EVALUATION OF BOND STRENGTH OF ACRYLIC DENTURE TOOTH TO HEAT POLYMERIZED DENTURE BASE RESIN AFTER DIFFERENT SURFACE TREATMENTS ON THE BONDING SURFACE OF ACRYLIC TOOTH - AN IN VITRO STUDY

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CERTIFICATE

This is to certify that the dissertation titled **" EVALUATION OF BOND STRENGTH OF ACRYLIC DENTURE TOOTH TO HEAT POLYMERIZED DENTURE BASE RESIN AFTER DIFFERENT SURFACE TREATMENTS ON THE BONDING SURFACE OF ACRYLIC TOOTH – AN IN VITRO STUDY** " is a bonafide record of work done by **Dr. D. SIVAKUMAR** under my guidance during his post graduate study period 2010 - 2013.

This dissertation is submitted to **THE TAMILNADU Dr M.G.R. MEDICAL UNIVERSITY,** in partial fulfilment for degree of **MASTER OF DENTAL SURGERY** in **Branch I – Prosthodontics and Crown and Bridge.**

It has not been submitted (partially or fully) for the award of any other degree or diploma.

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CONTENTS

LIST OF ABBREVIATION

mm	Millimeter
µ	Micron
µm	Micron Meter
MPa	Mega Pascals
IPN	Interpenetrating Polymer Network
ANOVA	Analysis Of Variance
HSD	Honestly Significantly Different
Fig	Figure
No.	Number Of Test Samples
P,p	Probability
S, Sig	Significant
Vhs	Very Highly Significant
Kg	Kilograms
N	Newton
MMA	Methyl Methacrylate
PMMA	Polymethyl Methacrylate
SEM	Scanning Electron Microscope

EVALUATION OF BOND STRENGTH OF ACRYLIC DENTURE TOOTH TO HEAT POLYMERIZED DENTURE BASE RESIN AFTER DIFFERENT SURFACE TREATMENTS ON THE BONDING SURFACE OF ACRYLIC TOOTH – AN IN VITRO STUDY

ABSTRACT

Debonding of acrylic denture tooth from the denture base resin is the most common failures in denture repair. The objectives of the study were (i) to evaluate and compare the bond strength of acrylic resin denture teeth to denture base resins after various surface treatments on the bonding area of acrylic denture teeth (ii) to evaluate the type of failure (adhesive or cohesive) between the bonding surface of acrylic teeth and the denture base resin after these surface treatments.

MATERIALS AND METHODS: 50 right and 50 left maxillary highly cross-linked acrylic central incisor denture teeth of same size and shade were selected. The 100 teeth were then divided into 5 groups. Group A served as control with no surface treatment. The other groups were B, C, D and E according to surface treatments with Heat-curing methylmethaacrylate Monomer, Acetone, Vitacoll bonding agent and Superbond bonding agent respectively. Wax models were made using a custom made jig such that the tooth was placed with a labial inclination of 130^0 from the denture base and were invested and de-waxed. Surface agents were applied on the bonding surface of acrylic denture tooth. The specimens were packed with heat polymerizing denture base resin, then cured, finished and polished. After storing 1week in water for aging, the bond strengths of each group samples were evaluated using a Universal Testing Machine and values recorded.

RESULTS: Bond strength values were subjected to statistical analysis using one way Anova, Tukey's HSD and Chi- square tests. The Group E- Superbond surface treated samples had the highest bond strength values and all the failures recorded were cohesive in nature. Group C - Acetone surface treated samples had better bond strength values. There was no statistical difference in bond strength values of Group A - Control, Group B- Monomer and Group D- Vitacoll bonding agent groups.

CONCLUSION: Surface treatment of the bonding surface of acrylic denture tooth before packing improved bonding with the denture base resin. Superbond- bonding agent samples had the highest mean bond strength values of all the tested samples with easy application protocol.

KEYWORDS: Bond strength, Acrylic denture tooth, Denture base resin, Surface treatment.

Introduction

INTRODUCTION

Acrylic resins, introduced in 1937, have enjoyed a continued popularity, which is attributed to its simple processing technique and relatively low cost of fabrication[30]. Despite the progress in the development of denture base resin and artificial tooth materials, dental clinics are still plagued with artificial teeth falling off the denture base[42, 47, 60].

Artificial dentures are fabricated by inset moulding prefabricated denture teeth into resin denture base by compressing, injecting, or pouring acrylic resin over and around the ridge lap and collar portions of the teeth. These techniques are designed to create a strong bond between the parts. Adequate bonding of acrylic resin teeth to denture base resin plays a vital role as it increases the strength and durability of the denture since the teeth become an integral part of the prosthesis.

Artificial teeth falling off the denture base is a usual problem encountered by patients during denture usage. This problem is often related to the material properties of the acrylic denture base resin used. A survey showed that 33% of denture repairs were to restore debonded teeth. [6, 13, 21, 24, 33]

Therefore, in the fabrication of removable dentures, the bond between the denture base resin and artificial teeth is one of the most important considerations in the technical procedure.

Schnoover et al were probably the first to study the issue of bond strength of teeth and denture base resins[52]. Since then several studies have been carried out to evaluate and study the compatibility of acrylic teeth to denture base resins. The National Standards set by America, Australia and ISO has various specifications for determining the bond strength values.

The forces generated in the denture teeth vary among different clinical conditions. The conditions being whether the denture teeth opposes natural teeth, or denture teeth, or fixed partial denture, or implant supported removable or fixed prosthesis with acrylic teeth or metal or porcelain teeth.

Presently implant dentistry is emerging as a boon to patients in replacing teeth. With implant-supported dentures and overdentures with copings on natural teeth becoming more familiar in preventive prosthodontics, the biting forces generated with such dentures has increased phenomenally. This increased biting forces rather also increased the mechanical failure of the prosthesis[41].

To withstand the forces being generated on the acrylic teeth against varied opposing teeth during the functional envelope of motion, a better bond between acrylic teeth and denture base resin is very important.

The advantage of acrylic teeth to other type of teeth (porcelain [29, 37], composite resin teeth[36, 54]) is their ability to realize a chemical bond to the denture base resin[21, 35]. Even though there is satisfactory bonding, but from previous studies it has been reported that debonding of teeth from the base resin is the most frequent repair in practice and it accounts to 30% of all denture repairs. This debonding also has been more common in the anterior region of the maxillary dentures[6, 24].

Inadequate thickness of acrylic resin in the anterior segment of a denture as a result of the dimensions of bar and clip attachments also lead to fracture of the denture and teeth debonding from the base[41].

Various factors have been reported for this failure[10, 22, 26]. Wax residues on denture teeth ridge-lap area[55], tin-foil substitute contamination[11,51], chemical or mechanical preparation on the ridge-lap[62], laboratory processing errors[11], type of tooth material (conventional or cross-linked), varied processing methods (heat or light or microwave polymerisation), cyclic loading[40], thermo-cycling[27, 39] and aging effects[29, 46] being common causes for failure.

Residual wax because of incomplete elimination[55] or contamination with tin foil substitutes[11, 42] on the ridge-lap area prevents chemical bonding between acrylic teeth and denture base resins[26]. This factor is the most important cause for bond failure.

Conventional acrylic teeth usually achieve a better bond to denture base resins than do highly cross linked teeth [34, 42]. The polymers, the main component of teeth and denture base resin determine their technological and physical behaviour and are characterized by long chains of repeated monomeric units. Acrylic teeth are made essentially of polymethylmethaacrylate (PMMA) copolymerized with a cross linking agent[1]. Strongly cross-linked polymers are insoluble in organic solvents[28]. In highly cross linked teeth, because of limited solubility and increased filler content, bonding is not as satisfactory as conventional resins[5, 15, 16].

From studies[35, 58], it is observed that heat polymerized resins revealed the highest bonding values than other methods of polymerisation like auto polymerisation[10], microwave polymerisation[32,34,49,53] and light polymerisation[18,19,20]. Some studies demonstrate microwave polymerized denture base resins have higher bonding values than heat polymerized resins[32, 34]. Visible light cured (VLC) denture base resins have been introduced but studies showed that bond values for these resins are weaker compared to heat or microwave processed methods[18, 19, 20].

Several authors have presented clinical methods of modifying and repairing acrylic resin denture teeth with composite. Composite has been used to build up or modify the facial surface of denture teeth to harmonize the aesthetics of the prosthetic teeth with that of the adjacent natural teeth or with facial characteristics of the patient[36].

In recent years, several new materials for denture construction have been introduced, with claims of increased wear resistance, better aesthetics and more convenient curing methods. But from most studies, the bond strength is comparably weaker than conventional materials[15]. Few other studies claim that these newer materials have improved bond strength and the mode of failure is mostly cohesive[6].

Various chemical applications like PMMA (monomer)[3,7,38,42,62], acetone[45,56], ethylene or methylene chloride[56], dichloromethane[16,46,57], chloroform[54], ethyl acetate, commercially available bonding agents[44], and mechanical retention by grooves[12,14], diatorics has been done with both positive and negative results related to bond strength values [4,8,9,12,13,17,31,34,40,43,51,54,56,59].

Maxillary anteriors are the most frequent teeth to dislodge[6,21, 33]. Denture teeth often separate from the denture base without any evidence of damage to the denture base or the teeth[47,48]. The causes may be (1) the material from which the teeth or the denture base are fabricated is slightly flexible (2) poor bond between denture base and artificial tooth because of impurities at the interface[26] (3) difference in structure of the two components because of their different processing routes (4) crack propagation from areas of high stress concentration[13].

Two processes affect the bond between the acrylic teeth and denture base resin: (i) the polymerising denture base resin must come into physical contact with the denture tooth resin and (ii) the polymer network of denture base resin must react with the acrylic tooth polymer to form an interwoven polymer network (IPN).

Examination and analysis of the direction of forces created during function, helps us to better understand the cause of bonding failure[41]. Sagittal section of a maxillary and mandibular denture through the maxillary and mandibular right central incisors suggest, incisal contact of these teeth during function create a lingually directed force on the mandibular incisor and an equal and opposite, facially directed force on the maxillary incisor denture tooth.[63]

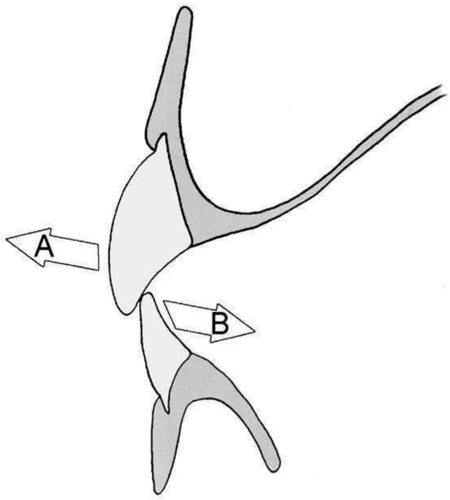


Figure 1.1 Cross–section through right central incisors of maxillary and mandibular dentures in occlusion. During function, labial force (A) is exerted on maxillary tooth, and lingual force (B) is exerted on mandibular tooth

The mandibular incisor tips lingually towards the denture and the denture base lingual to the tooth resists this movement. So the forces are on the denture base than at the juncture[63].

The maxillary central incisor rotates facially around a fulcrum located at the cervical portion of the tooth and the gingival cuff of the denture base, away from the denture base. Because resin denture teeth and denture base resins are slightly flexible, this denture tooth may become dislodged from the denture base if or when the adhesion or mechanical retention between the parts fail[63].

Basic understanding of the above causes and mechanism of bond failure could make us improve the various parameters in processing of dentures, thus improving the bond strength between acrylic teeth and denture base to the best possible extent.

The removable denture wearing population will be highly benefited along with the dental professionals, if frequent repairs and corrections of dentures are avoided. The psychological fear of the patients while eating harder food substances with the denture can also be reduced. Thus improving the denture base-acrylic teeth bond also improves the bond values in dentist-patient relations.

In literature, various chemical surface treatments, macro-mechanical retention on the ridge-lap surface of teeth and different types of polymerisation techniques were adopted to improve the bond strength between acrylic denture teeth and denture base resin.

The aim of this study was to evaluate the bond strength between the acrylic tooth and denture base resin using four different types of chemical surface treatment.

Aims and Objectives

AIM AND OBJECTIVE

AIM

The aim of the study was to evaluate the bond strength of acrylic resin denture teeth to heat cure denture base resin after various surface treatments on the bonding surface area of acrylic denture teeth.

OBJECTIVES

The objectives of the study were:

- To evaluate and compare the bond strength of highly cross linked acrylic resin denture teeth to high impact Trevalon heat cure denture base resin material after surface treatments on the bonding area of acrylic denture teeth done immediately after dewaxing and before packing the resin material for processing. The agents applied were methymethaacrylate monomer, acetone and two proprietary bonding agents namely Vitacoll and Superbond.
- To evaluate the types of failure (adhesive or cohesive) between the bonding surface of acrylic teeth and the denture base resin after these surface treatments.

Review of Literature

REVIEW OF LITERATURE

Morrow et al in 1978 [42] studied the bonding of plastic teeth to two heat cured denture base resins. The bond and tensile strength of a high impact denture base resin was compared to that of a conventional denture base resin. The effects produced by contamination of ridge lap surface with a tin foil substitute and the effects produced by coating unmodified glossy ridge laps with a monomer/polymer solution was also evaluated. They concluded that no significant difference in bond strength between standard and high impact resins. But the tensile strength was greater in high impact resins. Also, contamination of ridge lap surface with tin foil substitute and application of monomer reduced the bond strength.

Trudso et al in 1980[58] conducted a four year follow up study on processed pour acrylic resin and concluded that the pour (fluid resin) denture base had poor physiochemical properties which resulted in poor bond strength to acrylic teeth when compared to heat cured denture base resin.

Shen et al in 1984[54] investigated the effect of etching the denture by chemical treatment of the surface on repair strength. Roughening the surfaces enhanced bonding. However the SEM micrographs showed the presence of micro voids and overhanging grooves. Treatment of the fractured tooth with chloroform 5 seconds prior to repair improved the quality of site for bonding. However significant strength improvement was observed only when heat cured method was used. Bonding between acrylic resin teeth and composite is not satisfactory due to their chemical composition differences.

Cardash HS et al in 1986[12] evaluated the effect of various shapes of retention grooves on the ridge lap surface of acrylic resin teeth on tooth denture-base bond. Three different types of grooves were cut on the ridge lap surface of acrylic teeth with no preparation acting as control group. The bond strength was tested in a universal testing machine at a cross head speed of 5mm/min and the force was applied at 130^0 to long axis of the tooth. They concluded that there was no significance in the preparation of various types of grooves on the ridge lap surface of acrylic teeth over the tooth denture base bond.

Caswell et al in 1986[15] conducted a study to compare the bond strengths of three abrasion resistant plastic denture teeth bonded to a cross linked and a grafted cross linked denture base material. It was suggested that the ridge lap be reduced by 1mm to aid in the penetration of denture base acrylic monomer. In this study 83% of fractures occurred within the teeth itself. There was no significant difference in bond strength between types of teeth.

Spratley et al in 1987[55] conducted a study to investigate the adhesion of acrylic resin teeth to the dentures. It was concluded that wax was the principal contaminant and cause of adhesive failure, and its elimination at low temperature was ineffective. It was also concluded that painting the ridge laps of the teeth with monomer or grinding the ridge lap before packing did not seem to improve adhesion. On visual examination, most of the failures were cohesive.

Clancy et al in 1989[18] evaluated the bond strength of standard and IPN acrylic resin denture teeth to heat-cured, light-cured and auto polymerizing resin denture bases. They after bond strength testing concluded that strongest bond was between heat-cured resin and standard plastic teeth. Intermediate strength for heat cured resin and IPN teeth and auto-polymerizing resin to both teeth types. Lowest strength for light cured resin to both teeth types.

Cardosh HS et al in 1990[14] investigated the bond strength of acrylic resin teeth with and without retention grooves processed onto standard and high-impact denture base resin. Shear compressive force was applied at an angle of 130 degrees at a cross head speed of 5mm/min to the lingual surface of the teeth until fracture occurred. They concluded that canine teeth bonded better than central or lateral incisors. A significantly greater force was required to fracture teeth from high-impact resin. Vertical retention grooves of 2mm depth and width enhanced bond strength. Preparing retentive grooves of different shapes derived no statistically significant advantage

Clancy et al in 1991[19] conducted a study on tensile bond strengths and failure analysis of one heat cured and two visible light cured denture base resins of two types of denture teeth. The resins were processed into cylinders against denture teeth milled to the same size. Half of the specimens were thermocycled. After tensile testing it was concluded that the strongest bonding was with heat cured resin bonded to standard acrylic teeth. Abrasion resistant denture teeth and light cure had less bond strength comparatively.

Kawara et al in 1991[35]compared the bond strengths of three types of acrylic resin teeth(regular monolithic acrylic resin teeth, monolithic acrylic resin-IPN teeth, multilithic acrylic resin-composite resin teeth) with light activated resin, conventional heat cured resin and auto-polymerizing resin denture base materials. It was concluded from a four point flexure testing that auto-polymerizing resin showed highest interfacial failure with all acrylic resin teeth. Traditional regular monolithic acrylic teeth with heat cured resin had better bond strength. Light activated resin also exhibited debonding of denture teeth but the failure rate was comparatively less compared to auto-polymerizing resin. Heat cure denture base resin exhibited the best bonding compared to the other resins.

Polukoshko et al in 1992[48] compared heat-cured acrylic resin denture base plate distortions following second heat cure acrylic resin addition to the denture teeth. The second heat cure was done with three different water bath curing temperatures and distortions were evaluated in three planes by using a measuring microscope. It was concluded that recorded distortions were not clinically significant after second additions

Cunningham in 1993[21] made a review on the bond strength of denture teeth to acrylic resin. He made a survey of failure rate of acrylic resin dentures in Britian and Northern Ireland. He found that number of repairs was over 60% of the number of dentures produced. Out of this one-third was due to tooth debonding, mostly in anterior regions.

Catterlin et al in 1993[11] evaluated whether tin foil substitute contamination has any significant effect on the bond strength between acrylic resin teeth and processed acrylic resin base. The experimental group had the denture tooth ridge lap area contaminated with tin foil substitute unlike the control group and concluded that: contamination with tin foil substitute significantly reduced the bond strength of acrylic resin teeth bonded to denture base resin.

Darbar JR et al in 1994[24] carried out a survey to determine the prevalence of type of fracture by the distribution of questionnaires to three different laboratories. Results obtained showed that 33% of the repairs carried out were due to debonded/detached teeth.

Vallitu et al in 1994[62] evaluated the transverse strength of repaired heat-cured acrylic resin. The heat cured resin repair surfaces were wetted with monomer. They applied monomer for 5, 30, 60 and 180seconds before auto-polymerizing resin was applied on the repair surface. They concluded that increasing the time of wetting the surface with monomer (60,180s) showed better bond strength of acrylic teeth. Visual examination revealed a lesser adhesive failure when wetting time was increased. Scanning electron microscopic evaluation revealed a smoother surface texture dissolution of heat cured repair surface after monomer wetting of 60 and 180s.

Cunningham et al in 1995[23] determined the bond strength of denture teeth to acrylic resin denture bases by producing tensile test specimens from standardized and anonymously presented partial dentures. 10 maxillary removable dentures with 3 anterior teeth were produced from randomly selected commercial dental laboratories and 5 were produced in a university dental laboratory. The debonding forces of tooth exhibited a mean of 181N and a wide range of variation of 301N both within and between dentures. The university-produced dentures showed slightly improved tooth bond strength. They concluded that a standardized technique to provide satisfactory denture tooth bonding is needed.

Darbar et al in 1995[25] conducted a finite element study to examine the stress at the interface of tooth and denture base resin when a single static force was applied that resembled incisal bite force. They concluded that irrespective of the type of acrylic teeth used, maximum tensile stresses were found at the palatal aspect of the interface. It was suggested that boxing the tooth in the acrylic resin will help redistribute stress concentration favourably.

Arima T et al in 1996[4]used scanning electron microscopy to investigate the effect of resin surface primers for reline acrylic resins on the surface texture of denture base resin. The composition of the primers was analyzed and further classified into three groups: solvent based, monomer based, and monomer and polymer based. Scanning electron microscopic observation revealed various effects of the primers on the denture base resin surface, which depended on the composition of primers.

Buyukyilmaz et al in 1997 [10]investigated the effect of different polymerization temperatures on the bond strength and the type of bond failure between denture base polymers and polymer teeth using two auto-polymerized and one heat-polymerized denture base material. For this purpose, a peel test and a shear test were used. The strongest bond strengths occurred between the heat-polymerized denture base polymer and the polymer teeth whereas auto-polymerized denture base polymers showed lower bond strengths. With increasing temperatures, the bond strength of the auto-polymerized systems increased and the bonding characteristics changed from adhesive to cohesive failure, particularly at temperatures above 50 degrees C.

Vallittu et al 1997[61] examined the interface between acrylic resin polymer teeth and denture base polymers. An auto- polymerized denture base polymer was cured at 30, 50 or 70 degrees and heat cured denture base polymer was cured at 100 degrees in contact with acrylic resin polymer teeth. The specimens were ground wet and polished and they were treated with solvent tetrahydrofuran and then examined under scanning electron microscopy. It was then concluded that by increasing the polymerization temperature, the monomers of the denture base polymers diffused more effectively into acrylic resin polymer teeth which increased the bond strength between polymer teeth and the denture base polymer.

Barpal et al in 1998 [5]found that the bonding of highly cross-linked denture teeth to a denture base was significantly influenced by modifications of the ridge lap before processing. The ridge lap portion of identical denture teeth were modified by placing diaortic, using monomer to pre wet the teeth for 30 s and breaking the glaze. They micro-sand blasted the ridge lap portion of the denture tooth with 50 µ Al2O3 for 20 seconds only to break the glaze. A transverse angle of 60 degrees with a cross head speed of

5mm/min was applied until fracture occurred. For heat cured resins, highest failure loads resulted when the ridge lap was left with an intact glaze and did not have a diatoric, with no significant change from monomer application. For pour type resin, highest failure loads resulted when diatorics were used without monomer treatment and no significant influence from glaze. Monomer application had no effect in bond strength in either group.

Cunningham et al in 1999[22] evaluated the tensile bond strength of specimens produced by commonly employed tooth preparation and processing methods as used in dental laboratories. Twenty-two experimental groups, each consisting of 36 specimens, were investigated by subjecting the tooth-resin bond to tensile loading. The groups were subjected to five experimental sets to investigate: (a) effect of resin dough time, (b) effect of tooth surface condition, (c) effect of processing variables, (d) effect of monomer cementing, and (e) effect of acrylic resin cement. A significantly stronger bond was obtained when the resin was packed late in the dough stage, and a superior bond, in all cases, when high impact resin was used. Tooth surface modification by grinding or grooving made no significant difference when compared with unmodified surfaces. Wax contaminated surfaces produced highly significant weaker bonds. Time of introduction and duration of water-bath processing also had no significant effect on bond strength. But monomer cementing of the tooth surface with 180s application time, especially with high-impact resin monomer significantly improved the bond strength. The applications of resin cements significantly increase the denture tooth bond strength.

Papazoglou et a1 1999[46] examined shear bond strengths between composite and auto polymerized acrylic resin bonded to acrylic resin denture teeth. The surface treatments used for the denture teeth included wetting the ridge lap area with methyl methacrylate for 3 minutes, vinylethyl methacrylate monomer, and unfilled acrylic resin, composite bonding agent and composite color modifier. The specimens were stored in water for 7 days at 37^0 C and 100% humidity and thermocycled and subjected to testing. It was then concluded that the bond strength of composite to acrylic resin denture teeth was comparable to the bond strength of auto polymerized acrylic resin. Application of monomer for 3 minutes enhanced the bond strength. Hyrdrated and non- hydrated samples exhibited similar bond strengths.

Chai J, Takahasi Y et al in 2000[16] examined the bond strength of conventional denture teeth and cross linked denture teeth to a pour type denture base resin. The denture teeth were untreated, prepared with diatorics, or treated with dichloromethane, a solvent. Porcelain teeth were also used for comparison. Compressive load was applied at 45^0 on the palatal surface of each tooth until fracture. They found that there was no significant difference in bond strength between conventional and cross linked teeth groups. Thermocycling decreased the bond strength of resin teeth but porcelain teeth were unaffected. Dichloromethane significantly improved bond strength.

Cunningham in 2000[20] evaluated the shear bond strength of resin teeth to heat cured and visible light cured denture base resin. Specimens were treated with Vitacoll (a proprietary denture tooth bonding agent), an in-house experimental bonding agent composed of a solvent, a mild acid, and a cross-linking agent, and an untreated control group. Shear loading at a cross head speed of 2.5mm/min by a lading rod with a 2mm end radius was used. He inferred that the application of experimental bonding agent improved the shear bond strength. Application of Vitacoll, also improved the bond strength compared to no treatment but less than the experimental agent group. VLC resin showed inferior results compared to heat cured resins. He postulated that since the bonding agent increases the wettability of the tooth surface and has a solvent effect; it favoured a more effective diffusion of the monomers of the denture base polymer into the tooth.

Takahashi et al 2000 [57] examined the bond strength of two types of denture teeth and three denture base resins. The denture teeth were either left untreated or prepared with diatorics, or treated with a dichloromethane solvent. Conventional and cross-linked denture teeth were bonded to either a heat cured denture base resin, a microwave cured denture base resin or a pour-type denture base resin. Compressive load was applied at 45 degrees on the palatal surface of each tooth until fracture. They concluded that conventional resin teeth possessed greater strength than cross-linked denture teeth. Adhesive and cohesive failures were visually evaluated. The heat cured denture surpassed the microwave cured denture base resin, and both these materials were better than pour type resin. Application of dichloromethane resulted in improved bond strength.

Amin et al 2002[3] evaluated the effect of different surface treatment of the tooth ridge lap surface on the strength of the tooth denture base interfacial bonding. Micro-blasting (50 microns Al_2O_3 for 30s) coating with solvent based adhesive (di-methylene chloride in a polymer/monomer mixture) and combined micro-blasting and adhesive coating of the ridge lap surface were investigated. All tests were conducted according to ADA specification no 15. Adhesive coating of the ridge lap surface did not promote bonding significantly compared with the untreated tooth surface. Combined treatment with the adhesive did improve the bonding but was less comparative to that of micro-blast roughening Micro-blasting the tooth ridge lap surface seemed to have a major significant contribution to establishing a satisfactory interfacial bonding.

Frederick A. Rueggeberg in 2002[30] provided the historical background on the development of resin based dental restorative materials. Common problems associated with the use of resin –based materials are explained, and more advanced resin-based systems currently under development are briefly reviewed.

Schneider RL et al., in 2002[53] evaluated the tensile bond strength of 4 different types of acrylic resin denture teeth to a microwave or heat processed denture base resin material. They concluded that same type of denture base material recommended by the denture teeth manufacturer when used improved the bond strength. Heat polymerized groups exhibited better bond strength than microwave cured resin. Heat polymerized groups had cohesive failure and microwave processed groups had more of adhesive failures under scanning electron microscope.

Zuckerman et al in 2003[63] examined a denture tooth modification to determine whether the joint produced between the denture tooth and the denture base resin was stronger than the materials it was composed. Modified and unmodified resin denture teeth were processed to denture base and stressed until fracture occurred and the fragments were labeled, examined and evaluated. They used an angulation of 140 degrees where the force was applied and an explanation of this angulation. They concluded that the cingulum ledge lock modification produced a mechanical union of the resin denture teeth tested to the denture base material and a better bond strength.

Sinasi Sarac Y et al in 2005[56] studied the effect of chemical surface treatments (acetone-for 30s, methylene chloride- for 30s and monomer- for 180s) of denture base resins (processed by heat curing, injection moulding and microwave methods) on the shear bond strength of denture repair. They concluded that chemical treatments showed significant improvement in bond strength.

Beuer.F et al in 2006[9] investigated the acrylic tooth denture base bond after ridge lap area tooth preparation (macro-mechanical retention) and application of conditioners (chemical bond).140 upper incisors (80-Vita and 60-Mondial) teeth were selected. For macro-mechanical retention they made a deep drill hole of 3mm in the centre of ridge lap surface with a round bur to 20 teeth of both groups. Control group teeth were with neither of these treatments from each manufacturer. For chemical retention, they used bonding agents namely Vitacoll and Palabond of the respective teeth manufacturers. The samples were thermocycled and tested at an angle of 45^0 in a universal testing machine. They concluded that neither macro-mechanical retention nor proprietary bonding agents were necessary to enhance retention since all teeth fractured not at the interface between the denture base and tooth. They concluded that normal processing techniques with strict protocols will yield better bond.

Nishigawa G et al in 2006[44] examined the effect and durability of an adhesive primer developed exclusively for heat-curing resin on the adhesive strength of heat-curing denture base acrylic resin to plastic artificial tooth. The following treatments were done on the artificial tooth bonding surface: air abrasion, adhesive primer application, adhesive primer application after air abrasion, and pretreatment only (control). After heat curing of acrylic resin onto the bonding surface, shear test was performed for two storage periods: 24-hour versus 100-day water storage. From the results obtained, it was revealed that the evaluated adhesive primer was significantly effective in increasing adhesive strength between artificial tooth and acrylic resin, although specimens were stored in water for 100 days.

S.B.Patil et al in 2006[47] made a review that takes into account the majority of research papers published in the last five decades for determining the bond strength between acrylic teeth and denture base. They made a review of the following effects on the bond strength from literature (1) impurities of the tooth-denture base resin interface, (2) different types of denture base resins and the method of polymerization,(3) different types of acrylic teeth material,(4) polymerization temperature,(5) ridge lap area modification and/or the application of a bonding agent,(6) an analysis of stress distribution in the dentures. They reported that selection of more compatible combinations of denture base resins and acrylic teeth reduces the number of prosthesis fractures and the resultant repairs.

Saavedra et al in 2007[51] evaluated the durability of adhesion between acrylic teeth and denture base acrylic resin. The base surface of acrylic resin were flattened and subjected to four different surface treatments: no treatment, methyl methacrylate based bonding agent, air abrasion with silicone oxide plus silane and a combination of above. A heat polymerized acrylic resin was applied to the tooth and specimens were subjected to micro tensile test at dry and thermocycled conditions. The results concluded that methyl-methacrylate based monomer application produced the highest bond strength.

Chung et al in 2008[13] evaluated the effect of pre-processing surface treatments (grinding, Grinding plus sandblasting) of acrylic teeth on bonding to heat cured and microwave cured denture base. They found that the surface treatment with grinding plus sandblasting and processed with a heat-polymerized denture base provided the greatest bond strength between acrylic tooth and denture base.

Debora Barros Barbosa et al., in 2008[27] evaluated the bond strength of denture teeth to acrylic resin with different thermocycling and polymerization methods. They concluded that thermocycling decreased the bond strength, but not significantly for microwave or heat polymerized groups. Fast microwave processing should be avoided and longer heat curing cycles gave better bond strength values.

Moffit et al in 2008[41] conducted a study to compare fracture modes of three different commercially available denture teeth under compressive load at 30 degree off- axis angle. Three denture teeth were processed to two different denture base processing system namely the injection molding and compression molding system. Each specimen was processed to a metal framework simulating implant-supported prosthesis with bar attachments. A point compressive load with a cross head speed of 5mm/min was applied. Visible examination of adhesive or cohesive nature of fracture was observed. On an average, tooth within groups fractured at higher compressive force than the average maximum occlusal force in natural dentition. The study concluded that all the specimens were able to withstand 30 degree off axis loading which indicated that denture teeth were able to withstand normal occlusal forces. No significant difference in processing techniques.

Barbosa DB, Monteiro DR et al in 2009[7] evaluated the bond strength between acrylic resins and resin denture teeth by two protocols; monomer liquid application (60s,180s,no application) on the tooth surface and using different polymerization methods (microwave polymerized, heat polymerized, auto polymerized). They concluded that better bond strength values were found for monomer surface treatments regardless of the application time and polymerization cycles. Heat cured resins had better bond strength.

Bragaglia LE et al in 2009[8] compared the bond strength between acrylic denture base and teeth subjected to 6 surface treatments [no treatment <control>; methyl-methacrylate monomer etching; 50-µm-particle aluminum oxide air abrasion; glaze removal with a round bur; surface grinding with an aluminum oxide abrasive stone; cavity preparation (diatorics)]. They concluded that ridge lap surface grinding with an aluminum oxide abrasive stone provided the highest bond strength, though it differed significantly only when compared to diatorics. The other surface treatments provided similar bond between the acrylic denture base and teeth.

Chaves et al in 2009[17] evaluated the tensile bond strength of heat and microwave cured resins to the ridge lap surface with and without surface treatment of monomer application for 180s and thermocycling. They concluded that neither the polymer type, monomer surface treatment nor the thermocycling had any effect on the micro tensile bond strength of Biotone artificial denture teeth to denture base acrylic resins

Marra et al in 2009[39] evaluated the thermo cycling effects and shear bond strength of acrylic resin teeth to denture base resins. Three acrylic teeth (Biotone, Trilux and Ivoclar) were chosen for bonding to four denture base resins: microwave polymerized (Acron MC, heat polymerized (Lucitone 550 and QC- 20) and light polymerized (Versyo bond). The conclusions were drawn as follows:

i. Thermocycling significantly decreased shear bond strengths of Lucitone 550/Biotone, Lucitone 550/ Trilux, and Versyo bond/ Ivoclar specimen.

ii. Shear bond strengths of Acron/ Ivoclar and Lucitone 550/ Ivoclar specimens significantly increased after thermocycling.

iii. The highest shear bond strength values were observed with Lucitone 550 and Versyo bond acrylic resins and lowest with QC-20. Thermocycling had both positive and negative results.

Marra et al in 2009[38] studied the effect of methyl methacrylate monomer application for 180 seconds on the bond strength of three types of denture base resins (Acron MC, Lucitone 550 and QC-20) to two types of acrylic teeth (Biotone and Trilux). Methyl methacrylate monomer increased the bond strength of Lucitone denture base resins and decreased the bond strength of QC- 20. No difference was detected for the bond strength of Acron MC base resin after treatment with methyl methacrylate. They concluded that bond strength was either increased or decreased or no significant change with each type of teeth groups tested.

Photini et al in 2009[50] investigated the bond between four different denture base resins and one type of acrylic denture teeth. Each tooth was loaded separately until fracture. The mode of failure was classified as adhesive and cohesive by visual examination according to ISO3336. All the samples showed cohesive failure meeting the ISO3336 criteria.

Hatim NA et al in 2010[34] evaluated the bond strength and mode of failure of different tooth materials with and without surface treatment (monomer application for 180s) to acrylic resin denture base cured by microwave / water bath techniques. They concluded that the shear bond strength of acrylic teeth (with monomer surface treatment) to microwave cured resin were significantly higher than water-bath cured resin. Cross–linked acrylic teeth showed lowest shear bond strength values compared to other type of acrylic teeth.

Fletcher- Stark et al in 2011[31] evaluated the shear bond strengths of acrylic highly cross-linked denture teeth to heat and light polymerized denture base resins with or without surface treatments (diatorics, acrylate bonding agent). Shear bond strength was tested. They concluded that an acrylate bonding agent with light polymerized resin gave higher bond strength values than other groups.

Meng GK, Chung KH, Fletcher-Stark ML and Zhang H, in 2010[40] compared the bond strengths of denture teeth to auto-polymerized repair acrylic resin after various surface treatments, before and after cyclic loading. Mandibular lateral incisor denture teeth were selected and ground on the ridge-lap portion using a standardized jig. Specimens with a ground surface were used as controls. The experimental groups included: ground plus airborne-particle abraded, ground plus diatoric recess, and ground plus an experimental methyl acetate based bonding agent. The teeth were affixed by an auto-polymerized repair acrylic resin to denture bases.

Specimens (n=10) were subjected to compression testing (5 mm/min) at a 135-degree angle, before and after 14,400 loading cycles at 2 Hz and 22 N. Peak load to dislodgement was recorded . The specimens were then examined using x10 magnification, and fractures were categorized as adhesive, cohesive, or mixed .They concluded that the use of a bonding agent and the placement of a diatoric recess in the denture tooth resulted in higher bond strengths than grinding alone. Cyclic loading was found to have no significant impact on the bond strength of denture teeth to the auto-polymerized repair acrylic resin.

Amarnath GS, H S Indra Kumar et al in 2011[2] compared the bond strength of acrylic maxillary anterior teeth to heat, micro-wave, and self- cured denture base resins. The ridge lap areas were treated with sandblasting and grinding procedures. Bond strength values were tested with cross-head speed of 5mm/min in Universal testing machine. They concluded that sandblasting the ridge lap area of the acrylic denture teeth prior to denture base processing and with heat cured resins possessed higher bond strength. Selection of more compatible combinations of acrylic teeth and denture base resins reduce the number of prosthesis failures and the resultant repairs.

Elena Stoia. A et al in 2011[28] evaluated the bond strength of acrylic resin teeth to self-cured denture base repair resin. They applied 3 different organic solvents namely ethylene chloride, ethyl acetate and acetone to the ridge lap areas of teeth before processing. They concluded that chemical treatment with ethylene chloride had a better bond strength of artificial teeth to denture base resin compared to control. They also explained each organic solvent and its mechanism of action.

Materials and Methods

MATERIALS AND METHODS

The objective of this study was to compare the bond strength of acrylic teeth to heat polymerizing denture base resin after various surface treatments of the bonding surface area of acrylic denture tooth.

50 right and 50 left maxillary crosslinked acrylic central incisor denture teeth (Cosmo HXL^{TM} Acrylic two layered teeth, DENTSPLY Dental (Tianjin) Co., Ltd, China) of same size and shade were selected (Fig1-3). The 100 teeth were then divided into 5 groups with 10 right and 10 left central incisor teeth in each group. The 5 groups were named A, B, C, D and E (Fig14)according to the chemical surface treatments in which group A served as control with no surface treatment. The different chemical surface agents used were (i) Heat-curing Methylmethaacrylate monomer (Dentsply India Pvt.Ltd, Gurgoan, India) - Group B, (ii) Acetone (Merck Specialities Ptd.Ltd, Mumbai, India) - Group C and two commercially available bonding agents namely (iii) Vitacoll, (VITA, Germany) - GroupD and (iv) Superbond (ProTech Professional Products,Inc, Florida, USA) - GroupE (Fig19).

Wax models were made using a custom made jig (Fig11) such that the tooth was placed with a labial inclination of 130^0 from the denture base. The wax models were invested, dewaxed and application of chemical surface agents on the bonding surface was done according to grouping. The specimens were heat polymerized, finished and polished. After 1week of storage in water, the bond strengths of each group were tested.

SAMPLE GROUPING DESIGN TABLE

Table 4.1 The following table illustrates the sampling methodology of this study

100 SAMPLES of maxillary central incisor teeth (50 right and 50 left)					
5 GROUPS – Based on chemical surface treatment on bonding surface of acrylic tooth .					
GROUP	**GROUP A**	**GROUP B**	**GROUP C**	**GROUP D**	**GROUP E**
SAMPLES	20 samples 10 right CI, 10 left CI	20 samples 10 right CI, 10 left CI	20 samples 10 right CI, 10 left CI	20 samples 10 right CI, 10 left CI	20 samples 10 right CI, 10 left CI
TYPE OF SURFACE TREATMENT	No surface treatment	Monomer application	Acetone application	Vitacoll bonding agent application	Superbond bonding agent application

The following materials were used in the study:

Sl No.	Material	Manufacturer
1.	Maxillary central incisor acrylic tooth Shade/Mould –A2/93 (S8/7L) (Fig1-3)	Cosmo HXL^{TM} Acrylic two layered teeth, Dentsply Dental (Tianjin) Co., Ltd, China
2.	Modelling Wax (Fig-4)	Hindustan Dental Products, Hyderabad, India
3.	Type –II Dental Plaster	Asian chemicals, Rajkot, Gujarat, India
4.	Separating medium(Fig-18) (DPI Cold Mould Seal)	Dental Products of India, Mumbai, India
5.	Universal heat cure monomer (Fig-19)	Dentsply India Pvt.Ltd.,Gurgoan, India
6.	Acetone (Fig-19)	Merck Specialities Private Ltd, Mumbai, India
7.	Vitacoll bonding agent (Fig-19)	VITA, Germany
8.	Superbond bonding agent (Fig-19)	ProTech Professional Products, Inc. , Florida, USA
9.	Heat cure acrylic resin-polymer powder and monomer liquid (Fig-22)	Trevalon powder, Denture base material Universal Denture Liquid Dentsply India Pvt. Ltd., Gurgoan, India

The following equipments were used for the study:

Sl.No	Equipment	Manufacturer
1)	Straight fissure tungsten carbide bur	RA 701L, SS White, Lakewood, New Jersy, U.S.A.
2)	Pneumatic bench press (Fig-23)	SIRIO DENTAL Srl 47014 Meldola FC-Italy
3)	Curing Flask	SS Products, India.
4)	Acrylizer (Fig-24)	Confident Dental Equipments Private Limited, Bangalore, India.
5)	Dental Lathe	Suguna dental lathe, Coimbatore, India
6)	Lab Micromotor	Marathon, Gem Surg Equipments Pvt. Ltd, New Delhi, India.
7)	Universal Testing Machine (Fig-28)	Instron,5500R, Norwood, U.S.A.
8)	Contra angle micromotor handpiece	NSK Nakanishi Inc., Tokyo, Japan.

METHODOLOGY: The following methodology was adopted for the study:

STAGES	
I.	**Fabrication of test specimen** • Selection and preparation of acrylic teeth for the test sample • Preparation of wax model with acrylic denture teeth using custom made metal jig
II.	**Flasking and Dewaxing the samples**
III.	**Application of various chemicals on the bonding surface of the acrylic teeth**
IV.	**Acrylization of the test samples**
V.	**Finishing and polishing of the test specimens**
VI.	**Aging the specimens**
VII.	**Testing the samples for bond strength evaluation**
VIII.	**Statistical evaluation**

I. FABRICATION OF TEST SPECIMEN

Preparation of acrylic teeth for test sample

The selected teeth were removed from the manufacture's mould and cleaned off the carding wax used to hold them in the mould.

Description of custom made jig for preparing wax patterns

Two metal jigs were made to fabricate a wax model such that the acrylic tooth was held at a labial inclination of 130^o to the denture base. This is the angulation in which the lower anteriors contacts the lingual slopes of the upper teeth. This angulation has been used with references from literature[12,14].

Design:

Two jigs, an inner jig and an outer enclosing jig were made. (Fig-5-9)

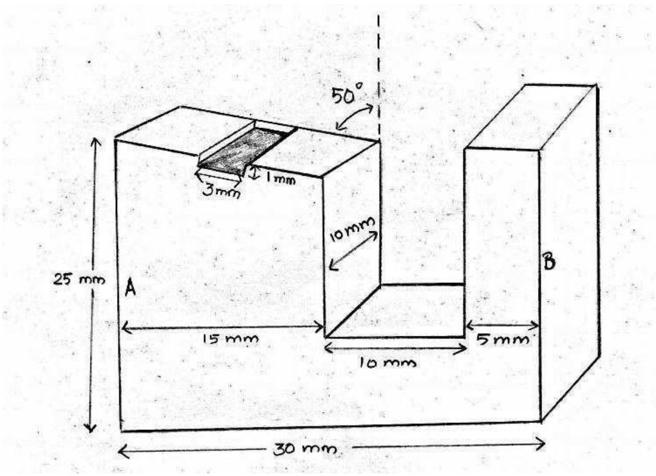


Fig 4.1: Inner metal jig- lateral view

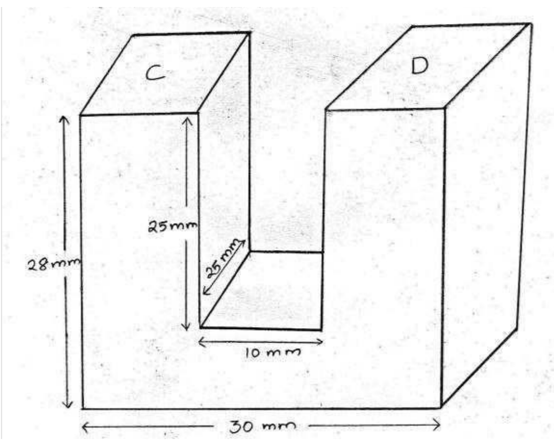
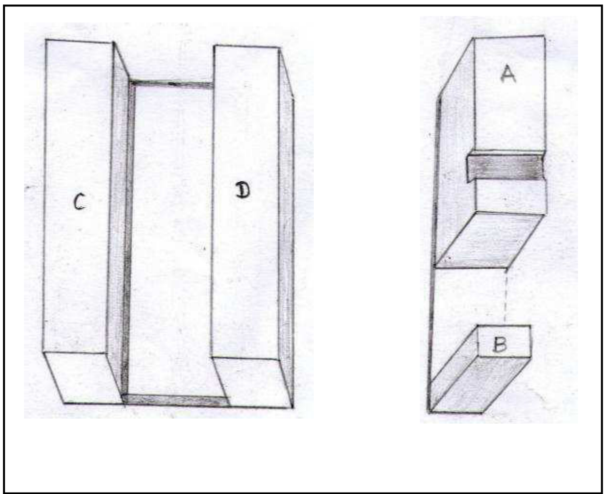


Fig 4.2: Outer enclosing jig- lateral view

The inner metal jig (Fig 4.1) of 30mm breadth, 25mm length and 10 mm width was milled such that it has two wall A and B. Wall A of 15 mm breadth was made such that it had an inclined surface sloping towards wall B. The inclination of the slope is 50^0 to the perpendicular inner wall. A 3mm width and 1mm depth horizontal trough was made on the inclined slope of wall B. It is on this trough that the labial surface of acrylic teeth was mounted to achieve 130^0 labial inclination. Wall B of 5mm breadth was made straight. The distance between the inner sides of both the walls was 10mm.

The outer enclosing jig (Fig 4.2) had 2 parallel walls of 25mm length and an inner trough. Inside this trough, the inner jig was inserted and this formed a closed casing (Fig 4.3, Fig 4.4) with opening in the upper part. Now wax can be poured into this casing and a wax model can be obtained.



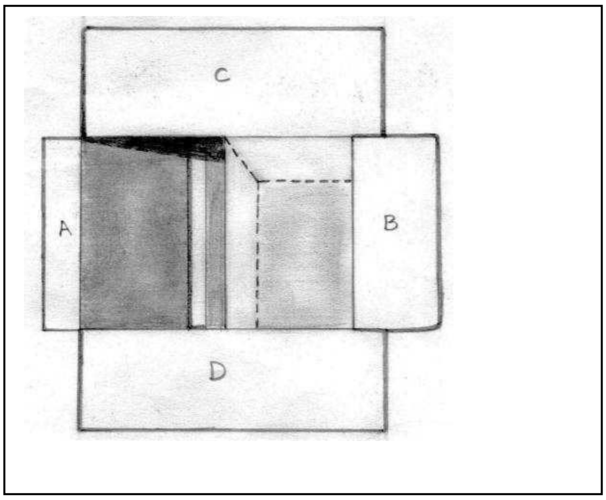


Fig 4.3: Inner and outer jigs from superior view

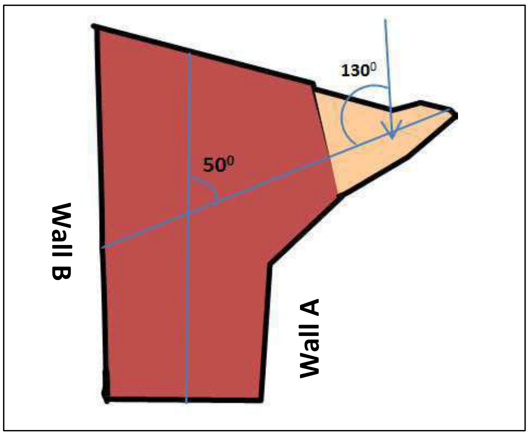
Fig 4.4: Assembled inner and outer jigs

Preparation of wax model: (Fig-9-14)

In the trough made in inclined slope of wall A of the inner metal jig, carding wax was placed and the facial surface of the sample tooth was secured in place.

The inner metal jig was then inserted into the trough of the outer casing metal jig .Into the enclosed area of both the jigs, modeling wax was melted and poured. The inner jig was removed from the outer encasing jig and the wax block separated out. The wax block was made such that the entire ridge lap area was covered with wax (Fig-12). The cervical portion of the tooth was also cuffed with wax to simulate the clinical situation. Final carving and polishing of the wax blocks were done.

Fig 4.5: The schematic diagram of the wax block shows how the tooth was oriented at 130^0 to the denture base.



II PROCESSING OF THE SAMPLES

Flasking procedure:

After the wax blocks were made the investing procedure was carried out in a conventional manner (Fig-15). 10 samples from a group were invested in a conventional flask with a mix of Dental stone and Plaster of Paris. White petroleum jelly (PRS Pharmaceuticals.Ptd.Ltd, Salem, India) was applied as separating medium and the counterpart was poured. The flask was fastened in the clamp and allowed to set completely.

De-waxing procedure:

Water was allowed to boil in a de-waxing water-bath. The flask was then immersed in boiling water for 10 minutes. It was then removed from the water bath and dewaxing procedure was done. Strict protocols were maintained in the dewaxing step as literature[26,55] warrants incomplete wax elimination as one of the most important causes of tooth debonding. A detergent was mixed in part of the boiling water and remaining water was kept plain. With the flow of detergent water dewaxing was done 3 times until complete elimination of wax (Fig-16). Finally, plain boiling water was used once to dewax and remove the detergent residues (Fig-17). It was ensured that wax was eliminated fully. After removal of the wax, Cold Mould Seal (Dental Products of India, Mumbai, India) was applied as separating medium over the entire plaster area (Fig-18). The above procedures of flasking and dewaxing were carried out for all the wax models of the 5 groups by investing 10samples in a flask

With the above procedures common to all the groups, the applications of chemical treatments were then done for each group accordingly after dewaxing procedure.

III. APPLICATION OF VARIOUS CHEMICALS ON THE RIDGE LAP AREA OF ACRYLIC TEETH

The dewaxed and grouped samples were then subjected to surface treatments. The entire application time and packing time was monitored with a stop clock.

Group A-

After dewaxing and application of separating medium on plaster area, the Trevalon heat curing acrylic resin was placed in the mould space and packed without any application of chemicals on the bonding surface and this group served as a control.

Group B-

On the dewaxed ridge lap areas of the acrylic teeth, heat-polymerizing MMA monomer universal liquid (Fig-19) of the same resin was used. The monomer was applied with a brush continuously on the ridge lap area of the teeth for 180 seconds. This application time of 180seconds was found to result in better bond strengths as compared to shorter duration application times of 30 seconds and 60 seconds from literature[22, 34, 56, and 62]. Packing was done immediately after application.

Group C-

Acetone (Fig-19) was applied with a brush continuously for 30 seconds on the ridge lap area of the teeth. 30 s application time made the surfaces completely clean and this is supported by previous studies[28, 47 and 56]. After 30s, packing with denture base resin was done.

Group D-

In this group VITACOLL (a mixture of methymetha acrylate and butanone) (Fig-19), a proprietary bonding agent was applied as per manufacturer's instructions explicitly. After the dewaxing procedure, with a contra angle micromotor hand piece, vertical grooves were made in one direction across the entire basal surfaces of the teeth using a straight fissure tungsten carbide bur (RA 701L, SS White, Lakewood, New Jersy, U.S.A). (Fig-20 and 21). After ensuring that the entire basal surfaces of the teeth were completely free of any insulating material, VITACOLL bonding agent was applied to keep tooth bases wet for 5 minutes. They were remoistened with VITACOLL without drying out for the entire reaction time of 5 minutes. It was maintained that the bonding agent was applied only on the basal surfaces of the teeth and not poured into the mould and contact was avoided with plaster surfaces. Packing was done within 10 minutes after application of the bonding agent.

Group E-

In this group, SUPER-BOND (ProTech, Professional Products, Inc, Florida, US) bonding agent (Fig-19) was used. It is a copolymer resin solution in combustible solvent. After complete wax elimination, with a camel's hairbrush, a thin coat of bonding agent was applied as uniformly as possible to the necks of the teeth, ensuring the entire basal surface is coated. Bonding agent was allowed to dry for 5 minutes. After 5 minutes packing was done.

APPLICATION TIME OF CHEMICALS AND PACKING PROCEDURE

Group A No-Surface Treatment	Group B Monomer Application	Group C Acetone Application	Group D Vitacoll Bonding agent Application	Group E Superbond Bonding agent Application
	180 Seconds	30seconds	Vertical Grooves Made In One Direction With A Straight Fissure Tungsten Carbide Bur (RA 701L, SS White, Lakewood, New Jersy, U.S.A.) BondingAgent Application- 5minutes	Applied Uniformly As A Thin Coat On Necks Of The Teeth.
Packed Immediately	Packed Immediately	Packed Immediately	Packed Within 10 Minutes After Application.	After Application Let It Dry For 5minutes And Packed Immediately.

IV. ACRYLIZATION OF THE TEST SPECIMEN:

After following the above protocol of application of chemicals on the ridge lap areas of acrylic teeth, the packing and acrylization procedures were carried out according to the manufacturer's instruction of the TREVALON heat curing acrylic resin(DENTSPLY, Gurgoan, India) (Fig-22). The teeth set and the denture base material were selected from the same manufacturer so that there won't be any bias regarding difference in the material.

Packing procedure

The Powder/Liquid ratio recommended was 24g-10ml.

10ml of liquid (Universal Denture Liquid for Trevalon Powder, DENTSPLY, Gurgoan, India) was measured and poured in a mixing vessel. 24g of Trevalon powder was measured and added to the liquid in a slow steady stream, until excess appeared on the surface. The mixing vessel was held in the hand and tapped 3 to 4 times to bring any excess monomer liquid to the surface and sufficient powder was added to absorb this liquid. The vessel was inverted and surplus powder removed.

After adding the powder, the mix was spatulated with a spatula for 1 minute. The vessel was covered with a lid and waited for the mix to reach the packing and pressing stage (dough time-10-12minutes). At this stage, the mix was separated cleanly from the walls of the mixing spatula without any stickiness or stringiness. The mix was then hand manipulated to a homogenous mass and packed into the mould space during the dough stage with a polyethylene sheet placed over the resin material to aid in trial closure to remove excess resin.

Bench press:

The counterparts were closed and bench press was done gently with a pneumatic press (Fig-23). The counterparts were separated and the polyethylene sheet teased out and flash removed. The counterparts were then closed and the final closure was done with 2000psi pressure and held for 5 minutes and transferred to the clamps and fastened tightly.

Bench curing:

The packed flasks were allowed to bench cure for 1 hour.

The above packing procedure was carried out to all the 10 flasks containing 10 specimens in each flask.

Acrylization Procedure:

After the packing procedure was completed, the curing procedure was done as per manufacturer’s instruction as follows.

The flasks were immersed in water at room temperature in the Acrylizer (Confident Dental Equipment’s Pvt. Ltd, Bangalore, India) (Fig – 24). The temperature was gradually raised to 74^0 C and maintained constantly for 2 hours and then it was finally increased to 100^0 C and processed for 1 hour.

Bench cooling:

The flasks were then allowed to bench cool for 30minutes. The flasks were then deflasked and the samples were retrieved gently (Fig-25).

V. FINISHING AND POLISHING OF THE TEST SPECIMENS:

The retrieved samples from each group were trimmed in a dental lathe with tungsten carbide burs, acrylic burs and cherry stone and smoothened with silicon carbide water proof papers (Carborandum universal) of grit size 220(coarse), 320(medium) and 400(fine). The specimens were then polished with wet rag wheels and pumice slurry and a high shine obtained using a felt wheel and cotton buffs. The dimensions of the samples were maintained during trimming (Fig-26).

VI. AGING THE SAMPLES:

The test samples were placed in 5 different containers for each group. The containers were labelled with group name, number of samples, date of immersion in water, and date of testing mentioned (Fig-26 and 27).

The samples were immersed in water for 7days as an aging process before testing (Fig-27). This was done to simulate the oral environment. Normally storage in water for a longer time was needed, but from literature[44, 46, 47] it was said that aging duration doesn't significantly affect the bond strength.

VII. TESTING THE SAMPLES:

The acrylic samples were tested for shear bond strength on an Instron Universal Testing Machine (Fig-28) at the Department of Physics, SITRA, Coimbatore, Tamilnadu, India.

A special chisel (Fig-4.5, 29) was made such that the diameter of the tip of the chisel was 8mm which was equal to that of the width of the lower incisor, so that it simulates the contacting lower incisor surface on the palatal aspect of the maxillary tooth.

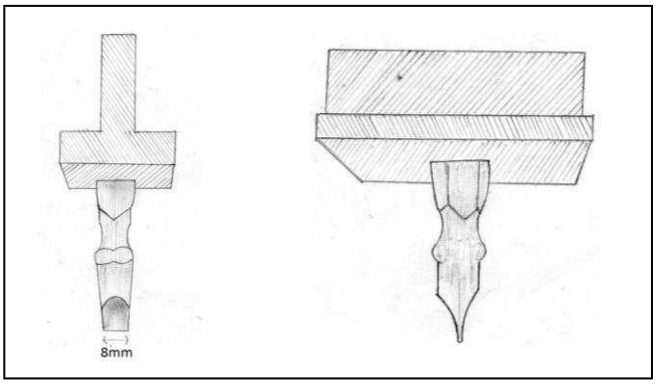


Fig 4.5 Different views of the special chisel

A marking was made 2mm from the incisal edge on the palatal aspect of the sample teeth so as to orient the chisel tip during application of the load. This position was maintained to all the test specimens. Also this junction was at 130degrees to the long axis of the tooth-denture base contact area, which is the angulation where the lower incisors contact the palatal aspect of maxillary tooth during masticatory impact force.

The test sample was fixed to the sample fixture at the bench vice of the machine, with the monobeveled chisel blade placed flat against the marking on the palatal aspect of the test tooth (Fig-30).

The force was applied at a cross head speed of 5mm/min at this junction till the tooth fractured [2, 5, 14, 40] (Fig-31). A computer attached to the testing machine recorded the load at which this fracture occurred. The load dropped instantly once the fracture occurred. The values were obtained in Newton.

The adhesive and cohesive nature of the failure on visual examination also was evaluated (Fig-32). From literature[8, 53, 57, 62] , on visual examination, an adhesive failure occurred when there was no trace of either tooth or denture base material on each other and it was a pure bond failure. A cohesive failure occurred when the fracture occurred at the interface but either tooth material was present on the denture base or vice-versa.

VIII. STATISTICAL EVALUATION:

The SPSS software (version 11.5) package was used for statistical analysis. Mean and Standard deviation were estimated from the results obtained from each sample for each study group. The values of the test result were statistically analysed using one way – ANOVA, Tukey’s HSD and Chi- Square tests.

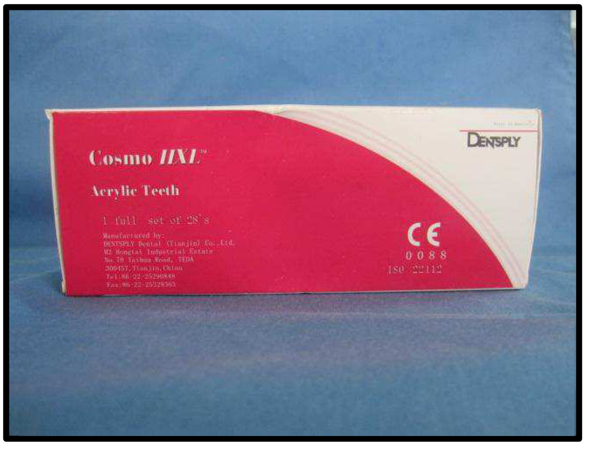


Fig-1 - Acrylic teeth set (Cosmo HXL, Dentsply, China)

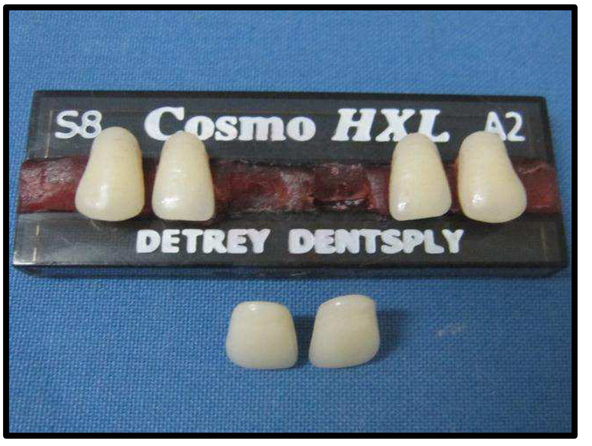


Fig-2 - Maxillary right & left central incisors

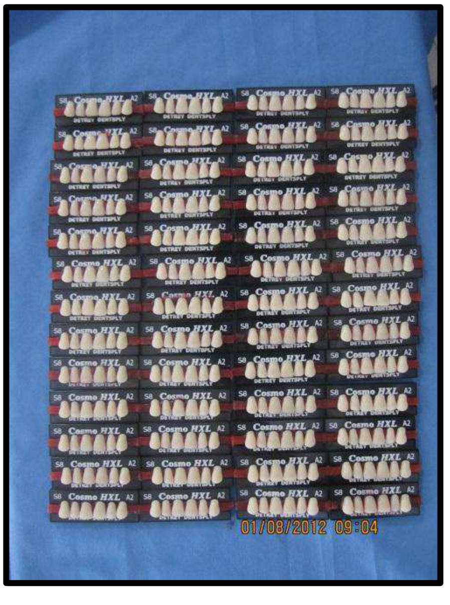


Fig-3 - 50 anterior acrylic teeth sets (Cosmo HXL, Dentsply, China)

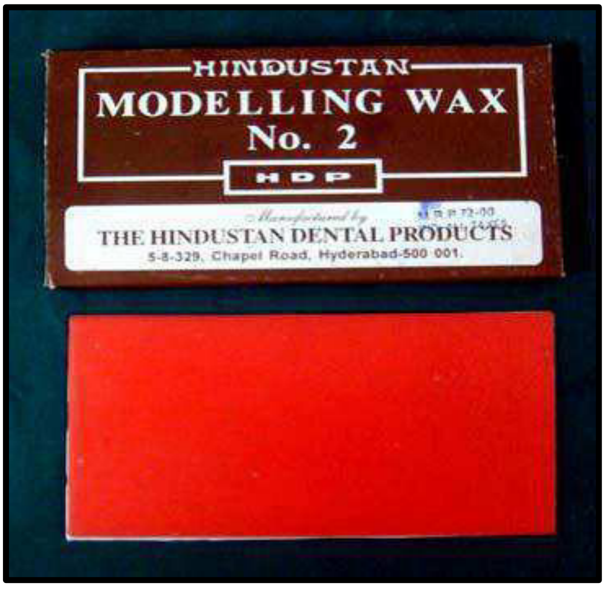


Fig-4 - Modelling wax (Hindustan Dental Products, Hyderabad, India)

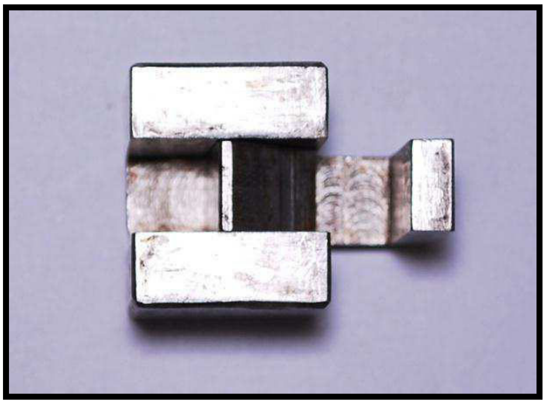


Fig-5 - Assembling of two parts of metal jig

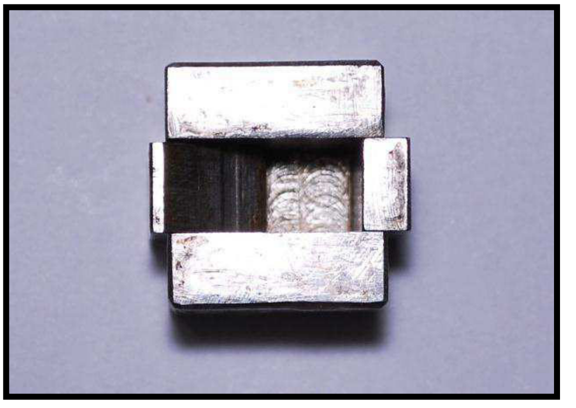


Fig-6 - Assembled metal jig forming a casing for wax model

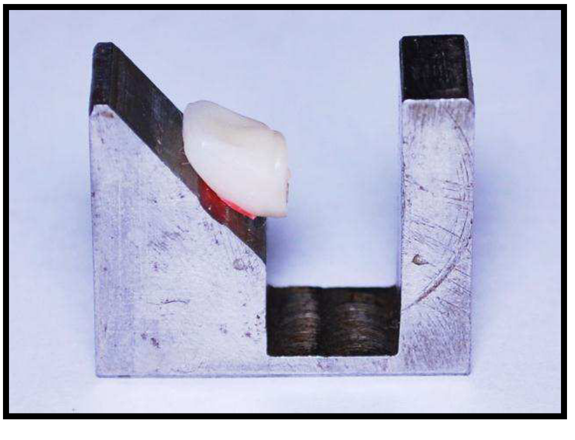


Fig-7 - Tooth being placed at 130^0 to denture base

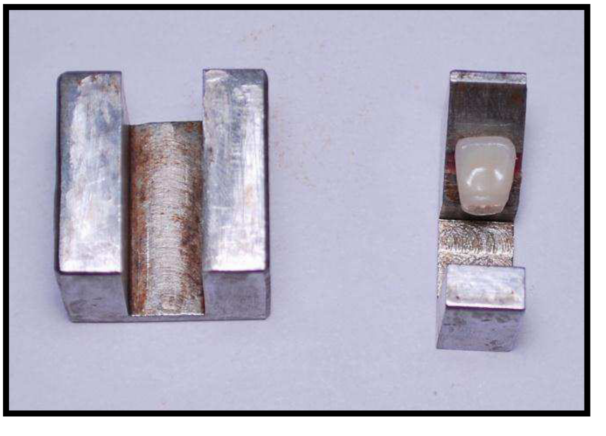


Fig-8 - Tooth positioned on the trough of the inclined slope of inner jig using carding wax

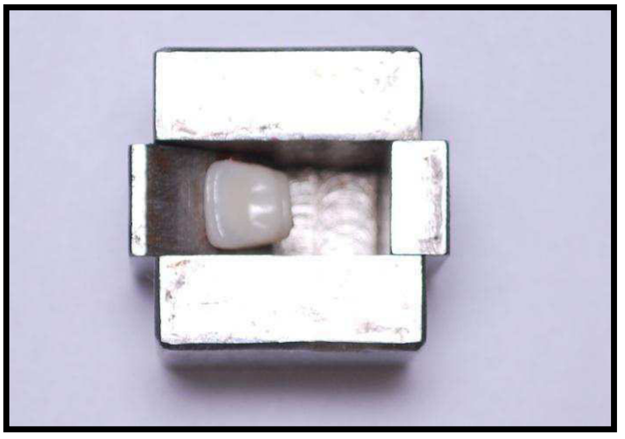


Fig-9 - Tooth placed on the assembled metal jig

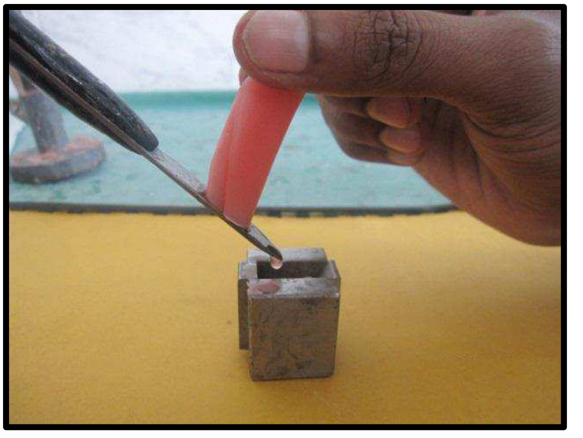


Fig-10 - Molten wax being poured into the assembled metal jig

Fig-11 - Tooth positioned at 130^0 in modelling wax - Superior view

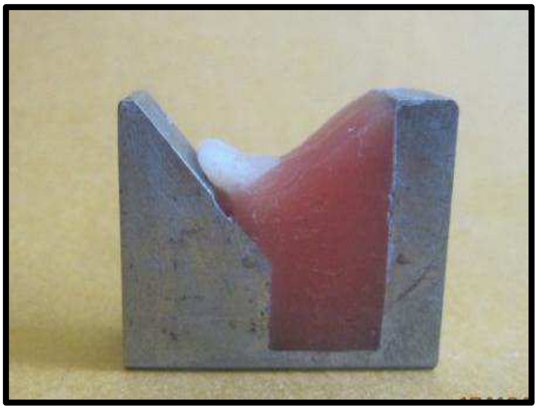


Fig-12 - Tooth positioned at 130^0 in modelling wax- Lateral view

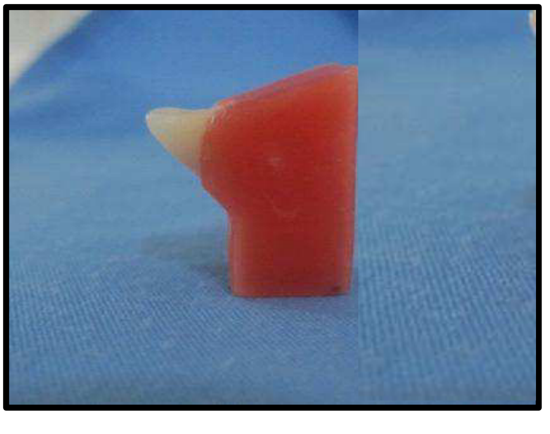


Fig-13 - Wax pattern removed from the metal jig- Lateral view

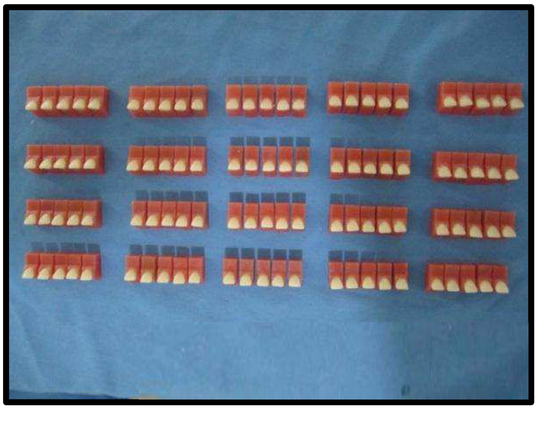


Fig-14 - 100 samples of the study

Fig-15 - Flasking the wax pattern samples

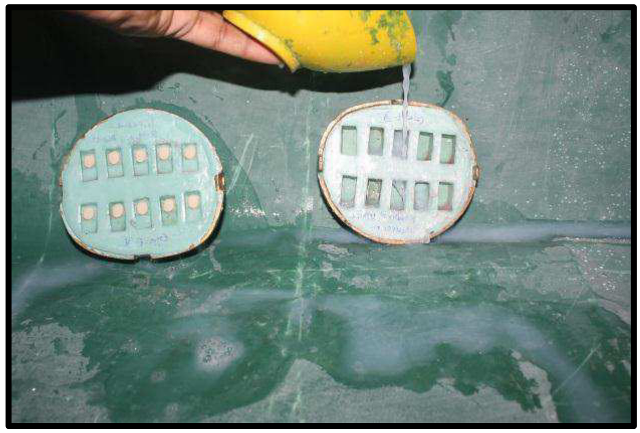


Fig-16 – Dewaxing with detergent boiling water

Fig-17 – Dewaxing completed with plain boiling water

Fig-18 – Application of separating medium- Cold Mould Seal(DPI, Mumbai, India)

Fig-19 - Chemicals used for surface treatments.[from left to right] Group B- Heat polymerizing monomer; Group C - Acetone; Group D - Vitacoll bonding agent Group E – Super bond bonding agent

Fig-20 - Vertical grooves made with contra-angle hand piece using straight fissure tungsten carbide bur (RA 701L)

Fig-21 – Straight fissure tungsten carbide bur(RA 701L,SS White, Lakewood, NewJersy, U.S.A) For Group-D samples

Fig-22 - Trevalon Heat Curing acrylic resin (Dentsply, India)

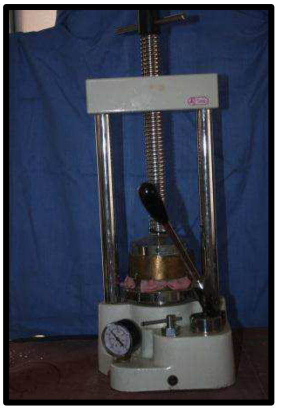


Fig-23 - Packing at 2000psi using pneumatic bench press

Fig-24 - Acrylizer (Confident Dental Equipments, India Pvt. Ltd.)

Fig-25 - Acrylized samples

Fig-26 - Trimmed and polished test samples arranged in their respective 5 groups of 20 each

Fig-27 - Samples labelled and kept in water for aging (1 week)

Fig-28 - Universal testing machine, Instron, 5500R, Norwood, U.S.A

Fig-29 - Special chisel with 8mm diameter bevel

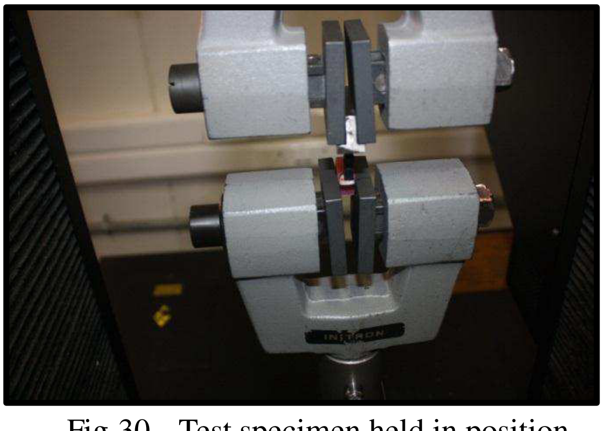


Fig-30 - Test specimen held in position in Instron machine

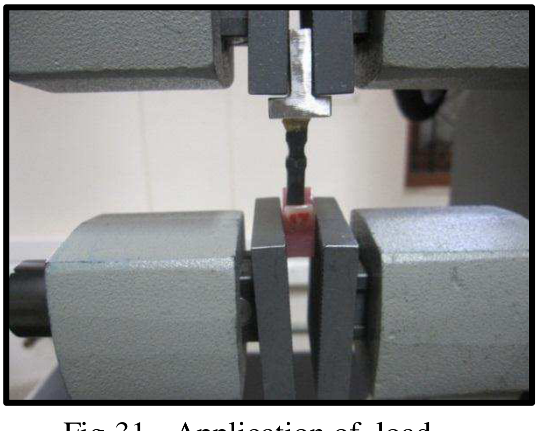


Fig-31 - Application of load

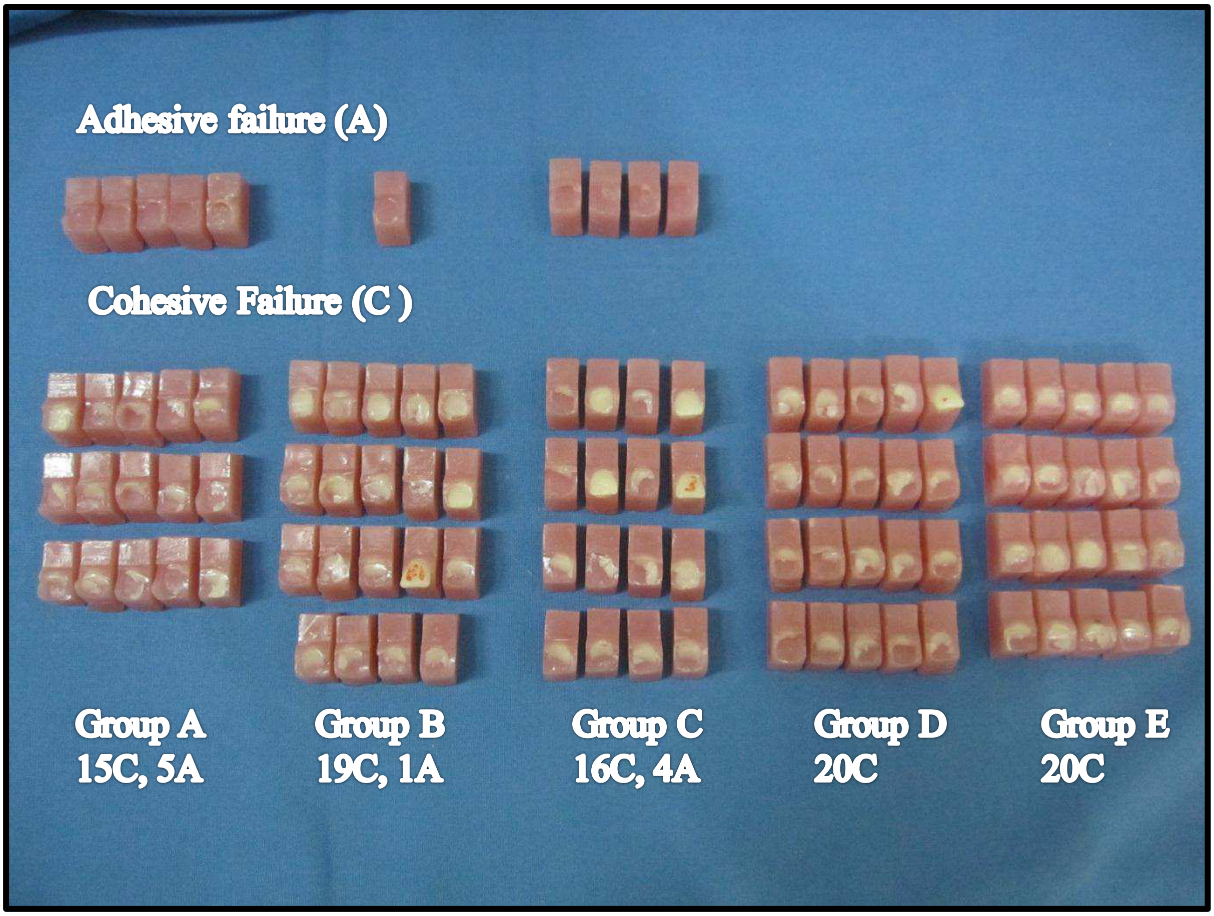


Fig-32 - Type of failures (A-Adhesive, C-Cohesvie) in each group

Results

RESULTS

The objective of this study was to compare the bond strength of acrylic denture teeth to heat polymerised denture base resins after various surface treatments on the bonding surface of acrylic tooth.

The type of failure, whether adhesive or cohesive, in nature would be useful in evaluating the bond at the interface of acrylic tooth to denture base.

With the above objectives in mind, the results of the study were statistically interpreted.

The bond strength values of the test specimens were calculated in Newtons (N).

Table 5.1 Illustrates the sampling based on this study

100 SAMPLES of maxillary central incisor teeth (50 right and 50 left)					
5 GROUPS – Based on chemical surface treatment on ridge lap area of acrylic teeth .					
GROUP	**GROUP A**	**GROUP B**	**GROUP C**	**GROUP D**	**GROUP E**
SAMPLES	**20 samples 10 right CI, 10 left CI**	**20 samples 10 right CI, 10 left CI**	**20 samples 10 right CI, 10 left CI**	**20 samples 10 right CI, 10 left CI**	**20 samples 10 right CI, 10 left CI**
TYPE OF SURFACE TREATMENT	**No surface treatment**	**Monomer application**	**Acetone application**	**Vitacoll bonding agent application**	**Superbond bonding agent application**

Table 5.2 Bond strength values and type of failure results of acrylic denture teeth to heat polymerised acrylic denture base resin with no surface treatment on the bonding surface of acrylic teeth before processing.

GROUP A- CONTROL, NO SURFACE TREATMENT

SAMPLE NO.	BOND STRENGTH VALUES IN NEWTON(N)	TYPE OF FAILURE A-Adhesive C-Cohesive
1	433.96	A
2	447.15	C
3	526.77	A
4	447.91	C
5	432.08	C
6	499.80	C
7	619.26	C
8	452.83	A
9	565.19	C
10	487.42	C
11	499.55	C
12	505.61	C
13	499.31	A
14	533.63	C
15	576.18	C
16	579.46	C
17	575.33	C
18	579.13	C
19	448.14	A
20	497.13	C
MEAN	**510.29**	**5A, 15C**

Table 5.3 Bond strength values of acrylic denture teeth to heat polymerised denture base resin with heat cure monomer surface treatment for 180s on the bonding surface of acrylic teeth before processing.

GROUP B (MONOMER APPLICATION FOR 180S)

SAMPLE NO.	BOND STRENGTH VALUES IN NEWTON(N)	TYPE OF FAILURE A-Adhesive C-Cohesive
1	590.16	C
2	516.36	C
3	469.04	C
4	596.87	C
5	495.29	C
6	593.57	C
7	486.59	C
8	389.97	C
9	483.51	A
10	521.40	C
11	452.67	C
12	452.60	C
13	557.53	C
14	480.05	C
15	579.47	C
16	489.08	C
17	564.03	C
18	596.19	C
19	579.86	C
20	492.35	C
MEAN	**519.33**	**1A,19C**

Table 5.4 Bond strength values of acrylic denture teeth to heat polymerised denture base resin with acetone surface treatment on the bonding surface of acrylic teeth before processing.

GROUP C (ACETONE APPLICATION FOR 30S)

SAMPLE NO.	**BOND STRENGTH VALUES IN NEWTON(N)**	**TYPE OF FAILURE A-Adhesive C-Cohesive**
1	657.84	C
2	512.97	A
3	586.11	C
4	589.19	C
5	572.78	C
6	732.82	C
7	601.51	C
8	582.81	C
9	593.11	C
10	644.87	A
11	735.49	C
12	769.41	C
13	761.54	C
14	598.76	A
15	748.61	C
16	583.18	C
17	802.62	C
18	675.01	C
19	616.68	A
20	567.78	C
MEAN	**646.65**	**4A, 16C**

Table 5.5 Bond strength values of acrylic denture teeth to heat polymerised denture base resin withVitacoll bonding agent surface treatment on the bonding surface of acrylic teeth before processing.

GROUP D (VITACOLL BONDING AGENT APPLICATION)

SAMPLE NO.	BOND STRENGTH VALUES IN NEWTON(N)	TYPE OF FAILURE A-Adhesive C-Cohesive
1	555.21	C
2	612.80	C
3	483.12	C
4	664.16	C
5	652.01	C
6	567.84	C
7	499.69	C
8	408.49	C
9	468.20	C
10	500.41	C
11	455.16	C
12	487.66	C
13	598.74	C
14	526.96	C
15	487.84	C
16	633.03	C
17	649.94	C
18	542.61	C
19	441.74	C
20	492.51	C
MEAN	**536.41**	**20C**

Table 5.6 Bond strength values of acrylic denture teeth to heat polymerised denture base resin with Super bond bonding agent surface treatment on the bonding surface of acrylic teeth before processing.

GROUP E (SUPERBOND BONDING AGENT APPLICATION)

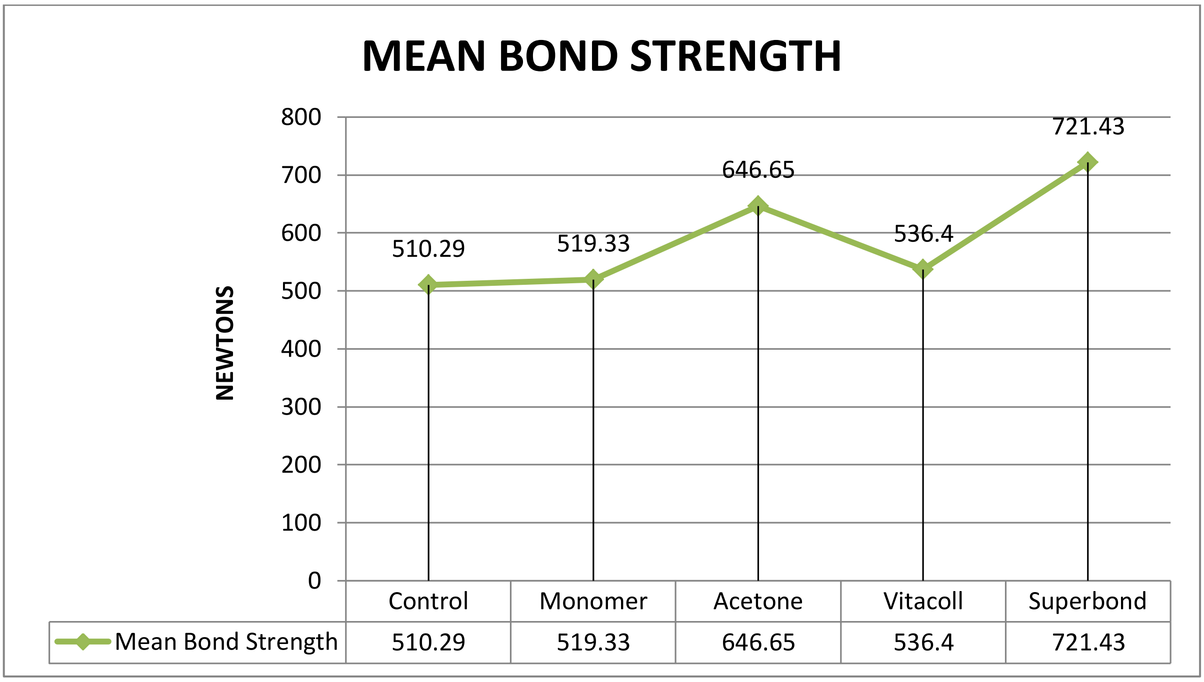
SAMPLE NO.	BOND STRENGTH VALUES IN NEWTON(N)	TYPE OF FAILURE A-Adhesive C-Cohesive
1	703.31	C
2	720.69	C
3	803.48	C
4	669.64	C
5	804.06	C
6	695.07	C
7	828.56	C
8	655.96	C
9	708.15	C
10	789.00	C
11	686.38	C
12	693.91	C
13	800.73	C
14	626.42	C
15	674.32	C
16	679.92	C
17	690.12	C
18	730.11	C
19	778.78	C
20	690.02	C
MEAN	**721.43**	**20C**

Table 5.7 The mean bond strength values of the groups and their type of failure summarized

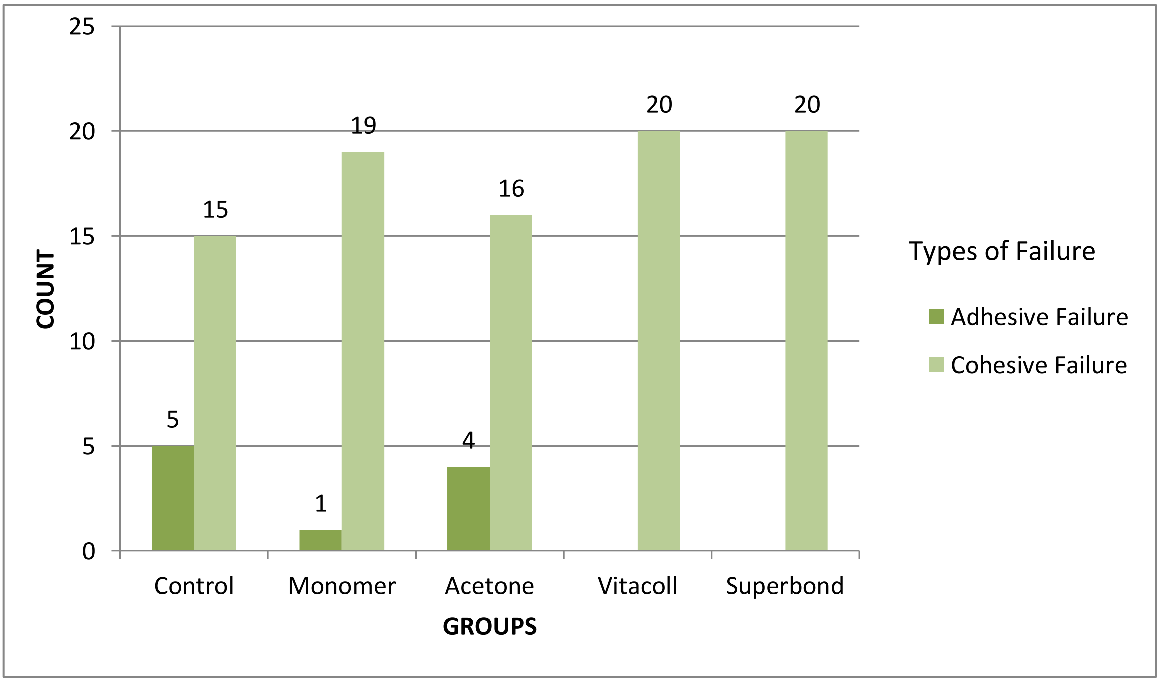
Group name	Mean bond strength values in Newtons	Type of failure (Adhesive/Cohesive)
Group A (no surface treatment)	510.29	5A,15C
Group B (Monomer application)	519.33	1A,19C
Group C (Acetone application)	646.65	4A,16C
Group D (Vitacoll bonding agent)	536.41	20C
Group E (Superbond bonding agent)	721.43	20C

The above test values were then subjected to statistical analysis to verify for their significance.

GRAPH 5.1 Illustrates the mean bond strength values of the groups and their comparisons with other groups.



Graph 5.2 Illustrates the mode of failure and their comparisons with other groups



STATISTICAL ANALYSIS

The statistical analysis was done with the mean bond strength values of the five groups with the SPSS 11.5 software.

Table 5.8 Bond strength mean and standard deviation values

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Control	20	510.2920	57.05459	12.7577	483.5896	536.9944	432.08	619.26
Monomer	20	519.3295	59.59418	13.3256	491.4386	547.2204	389.97	596.87
Acetone	20	646.6545	83.33724	18.6347	607.6515	685.6575	512.97	802.62
Vitacoll	20	536.4060	76.71701	17.1544	500.5013	572.3107	408.49	664.16
Superbond	20	721.4315	58.19478	13.0127	694.1955	748.6675	626.42	828.56
Total	100	586.8227	106.8617	10.6861	565.6190	608.0264	389.97	828.56

From the table 5.8 the mean and standard deviations obtained were subjected to One-Sample Kolmogorov-Smirnov Test. This test was done to verify whether the given distribution is normal or not. To test this, a null hypothesis was formed.

Null hypothesis H_0 : The obtained data followed normal probability distributions.

Table 5.9: NPAR TESTS

Table 5.9 One-Sample Kolmogorov-Smirnov Test		
		Bond strength
N		100
Normal Parameters(a,b)	**Mean**	586.8227
	Std. Deviation	106.86177
Most Extreme Differences	**Absolute**	.101
	Positive	.101
	Negative	-.054
Kolmogorov-Smirnov Z		1.006
Asymp. Sig. (2-tailed)		.263
a Test distribution is Normal.		
b Calculated from data.		

From the table 5.9, it was inferred that asymptomatic significance value(p) was greater than 0.05 (5% level of significance), so the null hypothesis was accepted for the given bond strength values. The results obtained were normally distributed.

From the interpretation of this test, analysis of variance (One Way ANOVA) could be used for this data set.

One Way ANOVA (Analysis of Variance) test:

ANOVA test is used to uncover the main and interaction effects of categorical independent variables (called "factors") on an interval dependant variable. One Way ANOVA is used to compare the means of three or more groups to determine whether they differ significantly from one another and to estimate the differences between specific groups.

The mean bond strength values were subjected to this test and a null hypothesis was formed.

Null hypothesis (H_1): There is no significant difference between the mean bond strength values of the 5 groups tested at 5% level of significance.

Table 5.10 ONEWAY ANOVA Bond strength					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	693069.941	4	173267.485	37.628	.000
Within Groups	437454.497	95	4604.784		
Total	1130524.438	99			

From the table 5.10, the one way ANOVA test was performed and the results show that the Significance value (p) is 0.000 which is less than 0.05 (5% level of significance). Since the p value is less than 0.05, the null hypothesis is rejected.

Rejection of null hypothesis inferred that there is significant difference between the mean bond strength values between the groups.

POST HOC STUDY

From the One-Way ANOVA test, it was inferred that there is a significant difference in the bond strength values between the 5 groups tested. Post Hoc test was used in conjunction with ANOVA to determine which specific group was statistically different from the other group.

In this Post Hoc study, Tukey's HSD (Honestly Significant Difference) test was applied to the mean bond strength values of the 5 groups at 5% level of significance (table 5.11).

From the Tukey's HSD test, homogenous subsets was formed to compare between groups (table5.12)

Table 5.11 Post Hoc Tests

Multiple Comparisons
Dependent Variable: Bond strength
Tukey HSD

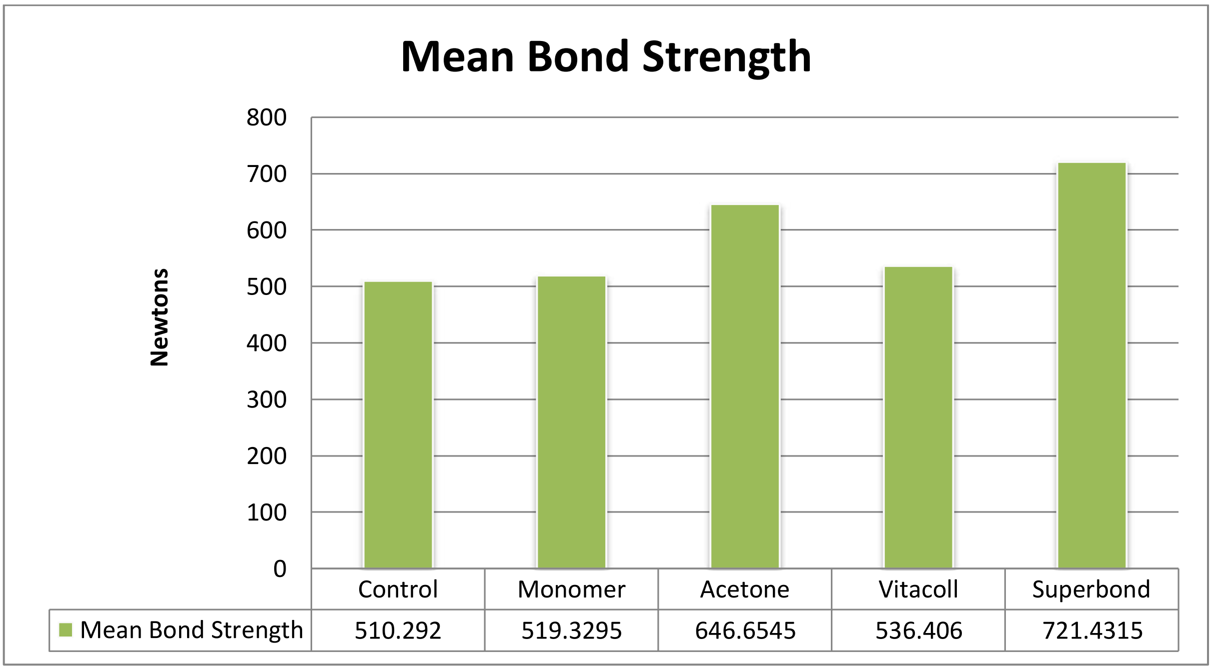
(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Control	**Monomer**	-9.0375	21.45876	.993	-68.7114	50.6364
	Acetone	-136.3625(*)	21.45876	.000	-196.0364	-76.6886
	Vitacoll	-26.1140	21.45876	.742	-85.7879	33.5599
	Superbond	-211.1395(*)	21.45876	.000	-270.8134	-151.4656
Monomer	**Control**	9.0375	21.45876	.993	-50.6364	68.7114
	Acetone	-127.3250(*)	21.45876	.000	-186.9989	-67.6511
	Vitacoll	-17.0765	21.45876	.931	-76.7504	42.5974
	Superbond	-202.1020(*)	21.45876	.000	-261.7759	-142.4281
Acetone	**Control**	136.3625(*)	21.45876	.000	76.6886	196.0364
	Monomer	127.3250(*)	21.45876	.000	67.6511	186.9989
	Vitacoll	110.2485(*)	21.45876	.000	50.5746	169.9224
	Superbond	-74.7770(*)	21.45876	.007	-134.4509	-15.1031
Vitacoll	**Control**	26.1140	21.45876	.742	-33.5599	85.7879
	Monomer	17.0765	21.45876	.931	-42.5974	76.7504
	Acetone	-110.2485(*)	21.45876	.000	-169.9224	-50.5746
	Superbond	-185.0255(*)	21.45876	.000	-244.6994	-125.3516
Superbond	**Control**	211.1395(*)	21.45876	.000	151.4656	270.8134
	Monomer	202.1020(*)	21.45876	.000	142.4281	261.7759
	Acetone	74.7770(*)	21.45876	.007	15.1031	134.4509
	Vitacoll	185.0255(*)	21.45876	.000	125.3516	244.6994

* The mean difference is significant at the .05 level.

Table 5.12 Homogeneous Subsets

Bond strength Tukey's HSD				
Groups	**N**	**Subset for alpha = .05**		
		1	**2**	**3**
Control	20	510.2920		
Monomer	20	519.3295		
Vitacoll	20	536.4060		
Acetone	20		646.6545	
Superbond	20			721.4315
Sig.		.742	1.000	1.000
Means for groups in homogeneous subsets are displayed.				
a Uses Harmonic Mean Sample Size = 20.000.				

Graph 5.3 Showing the mean bond strength values and their comparison with other groups.



From table 5.11, 5.12 and graph 5.3, the following statistical inferences were made

1. When comparing the other groups with the control group, there is a statistical difference between the mean bond strength values of Acetone and Superbond application levels .The mean bond strength values of Acetone and Superbond (646.65N and 721.43N) were significantly higher ($p<0.05$) than that of the control group (510.29N) as proved from Tukey's HSD test.
2. The application of monomer and Vitacoll (519.32N and 536.40N) had no statistically ($p>0.05$) significant mean bond strength values when compared to the control group (510.29N).
3. When compared to the Acetone and Superbond (646.65N and721.43N) application, Superbond application had statistically highest ($p<0.05$) mean bond strength value of 721.43N and was proved statistically with Tukey's HSD test.
4. The objective of using chemicals to improve the bond strength was proved statistically.

Statistical analysis for testing the type of failure

The samples were visually examined after fracture to the type of failure as adhesive or cohesive.

Adhesive failure means that there is a clean debonding of the acrylic denture tooth from the denture base resin with no traces of either being visible.

Cohesive failure is that where traces of tooth structure or denture base resin remain on either surfaces after fracture. Cohesive failure indicates that there is a good bond between the acrylic denture tooth and the denture base resin.

Cross tabs were made for the analysis of failure (table 5.13) from the values obtained and the values were tested using Chi-Square test(table 5.14). A null hypothesis was formulated.

Null hypothesis $H_{2:}$ There is no significant difference in the type of failure between the groups

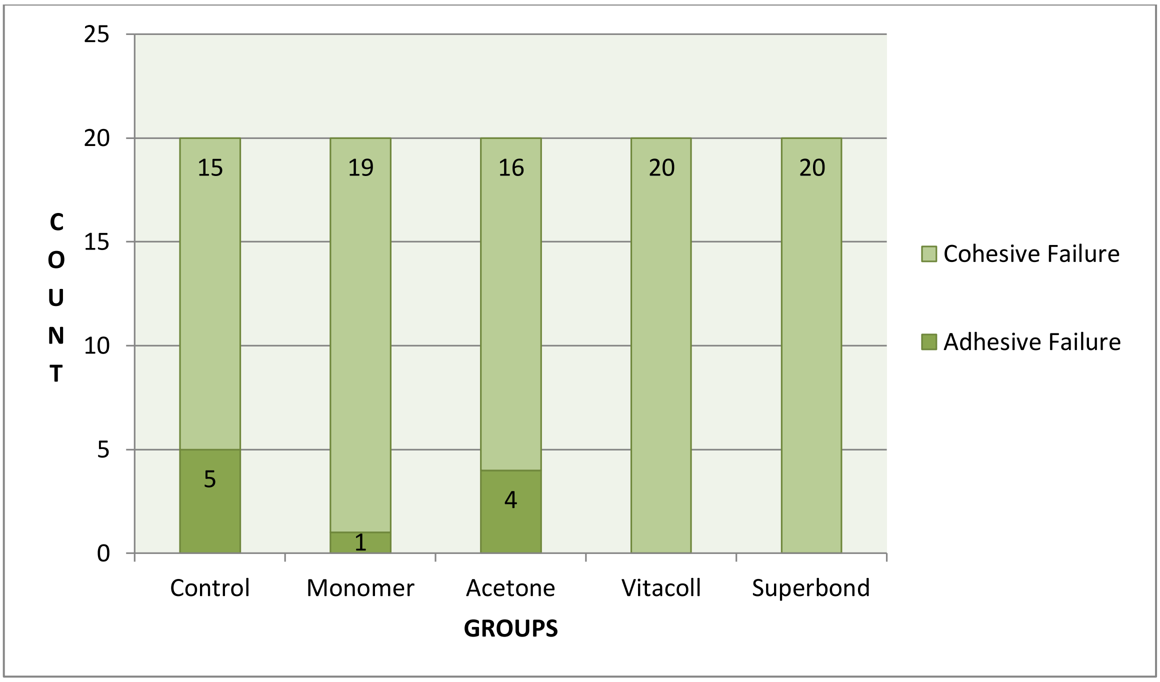
Table 5.13 Crosstabs

Groups * Type of failure Cross tabulation					
			Type of failure		Total
			Adhesive failure	Cohesive failure	
Groups	Control	Count	5	15	20
		% within Groups	25.0%	75.0%	100.0%
	Monomer	Count	1	19	20
		% within Groups	5.0%	95.0%	100.0%
	Acetone	Count	4	16	20
		% within Groups	20.0%	80.0%	100.0%
	Vitacoll	Count	0	20	20
		% within Groups	.0%	100.0%	100.0%
	Superbond	Count	0	20	20
		% within Groups	.0%	100.0%	100.0%
Total		Count	10	90	100
		% within Groups	10.0%	90.0%	100.0%

Table 5.14 Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	12.222(a)	4	.016
Likelihood Ratio	14.566	4	.006
Linear-by-Linear Association	6.655	1	.010
N of Valid Cases	100		
a 5 cells (50.0%) have expected count less than 5. The minimum expected count is 2.00.			

From table 5.14, the statistical interpretation revealed that asymptomatic significance value(p-0.016) is less than 0.05(5% level of significance), the null hypothesis was rejected. Thus the interpretation is that there is a significant difference among the type of failure between the groups.

Graph 5.4. Comparitive analysis of the type of failure between the groups.



From the table 5.14 and graph 5.4, the following inferences were made regarding the type of failure.

1. There was a significant difference (p<0.05) between the control group and the monomer (group B) and bonding agents groups (group D and groupE).
2. Acetone group had significantly more of adhesive failures compared to bonding agent and monomer groups.
3. There were only cohesive failures in the bonding agent groups (group D and group E).
4. There was no significant difference in bond strength values irrespective of the type of failures.

Discussion

DISCUSSION

Dentures – the mode of replacing teeth had become very popular since the introduction of acrylic resins in removable prosthodontics since 1937[30]. The acrylic resins and acrylic resin denture tooth combination had been used since they both shared the common composition, and were able to form a chemical bond[54].

Adequate bonding of acrylic resin teeth to denture base resin plays a vital role as it increases the strength and durability of the denture since the teeth become an integral part of the prosthesis.

Artificial teeth falling off the denture base is a usual problem encountered by patients during denture usage. This problem is often related to the material properties of the acrylic denture base resin used. A survey showed that 33% of denture repairs were to restore debonded teeth[6,13,24,33]. Therefore, in the fabrication of removable dentures, bond strength between denture base resin and artificial teeth is one of the most important considerations in the technical procedure.

Bond strength like any other strength property is statistical in nature, since the presence of intrinsic or extrinsic flaws strongly influences fracture. The mechanical testing of strength is complicated by specimen geometry, size, test grip alignment, force direction and other variables that usually produce complex stress distribution[14].

Different testing methods had been employed in the studies examining the denture base to tooth bond to establish suitability for clinical use. A review of recent studies in this field revealed a lack of uniformity in the testing methods [23,47].

Bond failures could either be adhesive or cohesive [10,50,55,57]. The failure is said to be adhesive if there is no trace of any denture base resin on the tooth surface after the fracture. The failure is said to be cohesive if there is a presence of any trace denture base resin on the surface of denture teeth or remnants of the denture tooth on the denture base. The denture teeth, often separate from the denture base without any damage to the denture base or teeth, indicating predominantly adhesive failure[40].

The bond failure between the tooth and the denture base may be caused by excessive stress or by fatigue[40]. Increased risk of displacement of artificial teeth from the denture base because of lack of proprioception is seen in implant-supported dentures [40].

Many authors had studied the effect of surface modifications either by macro-mechanical or chemical surface treatments. Macro-mechanical retentive methods of placement of vertical or horizontal retentive grooves of different shapes[3,12,14], diatorics or sandblasting[3,13] the ridge lap surface of acrylic tooth had been evaluated to improve bond strength with both success and failure or with no effects. Similarly, various chemical agents to treat the ridge lap area had been used namely, methyl methacrylate monomer[3,7,38,62], dichloromethane[16,57], acetone[45,56], ethyl/methyl acetate, methylene chloride[56] and proprietary bonding agents[9,44]. Even a combination of both macro-mechanical and chemical methods had been evaluated[3,8,9,12,13,17,22,36,40,43,45,51,54,56,59].

In light of the above, the bond strength between heat polymerised denture base resin and acrylic resin denture teeth with four different surface treatments of the bonding surface area were evaluated and compared with that of untreated teeth.

In this present study, 100 highly cross linked maxillary central incisor(50 right,50 left) acrylic denture teeth (CosmoHXL, Dentsply) was used. **Clancy** reported that heat-cured plastic teeth were 40% higher in bond strength than with IPN cross-linked teeth[18]. **Chai et al and Caswell et al** had reported that there was no significant difference in bond strength values of conventional and cross linked acrylic teeth [15,16].

As the cross-linking enhanced strength and abrasion resistance, presently cross-linked acrylic teeth are more preferred for dentures. In this study, cross- linked acrylic teeth (Cosmo HXL, Dentsply) were used. High impact Trevalon denture base resin of the same company was used. From literature[2,47], using the same combinations as recommended by the manufacturer had improved bond strength than different combinations.

The 100 teeth were then divided into 5 groups with 10 right and 10 left central incisor teeth in each group. The 5 groups were named A, B, C, D and E according to the surface treatments in which group A served as control with no surface treatment. The different chemical surface agents used in this study on the bonding surface of acrylic denture teeth were methylmethaacrylate monomer (group B), acetone (group C) and two commercially available bonding agents namely Vitacoll (group D) and Superbond (group E) bonding agents (Table 4.1) (Fig 19).

Wax models were made using a custom made jig such that the tooth was placed with a labial inclination of 130^0 from the denture base (Fig 11,12). This is the angulation in which the lower anteriors contacts the lingual slopes of the upper teeth[12,14,63]. The wax models were then invested. Dewaxing was done with strict protocol by using 3 times flow of detergent containing boiling water followed by plain boiling water once. Since it has been proved from studies that wax contamination as the major cause for debonding[55].

After application of surface agents on the bonding surface according to the different groups, the specimens were heat polymerised with a curing cycle according to manufacturer's instruction in an acrylizer. All the samples were retrieved from the investment, finished and polished.

Compared to the modes of polymerisation like light curing, self-curing and microwave curing, it was proved from most studies that heat polymerization yielded better bond strength [7,18,19,20,34,35,49,53]. Compression moulding yielded better bond strength values than of injection moulding technique employed in the packing of heat cure acrylic resin[41].

So in this study we used the compression moulding technique and heat polymerisation for processing.

The specimens were then stored in water as a process of aging for 1 week[46]. The process of aging was done to simulate the oral conditions where the denture remains in a moistened environment. The effects of aging and thermocycling on the bond strength values were evaluated in previous studies and most studies concluded that there was no significant difference[27,39,44,46].

The samples were tested for bond strength using an Universal testing machine (Instron 5500R, Norwood, U.S.A) at a cross head speed of 5mm/min [2,5,14,40,41]. The values were obtained in Newtons.

The adhesive and cohesive nature of the failure of the fractured specimens on visual examination was evaluated[55]. These test values were subjected to statistical analysis using one way-ANOVA, Tukey's HSD and CHI- SQUARE tests with the SPSS software (version 11.5)

In group A samples, the bonding surface of denture teeth was left untreated, to assess the original bond strength between acrylic teeth and denture base resin. The mean bond strength of this group 510.29 N was compared with the rest of the groups (Table 5.11, 5.12)

Vallittu et al demonstrated the swelling phenomenon of acrylic resin polymer teeth due to the diffusion of monomers from the denture base polymers[61]. He also stated that by increasing the polymerization temperature, the monomers of the denture base polymers diffused more effectively into acrylic resin polymer teeth[60.61]. This increased the bond strength between the polymer teeth and the denture base polymer. He has demonstrated that application of monomer for 180seconds improved bond strength compared to 30s and

60s of monomer application time[62]. Other studies have also concluded that there was an increase in bond strength by 180s application of monomer [7,38,42,62].

In group B samples, the heat cure polymerizing Universal monomer liquid (Dentsply Co.) was applied for 180s. Processing was done and bond strength values were recorded in Newtons and compared with the other groups. From the results obtained, the mean bond strength values of monomer group 519.33N was similar to the control group 510.29N with only a marginal increase in the mean bond strength values and was not statistically significant at 5% level of significance. The bond strength of group B monomer samples were similar to the control group A samples due to reduced solubility in highly cross linked teeth leading to lesser penetration of monomer to form interpenetrating network formation.

Sinasi Sarac et al applied acetone on the bonding surface for 30s and found that application of acetone created a smoother surface with superficial pits and the bond strength was improved with acetone surface treatment [56]. Studies had been done with both positive and negative results with the application of acetone for 30s[45, 56].

In group C samples, acetone was applied for 30s on the bonding surface of teeth. The results obtained showed that there was a significant improvement ($p<0.05$) in the mean bond strength value of acetone group 646.65N compared to the control group 510.29N, monomer group 519.32N and Vitacoll group 536.40N. But the bond strength was significantly less when compared to the Superbond bonding agent group 721.43N (Table 5.11, 5.12).

Proprietary bonding agents had been used commonly to improve adhesion[31,44,51].

In this study, two proprietary bonding agents namely Vitacoll and Superbond were used. Vitacoll bonding agent was a mixture of methyl methacrylate and butanone.

Superbond bonding agent was a copolymer resin solution in combustible solvent which evaporated leaving a protective coating.

In group D samples, Vitacoll bonding agent was applied as per the manufacturer's instruction.After dewaxing, vertical retention grooves were made in one direction with a straight fissure tungsten carbide bur(RA 701L, SS White, Lakewood, New Jersy, U.S.A.) on the ridge lap surface of the invested sample tooth. The bonding agent was applied for 5minutes and packing was done within 10 minutes. Retention grooves were made after dewaxing to avoid the contamination and improper elimination of wax inside the grooves .Those grooves increased the bonding surface area. Even though the placement of grooves was a mechanical retentive feature, the manufacturer's instructions were followed.

The mean bond strength of group D 536.40N was not statistically significant ($p>0.05$) when compared to the control group 510.29N and monomer group 519.32N. When the mean bond strength was compared with the acetone group 646.65N and Superbond 721.43Ngroups, the bond strength was significantly less ($p<0.05$) (Table 5.11, 5.12).

From literature[12, 14], placement of retentive grooves either increased or had no remarkable effect on bond strength. **Cardash et al** concluded that there was no significant difference in bond strength values on placement of retentive grooves of any shape on ridge lap surface[12]. Similarly, **Beur et al** concluded that there was no significant difference in bond strength values by application of bonding agents[9].

The placement of grooves and the application of Vitacoll bonding agent did not significantly improve the bond strength properties even though there was no adhesive failures and which suffices the conclusions of Beur et al and Cardash et al.

In group E samples, Superbond bonding agent group (GroupE) was applied on the bonding surface area and allowed to dry for 5minutes and packing was done at the earliest as per manufacturer's instruction. The bond strength values were evaluated. The mean bond strength 721.43N of this group E was statistically ($p<0.05$) the highest among all the other groups (Table 5.11, 5.12)

The nature of failure, whether adhesive or cohesive were visually inspected and the following interpretations were made regarding the type of failure. (Table 5.13) (Graph 5.4)

In group A (no surface treatment) samples, there were 5 adhesive failure (25%) of the 20 samples. There was also a significant difference ($p<0.05$) with the bonding agent groups where there was only cohesive failures.

In group B samples, (monomer application), there was only 1 adhesive failure out of the 20 tested samples which was significant ($p<0.05$) compared to the control group. The bond was mostly cohesive.

In group C (acetone application) samples, there were 4 adhesive failures of the 20 samples tested. This was nearly equal to the control group with 5 adhesive failures. Even though the bond strength values were higher, there were more of adhesive failures in this group than the samples of other three groups B, D and E.

In group D (Vitacoll bonding agent application) samples, the nature of failure was entirely cohesive in all the 20 tested samples. This was significant when compared to control, monomer and acetone groups where there were both adhesive and cohesive failures. But when compared to the Superbond group, both had cohesive failures.

In group E (Superbond bonding agent application) samples, the nature of failure in all samples was entirely cohesive as in the Vitacoll bonding agent group.

The ease of application procedure of bonding agent, higher bond strength value and cohesive mode of failure of these group E samples substantiated the use of surface treatment to increase the bond strength of acrylic resin teeth to heat cure denture base resin.

The null hypothesis of this study was that there was no significant difference in the bond strength values of acrylic resin denture tooth to the heat polymerized denture base resin after application of surface treatments and there was no significant difference in the modes of failure. The results obtained from the study rejected the null hypothesis. There was a significant improvement in the bond strength due to application of Superbond bonding agent. It yielded the highest mean bond strength than the other groups with only cohesive mode of failure.

Even though the study proved to be effective, in comparing the bond strength between different surface treatments on the bonding surface area of acrylic tooth to the denture base resin, it had certain limitations. The effects of the inherent strengths of acrylic tooth and denture base material cannot be eliminated. It is well accepted that in vivo performance does differ from an in-vitro setting. This in vitro study design did not consider the effects of thermocycling and cyclic loading of the test specimens. The denture is normally held against a resilient mucosa and some stresses may be distributed to the denture bearing mucosa also which may not be simulated in such in-vitro studies. The mechanism of action of the bonding agents on the bond strength effects had to be studied.

Future experiments, to investigate and understand the effects of the internal strength of both the acrylic tooth and denture base material on the mechanism of debonding with or without surface modifications are recommended.

Summary

Summary

This study was conducted to evaluate the bond strength between heat polymerized denture base resin and acrylic denture tooth by using four different surface treatments on the bonding surface of acrylic tooth. The chemical agents used were methylmetha acrylate monomer, acetone and two proprietary bonding agents namely Vitacoll and Superbond. These surface treatments were compared with an untreated control group with no surface treatment on the bonding surface of acrylic tooth.

100 maxillary central incisors (50 right,50 left) were divided into 5 groups with 10 right and 10 left central incisors in each group according to the surface treatments on the bonding surface of tooth. Group A served as a control group with no surface treatments. Wax models were fabricated using a custom made jig such that the tooth was placed with a labial inclination of 130^0 from the denture base. The wax models were invested, dewaxed and chemical surface agents were applied according to the grouping. The specimens were then heat polymerised, finished and polished. All the samples were then stored in water for 1week as an aging process and were labelled according to the group, number of samples, date of immersion in water and date of testing mentioned.

All the samples were tested for bond strength in a Universal testing machine till the fracture occurred. The machine was connected to a computer from which the results were obtained. The bond strengths recorded for each group were tabulated and subjected to statistical analysis using one way Anova, Tukey's HSD and Chi- square tests.

From the results obtained, it was clear that the surface treatment on the bonding surface of acrylic teeth before packing definitely improved bond strength. The Superbond

surface treated group had the highest mean bond strength values and all the failures were cohesive in nature. Acetone surface treated group had good bond strength values but more of adhesive failure was noted. There was no statistical difference in mean bond strength values of control, monomer and Vitacoll bonding agent groups. Adhesive failures were seen in the acetone and control groups. Both proprietary bonding agents, Vitacoll and Superbond had good bond strengths leading only to cohesive failure.

Within the limitations of this study, application of Superbond bonding agent was proven to be more effective with simpler application technique and processing procedures except for the cost of the bonding agent.

Conclusion

CONCLUSION

Within the limitations of this in-vitro study, the following conclusions were made

1. There was significant difference in the mean bond strength values after different surface treatments. The mean bond strength of the Superbond bonding agent 721.43N was the highest and control group 510.29N was the lowest. Acetone group 646.65N was significantly higher than monomer and control groups.
2. The mean bond strength values of control 510.29N, monomer 519.32N and Vitacoll 536.40N groups were not statistically significant.
3. There was more of adhesive failure in the control group with no surface treatment done when compared to other groups.
4. In all the groups, the type of failure was independent of the bond strength values since it occurred between both the mean highest and lowest bond strength values within the groups.
5. The monomer group had only one adhesive failure and all other samples of this group had cohesive failures.
6. The acetone group had comparably equal number of adhesive failures as the control group. But acetone groups had better bond strength than control group. Eventhough the acetone groups had better bond strengths the surface modification property was comparable with the control group when interpreted from the type of failure.
7. Both bonding agents namely Vitacoll and Superbond failed cohesively only.
8. Superbond bonding agent with its improved bond strength properties and cohesive mode of failure would serve as a better surface treatment to be used to improve the

bond strength of acrylic denture tooth to the denture base resin. The ease of application of this bonding agent and the use of common modes of fabrication of heat cured acrylic resin with compression moulding technique would make the processing procedures easier. Except for the cost of the Superbond bonding agent, within the limitations of this study it can be used more effectively in improving the bond strength of acrylic denture tooth to the denture base resin.

References

REFERENCES

1. Anusavice KJ. Philips' Science of Dental Materials. Philadelphia: WB Saunders,1996:46-47
2. Amarnath GS, H S Indra Kumar et al. Bond strength and tensile strength of surface treated resin teeth with microwave and heat cured acrylic resin denture base: An in-vitro study Int. Journal of Clinical Dental Science February;2011; 2(1):27-32
3. Amin W. Improving bonding of acrylic teeth to self-polymerizing denture base resins. Saud Dent Journal, January- April 2002; 14(1):15-19
4. Arima T, Nikawa H, Hamada T, Harsini A. Composition and effect of denture base resin surface primers for reline acrylic resins. J Prosthet Dent. 1996; 75:457–462.
5. Barpal D, Curtis DA, Finzen F et al. Failure load of acrylic resin denture teeth bonded to high impact acrylic resins. J Prosthet Dent. 1998; 80: 666–671.
6. Beyli M.S., Med Dent et al. An analysis of causes of fracture of acrylic resin dentures. J Prosthet Dent. 1981; 46: 238-24.
7. Barbosa DB, Monterio DR et al. Effect of monomer treatment and polymerization methods on bond strength of resin teeth to denture base material. Gerodontolgy 2009; 26: 225-231
8. Bragaglia, Prates LH, Calvo et al. The Role of Surface Treatments on the Bond between Acrylic Denture Base and Teeth. Braz Dent J. 2009; 20 (2): 156-161.
9. Beur.F, K. J. Erdeit,R.Friedrich et al. Retention and fracture resistance of acrylic denture teeth on the denture base. Deutsche Zahnarzliche Zeitschrift 2006;61(3):147-150
10. Buyukyilmaz S, Ruyter IE. The effects of polymerization temperature on the acrylic resin denture base-tooth bond. Int J Prosthodont 1997; 10: 49–54.

11. Catterlin RK, Plummer KD and Gulley ME Effect of tin foil substitute contamination on adhesion of acrylic resin denture tooth to its denture base. J Prosthet Dent. 1993; 69: 57-59.
12. Cardash HS, Liberman R, Helft M. The effect of retention grooves in acrylic resin teeth on tooth denture base bond. J Prosthet Dent 1986; 55: 526-528.
13. Chung K.H., Chung C. Y, Chung C Effect of pre-processing surface treatments of acrylic teeth on bonding to the denture base. J Oral Rehab 2008; 35: 268–275.
14. Cardash HS Applebaum B Baharav H, Liberman R. Effect of retention grooves on tooth-denture base bond. J Prosthet Dent 1990; 64:492-496
15. Casewell CW, Norling BK. Comparative study of the bond strengths of three abrasion- resistant plastic denture teeth bonded to a cross-linked and a grafted, cross-linked denture base material J Prosthet Dent. 1986; 55:701-708
16. Chai J, Takahashi Y, Takahashi T et al. Bonding durability of conventional resinous denture teeth and highly cross-linked denture teeth to a pour-type denture base resin. Int J Prosthodont 2000; 13: 112–116.
17. Chaves CAL, Regis RR, Machado AL, Souza RF. Effect of ridge lap surface treatment and thermocycling on microtensile bond strength of acrylic teeth to denture base resin. Braz Dent J. 2009; 20(2):127-31.
18. Clancy JMS, Boyer DB. Comparative bond strengths of light-cured, heat-cured and auto-polymerizing denture resins to denture teeth. J Prosthet Dent 1989; 61: 457–462.
19. Clancy JMS, Hawkins LF, Keller JC et al. Bond strength and failure analysis of light-cured denture resins bonded to denture teeth. J Prosthet Dent 1991; 65: 315–324.

20. Cunningham JL. Shear bond strength of resin teeth to heat-cured and light-cured denture base resin. J Oral Rehabil 2000; 27: 312–316.
21. Cunningham JL. Bond strength of denture teeth to acrylic base. J Dent 1993; 21: 274–280.
22. Cunningham JL, Benington IC. An investigation of the variables which may affect the bond between plastic teeth and denture base resin. J Dent 1999; 27:129–135.
23. Cunningham JL, Benington IC. Bond strength variation of synthetic resin teeth in dentures. Int J Prosthodont 1995; 8: 69–72.
24. Darbar UR, Huggett R, Harrison A.A Denture fracture – a survey. Br Dent J 1994; 176: 342–345.
25. Darbar U.R., Finite element analysis of stress distribution at the tooth-denture base interface of acrylic resin teeth debonding from the denture base J Prosthet Dent. 1995; 74:591-594
26. Darbar UR, Huggett R, Harrison A et al. The effect of impurities on the stress distribution at the tooth/ denture base resin interface. Asian J Aesthet Dent 1994; 2: 7–10.
27. Debora Barros Barbosa et al., Bond strength of denture teeth to acrylic resin: effect of thermocycling and polymerisation methods. Gerodontology 2008; 25: 237–244.
28. Elena Stoia.A, Sorin Lakatos, Mircea Pielmusi et al. Chemical treatment of acrylic teeth ridge lap area trough tensile strength investigations. International Journal of Biology and Biomedical Engineering 2011;Is 4;5:163-172.
29. El-Sheikh MM, Powers JM. Tensile bond strength of porcelain teeth to denture resin before and after aging. Int J Prosthodont 1998; 11: 16–20.
30. Frederick A. Rueggeberg. From vulcanite to vinyl, a history of resins in restorative dentistry .J Prosthet Dent 2002; 87: 362-79.

31. Fletcher-Stark ML, Chung KH, et al. Shear bond strength of denture teeth to heat- and light- polymerized denture base resin. J Prosthodont 2011 Jan; 20(1); 52-9.

32. Geerts G, Jooste CH. A comparison of the bond strengths of microwave- and water bath-cured denture material. J Prosthet Dent 1993; 70: 406–409.

33. Huggett R, John G, Jagger RG, Bates JF. Strength of the acrylic denture base tooth bond. Br Dent J 1982; 153: 187-190.

34. Hatim NA,Hasan RH. Bond strength of different artificial tooth manufacturing to microwave cured acrylic denture base. Al-Rafidain Dent J.2010;10(1):8-16.

35. Kawara M, Carter JM, Ogle RE et al. Bonding of plastic teeth to denture base resins. J Prosthet Dent 1991; 66: 566–571.

36. Lagouvardos PE, Polyzois GL. Shear bond strength between composite resin and denture teeth: effect of tooth type and surface treatments. Int J Prosthodont 2003; 16: 499–504.

37. Marchack BW, Yu Z, Zhao XY, White SN. Adhesion of denture tooth porcelain to heat-polymerized denture resin. J Prosthet Dent.1995; 74: 242-249.

38. Marra et al ; Effect of methyl methacrylate monomer on bond strength of denture base resin to acrylic resin International journal of Adhesion and Adhesives 2009; 29: 391-395

39. Marra et al : Evaluation of the Bond Strength of Denture Base Resins to Acrylic Resin Teeth: Effect of Thermocycling, Journal of prosthodontics 2009; 18: 438-443

40. Meng GK, Chung KH, Fletcher-Stark ML and Zhang H, Effect of surface treatments and cyclic loading on the bond strength of acrylic resin denture teeth with auto-polymerized repair acrylic resin. J Prosthet Dent 2010; 103: 245-252.

41. Moffit AR, Woody DR Failure modes with point loading of three commercially available denture teeth. J. O. Prostho 2008; 17:432-38.

42. Morrow RM, Matvias FM, Windeler AS, Fuchs RJ.Bonding of plastic teeth to two heat-curing denture base resins. J Prosthet Dent 1978; 39: 565-568.

43. Nabeel Abdul-Fatah, Mithaq Radhi Mohamed. Effect of surface treatment on shear bond strength of artificial teeth to the denture base. MDJ 2011; 8(2):171-176.

44. Nishigawa G, Maruo Y, Okamoto M, Oki K, Kinuta Y, Minagi S,et al.. Effect of adhesive primer developed exclusively for heat cuing resin on adhesive strength between plastic artificial tooth and acrylic denture base resin. Dent Mater J 2006; 25:75-80.

45. Palitsh A,Hanning M,Ferger P et al.Bonding of acrylic denture teeth to MMA/PMMA and light-curing denture base materials: the role of conditioning liquids. J Dent 2012 Mar;40(3):210-21

46. Papazoglou E, Vasilas AI. Shear bond strengths for composite and auto-polymerized acrylic resins bonded to acrylic resin denture teeth. J Prosthet Dent 1999; 82:573–578.

47. Patil SB, Naveen BH, Patil NP. Bonding acrylic teeth to acrylic resin denture bases: a review. Gerodontology 2006; 23: 131–139.

48. Polukoshku MK, Brudvik J, Nicholls J, Smith DE. Evaluation of heat-cured resin bases following the addition of denture teeth using a second heat cure J. Prosthet. Dent 1992, 67: 556-562

49. Polyzois GL, Dahal JE. Bonding of synthetic resin teeth to microwave or heat activated denture base resin. Eur J Prosthodont Restor Dent 1993; 2: 41–44.

50. Photini Kamposiora, Triantafillos Papadopoulos et al.A Qualitative Evaluation-Denture Base Resin- Acrylic Tooth Bond. Journal of Dental Technology May, 2009; 30-35.

51. Saavedra G, Valandro LF, Leite FP, Amaral R, Ozcan M, Bottino MA, et al.. Bond strength of acrylic teeth to denture base resin after various surface conditioning methods before and after thermocycling. Int J Prosthodont 2007; 20: 199-201.

52. Schoonover IC, Fischer TE, Serio AF et al. Bonding of plastic teeth to heat-cured denture base resins. J Am Dent Assoc 1952; 44: 285-287.

53. Schneider RL, Curtis ER, Clancy JMS. Tensile bond strength of acrylic resin denture teeth to a microwave- or heat-processed denture base. J Prosthet Dent 2002; 88: 145–150.

54. Shen C, Colaizzi FA, Birns B. Strength of denture repairs as influenced by surface treatment J. Prosthet. Dent 1984; 52; 844-848.

55. Spratley MH. An investigation of the adhesion of acrylic resin to dentures. J Prosthet Dent 1987; 58: 389–392.

56. Sinasi Sarac Y et al. The effect of chemical surface treatments of different denture base resins on the shear bond strength of denture repair. J Prosthet Dent 2005; 94: 259-66.

57. Takahashi Y, Chai J, Takahashi T et al. Bond strength of denture teeth to denture base resins. Int J Prosthodont 2000; 13: 59–65.

58. Trudso H, Budtz EJ. A four year follow up study on processed pour acrylic resins J. Prosthet. Dent 1980, 44; 495-96

59. Vargani C, Machado LA. Effects of Surface treatments on the bond strength between composite resin and acrylic resin denture teeth Int. J. Prostho 2000; Vol 13:383-386.

60. Vallittu PK. Bonding of resin teeth to the polymethyl methacrylate denture base material. Acta Odontol Scand 1995; 53: 99–104.

61. Vallittu PK, Docent DT, Ruyter IE, Nat R. The swelling phenomenon of acrylic resin polymer teeth at the interface with denture base polymers. J Prosthet Dent 1997; 78: 194–199.

62. Vallittu PK, Lassila VP, Lappalainen R. Wetting the repair surface with methyl methacrylate affects the transverse strength of repaired heat-polymerized resin. J Prosthet Dent. 1994;72: 639–643.

63. Zuckerman GR. A reliable method for securing anterior denture teeth in denture bases. J Prosthet Dent 2003; 89: 603-607.