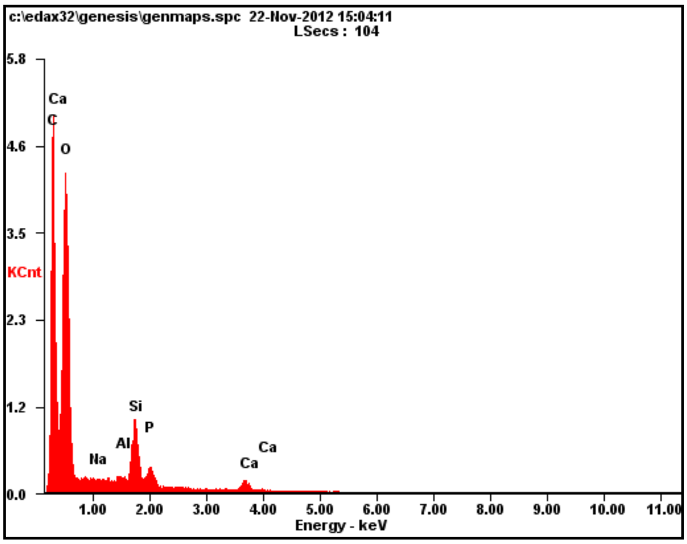


FIGURE 19-EDS Analysis for evaluation of the presence of Ca^{++} on the composite bracket base after debonding showing the elements by peaks derived from the *k* shell of atoms.

Element	*Wt%*	*At%*
CK	15.85	20.72
OK	76.69	75.26
NaK	00.23	00.16
AlK	00.44	00.26
SiK	04.81	02.69
PK	01.23	00.63
CaK	00.73	00.29
Matrix	Correction	ZAF

TABLE 7-Amount of elements on the composite bracket base. (Group II sample no.1)

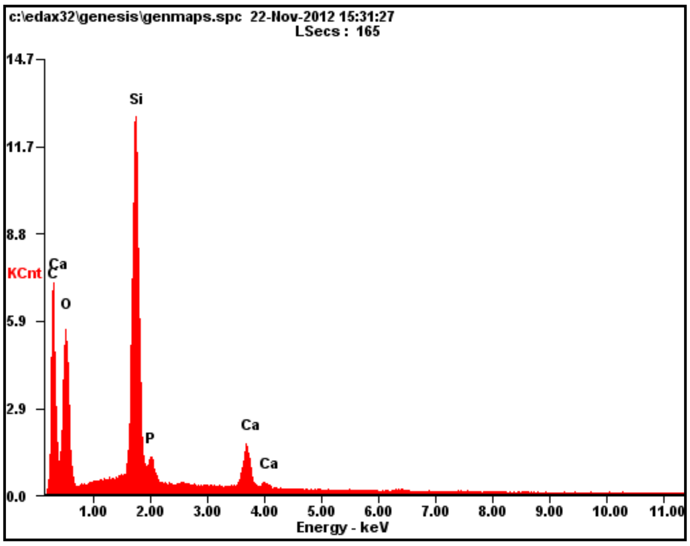


FIGURE 20-EDS Analysis for evaluation of the presence of Ca^{++} on the stainless steel bracket base after debonding showing the elements by peaks derived from the *k* shell of atoms.

Element	*Wt%*	*At%*
CK	21.98	30.56
OK	52.59	54.88
SiK	20.85	12.40
PK	02.06	01.11
CaK	02.51	01.05
Matrix	Correction	ZAF

TABLE 8-Amount of elements on the stainless steel bracket base. (Group III sample no.1)

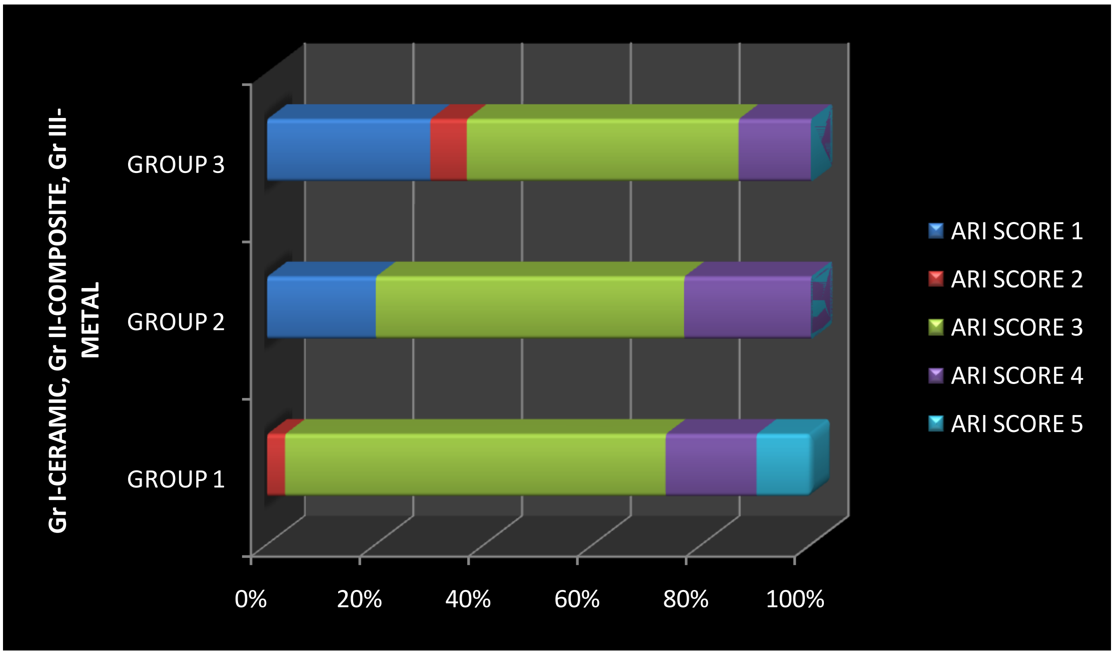


CHART No.3-Modified ARI score on bracket surface

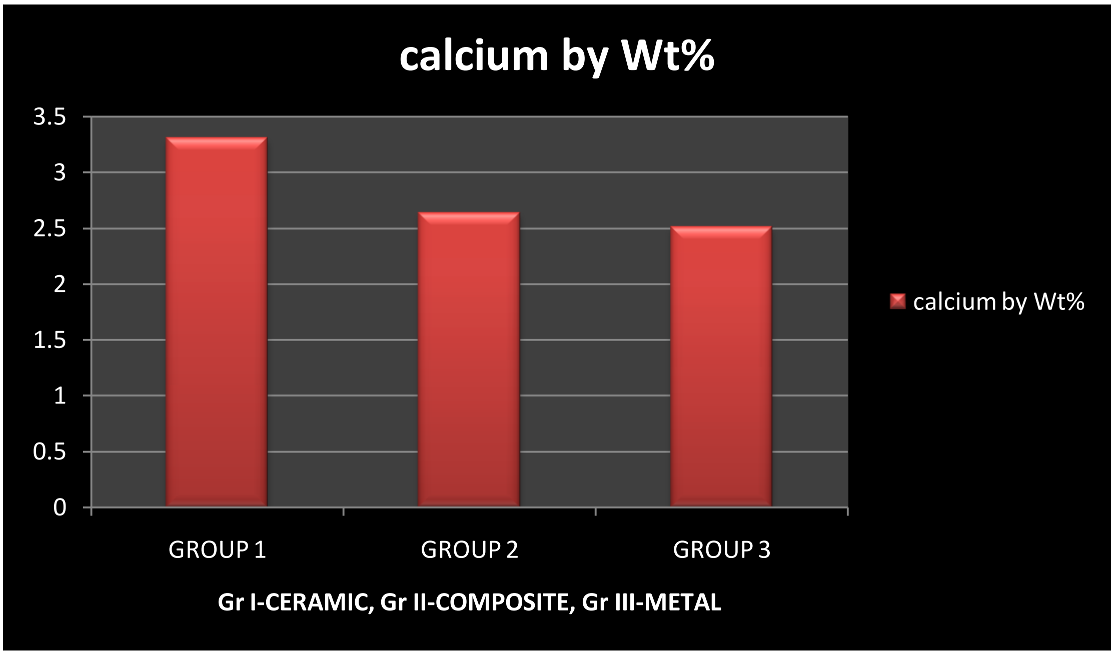


CHART No.4 -Elemental Calcium present on bracket base

DISCUSSION

Potential detrimental effects of debonding on surface enamel either during bracket debonding or removal of the remnants is an iatrogenic problem. Calcium loss from the enamel surface particularly can result in dental erosion, which is a localized loss of dental hard tissues[6,96]. Preservation of maximum amount of enamel surface structure with least amount of enamel loss while debonding of bracket and polishing after orthodontic treatment is beneficial[20,32,70,94.]. The outermost layer of enamel should be left as intact as possible after debonding, since it has greater micro hardness and contains more minerals and fluoride than the deeper zones. On the contrary, the loss of surface enamel and associated exposure of the enamel prism endings to the oral environment might cause a decrease in the resistance of enamel to the organic acids in plaque. This eventually makes enamel more prone to demineralization.

Brudevold[16],Koch[45], Mellberg[52],and Weatherell[90] in their studies about the fluoride content of enamel surface stated that the gradient from the surface inward is very steep, with the highest fluoride concentration at the surface layer, and a rapid decline in concentration in the first 20 µm of enamel. It would therefore seem desirable to maintain that much enamel after any treatment procedure.

To maintain the enamel structure to its pretreatment condition and to reduce the iatrogenic damage, correct bonding and debonding techniques are of fundamental importance. The most important factors involved in debonding are the type of bracket and adhesive used, instruments used for bracket removal, and the armamentarium for resin removal.

Plastic brackets, ceramic brackets and ceramic filler reinforced plastic brackets[94] were developed to meet the esthetic demand of adult patients who seek treatment at a larger number than ever before. The quest for esthetically superior appliances are increasing today and this has lead to the development and improvisation of these bracket materials, but still the disadvantages of these materials remain unresolved. One such aspect of concern is enamel loss and cracks after debonding of ceramic brackets. Enamel fracture or the appearance of fracture lines during debonding is related to the high bond strength of ceramic brackets. The fracture toughness of the enamel is lower than that of ceramic, so the ceramic brackets bonded to rigid, brittle enamel have little ability to absorb stress; hence debonding of these brackets resulted in bond failure at the enamel surface, rather than at the bracket adhesive interface[90]. Two particular properties of ceramics—hardness and brittleness—have necessitated the use of special debonding instruments to prevent both the enamel and bracket fracture. Virage brackets used in this study were debonded by using the recommended #001-343E debonding pliers.

The plastic brackets have become quite popular since the 1990s, when the damage to enamel that was caused by the ceramic brackets during debonding became evident. New types of reinforced plastic brackets with and without steel slots inserts have been introduced. Steel-slotted plastic brackets (Silkon plus composite plastic brackets) are useful as an aesthetic alternative, and hence were used in this study. They were debonded by ligature cutters by giving pressure from the mesial and distal aspects.

Stainless steel brackets are most commonly used in practice today as they are cost effective. Several different procedures for debracketing of these metal brackets with pliers are available.

The recommended technique, in which brackets are not deformed, is the technique that uses a peeling-type force, which creates peripheral stress concentrations that cause bonded metal brackets to fail at low force values. The break is likely to occur in the adhesive–bracket interface, thus leaving adhesive remnants on the enamel. Mini master series stainless steel brackets used in this study were debonded using debonding pliers by applying peeling-type force from the gingival to occlusal aspect at 45° angulations[30].

After debonding the tooth surfaces were evaluated for remaining adhesive by using Adhesive Remnant Index(ARI) score that was introduced by Artun and Bergland[3] (1984). ARI scores provide a qualitative assessment of the tooth surface after debonding. It provides a rank score, not a true numerical value. It is also a surface-area assessment, not a 3-dimensional (3D) volumetric measure. Alternative methods include quantitative analysis using a miniaturized Boley gauge[15], scanning ruby laser digitizer[67], non-contacting laser probe[2] or a 3D laser profilometer[56]. The amount of residual adhesive can be assessed with both qualitative and quantitative methods. Due to its simplicity, qualitative assessment of the residual adhesive by using the ARI has remained the most frequently used method. Being qualitative in nature, both the original 4-point scale was used for tooth surface examination (here after referred to as ARI_{TOOTH}) and modified 5-point scale version introduced by

Bishara and Trulove was used for bracket surface examination (here after referred to as $\text{ARI}_{\text{BRACKET}}$) in this study.

Table I lists the frequency of ARI scores on tooth surface after debonding of 3 types of brackets. It shows the difference between the three groups is statistically significant (significant at 5% level).Group I (ceramic brackets)showed a high frequency of $\text{ARI}_{\text{TOOTH}}$ score 1 compared to other groups, signifying less adhesive remaining on tooth surface. Group II (composite plastic brackets) showed equal distribution of $\text{ARI}_{\text{TOOTH}}$ scores 1&2, indicating that some adhesive always remains on tooth surface. In group III (metal) $\text{ARI}_{\text{TOOTH}}$ score 3 is seen at a higher frequency when compared to other groups indicating there is more amount of residual adhesive remaining on tooth surface. Low $\text{ARI}_{\text{TOOTH}}$ score usually corresponds to more damage to the enamel surface. The results of our study shows an $\text{ARI}_{\text{TOOTH}}$ score of 3 for 40% of metal brackets & $\text{ARI}_{\text{TOOTH}}$ score of 3 for 6.7% of the ceramic brackets. This is in contrast to the reports of Bulent haydar, Simtent sarikaya[17] which showed a $\text{ARI}_{\text{TOOTH}}$ score of 3 for all the metal brackets, $\text{ARI}_{\text{TOOTH}}$ score of 3 for 40% of ceramic brackets. This may be due to the difference in composite adhesive material used in their study.

After debonding, tooth surfaces corresponding to lower $\text{ARI}_{\text{TOOTH}}$ score were examined for presence of enamel cracks. Cracks, occurring as split lines in the enamel, are prone to debris and stains leading to discoloration of teeth and esthetic problems for the patients [11,94] .With ceramic brackets, the risk for creating enamel cracks is greater than for metal brackets. The lack of ductility of ceramic bracket may generate stress in the adhesive–enamel interface that may produce enamel cracks at debonding. Mode of debonding has been a factor potentially capable of creating enamel cracks[68] .In this study the original method of debonding with a twin-beaked pliers advocated by Bishara et al[75] was used to simulate clinical situation.

Cracks can be distinguished by finger shadowing in good light or, preferably, fiber-optic trans-illumination. Recently developed magnetic resonance imaging (MRI) technique, called SWeep Imaging with Fourier Transform (SWIFT), is capable to visualize dental tissues including enamel cracks (3).In this study scanning electron microscopy (SEM) that produces images of a sample by scanning it with a focused beam of electrons was used to detect the enamel cracks.

While examining the tooth surfaces under SEM, enamel cracks were seen in nine of the specimens after debonding of the ceramic brackets. Minute enamel crack was seen in the enamel surface of one of the specimens after debonding of composite brackets. No evidence of enamel cracks in specimens after debonding of metal brackets. These findings are similar to the reports of Olsen M, Bishara S, Boyer D[60](1996),Bishara SE, Fehr DE[10](1997) and, Sinha PK, Nanda RS[65], Habibi M,Nik TH[51] which showed enamel damages subsequent to debonding. However other studies[78,81] did not demonstrated any permanent damage to tooth enamel after debonding of ceramic brackets with mechanical retention. Differences in the results of studies might be attributed to different retention mechanisms of brackets, the method of bonding and the type of adhesive.

Adhesion of composite has 2 aspects—one to the tooth surface and the other to the bracket base—evaluation of the ARI_{TOOTH} scores also provides information on the site of bond failure. Possible failure types after bracket debonding are in the interface between the enamel and the adhesive resin, partially adhesive and cohesive in the adhesive resin (mixed), and interface between the bracket base and the adhesive resin, where the latter 2 require removal of the remnants. Macroscopic evaluation could also show cohesive failures in the enamel or in the adhesive resin. Score 0 implies weak adhesion between the adhesive and the enamel, and Score 3 means weak adhesion between the bracket and the adhesive resin. Though the ARI_{TOOTH} score of 0 is often considered to represent a weak bond or a lower hazard to the enamel, calcium loss is still possible[3,25,96]. This further indicates cohesive failures in the enamel prisms that could be detrimental for possible demineralization or erosion. Therefore, after bracket debonding, with ARI_{TOOTH} scores of 0, 1, or 2, these teeth need to be monitored for higher calcium loss from their enamel. The failure site at the bracket-adhesive interface macroscopically indicates safe debonding and less chance of enamel loss. In this study, no macroscopically cohesive failures in the enamel were observed for all the three groups. Table II lists the bond failure pattern of three groups' .The difference between composite plastic and stainless steel brackets is not statistically significant. This is in contrast to the findings of Diedrich[22] which showed that plastic brackets displayed more torn-off fragments of enamel than the metal brackets and in which fracture mainly occurred at the adhesive-bracket interface. Bracket fracture occurred during debonding of composite brackets. The difference between ceramic and plastic brackets is statistically significant. This differs from the results of M. Özcan, K. Finnema[61] in which no difference in failure sites observed between the ceramic and polycarbonate brackets. The difference may be due to the different adhesive material (Enlight Light Cure Adhesive,Ormco) used in their study. The difference between ceramic and stainless steel is statistically more significant.

The mode of failure for the metal brackets was predominantly at the bracket-adhesive interfaces. This coincides with the results of other investigations[17,22] in which primarily bracket-adhesive failure with metal brackets was found.

Twelve specimens in ceramic brackets group showed failure at the enamel-adhesive interface. These findings could be related to the fact that mechanically retained ceramic brackets had higher mean debonding strengths, and the site of bond failure shifted toward the enamel adhesive interface. Ceramic brackets showed a higher frequency (40%) of bond failure at enamel-adhesive interface when compared to other groups, indicating debonding of ceramic brackets should be done cautiously. This is similar to the findings of Thomas.B.Redd,Shiv puja[68] in which 20% of the ceramic brackets (Transcend 2000) showed failure at the enamel-adhesive interface. However this is in contrast to the findings of Lina P.Theodorakopoulou, Alex Jacobson[84], in which 10% failed at the combination of bracket-adhesive and adhesive-enamel interface, and Samir E. Bishara, Adam Wade Ostbyb[77] in which 40% of ceramic brackets failed showed combination failure.

Bracket surfaces were examined and evaluated using Modified Adhesive Remnant Index (mARI). Montasser and Drummond[55] compared ARI scores under different magnifications (×10 and ×20) and concluded that the results would be more accurate under higher magnifications. Accordingly, the magnification factor was set at ×20 for visual assessments in the present study.

S. Burcak Cehreli, Omur Polat-Ozsoy[19] results show that qualitative visual assessment using the 5-point $\mathrm{ARI}_{\mathrm{BRACKET}}$ scale was capable of yielding high precision and conclusive results. In this study optical stereo microscope was used to assess the Modified ARI index. It produces a three-dimensional visualization of the sample being examined. Table III shows the Modified $\mathrm{ARI}_{\mathrm{BRACKET}}$ score values for three groups of bracket surfaces. Statistical analysis showed a significant difference between three types of brackets tested. Ceramic brackets showed a higher frequency score of 5 compared to other groups indicating 100% adhesive remains on bracket surface. They also showed a higher frequency of score 3 within their group indicating remaining adhesive level of more than 10% but less than 90%.Stainless steel brackets had a higher frequency of $\mathrm{ARI}_{\mathrm{BRACKET}}$ score 1 compared to other 2 groups, indicating no adhesive remains on bracket surface. All the three groups showed a higher frequency of score 3. On evaluation stainless steel brackets showed lower $\mathrm{ARI}_{\mathrm{BRACKET}}$ scores mostly, followed by composite and ceramic brackets. Most of the stainless steel brackets showed $\mathrm{ARI}_{\mathrm{BRACKET}}$ score 3 and followed by composite brackets (but less than metal brackets).Twelve ceramic brackets showed $\mathrm{ARI}_{\mathrm{BRACKET}}$ score 5,five ceramic brackets showed $\mathrm{ARI}_{\mathrm{BRACKET}}$ score 4,while two composite brackets showed score 4. These differences were statistically significant at 5% level. These results were consistent with the findings of Maryam Habibi[51] .

Following visual scoring, the brackets with higher $\mathrm{ARI}_{\mathrm{BRACKET}}$ scores of each group were subjected to Quantitative assessment in a High Resolution Scanning Electron Microscope with Energy-dispersive X-ray spectroscopy (EDS or EDX). It is an analytical technique used for the elemental analysis or chemical characterization of a sample**.** EDS analysis showed a very high amount of elemental calcium (Ca) on the composite attached to the base of group 1(ceramic brackets), while a high amount of elemental calcium(Ca) was observed in group 2(composite plastic brackets).

EDS showed that by Wt% the metal brackets (Group III) demonstrated very less amount of elemental calcium which cannot be compared statistically with other groups. These findings were similar to that of Diedrich[22] who demonstrated that localized detachments of terraced or ribbed enamel particles occurred more frequently with plastic than with metal brackets and similar to the findings of Ponts[34] who reported that the more ARI remnants on the bracket base, the higher the Ca% revealed by EDS.

These findings were in contrast with the report of Wei Nan Wang, DDS, a Ching Liang Meng[90] in which no enamel detachment was found by EDS in the base of either metal or mechanically retained ceramic bracket after debonding and to the reports of U. Stratmann, K. Schaarschmidt[82] which showed least amount of calcium loss with ceramic brackets when compared to metal brackets. This difference may be due to the technique of thermal debonding of ceramic brackets used in their study.

SUMMARY AND CONCLUSION

The extent of damage to the enamel surface following the use of ceramic, composite plastic and stainless steel brackets was assessed after debonding of brackets in-vitro both qualitatively and quantitatively. Adhesive Remnant Index on tooth surface, Scanning electron microscopic examination of tooth surface for enamel cracks, modified Adhesive Remnant Index on bracket surface were the qualitative methods and quantitative assessment was done using Energy Dispersive Spectroscopy analysis(EDS).

The following conclusions were derived from the study.

1. Adhesive Remnant Index on tooth surface bonded with ceramic brackets showed least amount of lower ARI_{TOOTH} score which implies more damage to enamel surface and composite plastic and stainless steel brackets showed mostly higher ARI_{TOOTH} Score indicating less damage to tooth surface.
2. On scanning electron microscopic examination, the enamel surfaces bonded with ceramic bracket resulted in more enamel cracks; composite plastic bracket showed negligible amount of enamel crack and stainless steel brackets showed no enamel cracks.
3. Ceramic brackets showed higher $ARI_{BRACKET}$ score indicating more damage to enamel surface, composite plastic bracket and stainless brackets showed lesser values indicating least amount of enamel damage.
4. Energy Dispersive Spectroscopy analysis proved that the loss of elemental calcium is more evident in tooth surface bonded with ceramic bracket

LIMITATIONS OF THE STUDY

1. As it is an in-vitro study, results may not correlate with the clinical situation.
2. The structure of enamel and their response to debonding varies between anterior and posterior teeth. Since this study was conducted using maxillary premolars, the results might not represent the anterior teeth.

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