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Evaluation and assessment of bonding of heat cure acrylic resin to cobalt-chromium alloy: Old ideas employing newer concepts

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ABSTRACT

Literature has evidenced marvelous work on increasing bond strength between acrylic resin and partial denture casting alloys in past by various pioneer workers. Several systems have been employed to increase the bond strength between acrylic resin and partial denture casting alloys. Some of the popular methods were silicate layer silane coupling agents, active acrylate monomers: Polyfluormetacrylate bonding agents, tin oxide layer, and bifunctional monomer (dual function group). With the exception of air abrasion, most techniques are associated with expensive equipment, technique sensitivity, and harmful chemicals. Air abrasion, however, consistently has been associated with improved bond strengths. Traditionally, denture base acrylic resin is attached to the metal framework by three types of retentive aids: Mechanical, chemical, or combination of both. Advantage of retentive elements weakens the acrylic resin base by creating stress and by replacing its bulk on which resin depends for strength. Failure of the resin at the interface is a common source of problems when forces exceed the capacity of the retentive mechanisms. Here, authors have sought to review the bonding strength between acrylic resin and partial denture casting alloys along with their clinical applicability that can best retain the said prosthesis with minimal failure.

KEYWORDS: Acrylic resins, chromium alloys, denture bases, surface properties

Introduction

In removable prosthodontics, durability of removable partial denture is dependent on strong adhesion between the metal framework and acrylic resin.[1] Any incongruity of chemical bond between polymethylmethacrylate (PMMA) and base metal alloy directly affects the metal-resin interface, however; a microscopic space exists between the metal framework and the resin denture base.[2] Weak adhesion and lack of a chemical bond cause separation of denture base from framework.[3,4]

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Discrepancies in the coefficient of thermal expansion among these components may promote this space, leading ultimately to microleakage of salivary substitutes.[5] Furthermore, microleakage in the area of internal and external finishing lines results in discolouration, deterioration of denture base material, and introduction of potentially pathogenic microorganisms that may be harbored within the crevice and contribute to an adverse soft tissue response. In removable prosthodontics, partial dentures are commonly fabricated with acrylic resin and metal framework. Base metals, such as cobalt-chromium (Co-Cr alloy), nickel-chromium alloy (Ni-Cr alloy), and commercially pure titanium (CP Ti) are commonly used for removable partial dentures (RPDs) that contain metal frameworks, bars, or clasps. These are well-suited for such frameworks because of their mechanical properties, biocompatibility, and corrosion resistance.[6]

Literature search has very well revealed that heat polymerized acrylic resin polymethyl methacrylate (PMMA) is normally used as a denture base resin for removable prostheses. Therefore, the bonding between the metal components and the denture base resin plays an important role in the longevity of the prosthesis. Unadventurously, denture base acrylic resin is attached to the metal framework by three types of retentive aids: Mechanical, chemical, or combination of both. Any kind of failure of the resin at the interface is a common source of dilemma when forces exceed the capacity of the retentive mechanisms. Removable partial prostheses are subjected to variations in temperature during oral function; this factor may lead to microleakage. Shrinkage of acrylic resin volume also has been associated with worsening at the interface between metal alloys and acrylic resins, fluid percolation, and the deterioration of contact between the metal alloys and the acrylic resin.[7]

Substantial bonding between the metal framework and denture resin is also important; especially in situations such as limited interridge space, short span edentulous area, and where excessive functional forces are anticipated. Livaditis described the micromechanical retention for resin-alloy systems in which electrochemical and chemical etching procedures were used.[8] Yasuda[9] reported that the adhesive resins containing 4-methacryloyloxyethy trimellitate anhydride (4-META) adhered strongly to the oxidized Ni-Cr alloy as well as to the resin. Additionally, Tanaka *et al*.,[10] introduced a 4-META preparation and described its effectiveness in adhesion to treated dental alloys. The bonding system of an adhesive primer containing functional monomer is considered a technique that facilitates chemical adhesion. Chemical bonding is more desirable than mechanical retention when resin is incorporated.[11,12] Even though many bonding systems for base metals including new priming agents have been developed for dental prosthesis, systematic literature search explore only limited and little information with this perspective. Keeping this fact in mind, authors have genuinely investigated the relevant historical perspectives (until 1980) to enlighten the effect of primers on bond strength between metal framework and denture base resins.

Methods of literature search

Various internet-based popular search engines (Google, Yahoo), scholarly search bibliographic databases (PubMed, PubMed Central, Medline Plus, Cochrane, Medknow, EBSCO, Science Direct, Hinari, WebMD, IndMed, Embase), and textbooks were searched until Aug 2013 using MeSH (Medical Subject Headings; PubMed) based keywords such as "Acrylic Resins," "Chromium Alloys," "Denture Bases," and "Surface Properties." The search was limited to reviews, systematic researches, and meta-analyses in various dental journals published over the last 35 years in English and Spanish. A total of 65 articles were identified; however, after examining the titles and abstracts, this number was finally condensed to 39 articles.

Bonding of heat cure acrylic resin to co-cr alloy; a systematic literature view point

In removable prosthodontics and especially in context of removable partial dentures, acrylic resin has been a material of choice since ages. This is particularly true mainly because of its easier attachment to artificial teeth and to metal framework. However, in day to day clinical practices and in methodological studies, we do see cases of failure attributed to bonding between the metal and acrylic. Most of the related studies seem to be focused on improving the bonding either by using metal primers or doing different surface treatments on metal surface.

Tanaka *et al*.,[13] evaluated the effect of surface treatment on nonprecious alloys (Ni-Cr and Co-Cr alloy) for adhesion-fixed partial dentures. They used four nonprecious alloys. Surface treatment was completed by immersing them in an oxidizing solution. They concluded that two Ni-Cr alloys for metal-ceramic crowns developed superior bonding strength and adhesive durability after sandblasting with alumina and oxidation. Sufficient bonding strength and adhesion were obtained for the Co-Cr metal ceramic crowns and metal base dentures by merely sandblasting and ultrasonic wave washing. Thereafter, Zurasky *et al*.,[14] evaluated adhesion of acrylic denture resins to base metal alloys. Ni-Cr samples were cast and groups were further prepared for surface treatment of electrolytic etching and bead retention. They concluded that using electrochemical etching to obtain microscopic retention of PMMA produces significantly greater tensile bond strength than those obtained with acceptable bead retention. Ferrari *et al*.,[15] also assessed two chemical etching solutions for nickel-chromium-beryllium alloys and a Co-Cr alloy. They were (A) Assure etch (solution A) and (B) a solution with 800 mL of methanol, 200 mL of 37% HCI, and 2 mL of ferric chloride (solution B). They concluded that the two chemical etching solutions created a highly microretentive surface when nickel-chromium-beryllium alloys were treated and the Co-Cr alloy revealed lesser micromechanical retention after surface treatment with both chemical etching systems. Kohli *et al*.,[16] further clarified this dilemma by evaluating the effect of three different surface treatments on the tensile bond strength of the resin bond to Ni-Cr-Be alloy. It was concluded that chemical etching of the metal for 1 h imparted the highest strength, followed by air-abraded bond samples and the tensile strength of samples etched with Assure-Etch etchant was significantly higher than that obtained with samples etched with Met-Etch etchant. The study results were similar to some extent as of Kolodney *et al*.[17] They studied to evaluate shear bond strengths of adhesive systems to a nickel-chromium-beryllium alloy. They actually aimed to compare prosthodontic adhesive systems and/or Panavia. It was concluded that use of an unfilled resin as an intermediate layer bonded to silicoater yielded superior shear bond strength.

Sedberrry *et al*.,[18] also compared the tensile bond strength of three chemical and one electrolytic etching system for a base metal alloy. They have taken 300 plastic rexillium III disks which were cast and etched by the following etching systems: Electrochemical, Assure-Etch, Met-Etch gel, and Etch-It gel. These processed thermo-cycled samples were loaded to failure in tension on an universal testing machine using a crosshead speed of 5 mm/min. Their study results further clarified the fact that samples etched electrochemically yielded significantly greater bond strengths than those etched chemically. May *et al*.,[19] evaluated the effect of three different surface treatments on the shear bond strength of PMMA bonded to titanium partial denture framework material. The results of this study showed that surface pretreatment of titanium with 110 μm alumina air abrasive plus silicoat silane coating significantly enhances the bond shear strength of PMMA more than 60% when compared with no treatment. Kourtis[1] also evaluated the bond strength of resin to metal bonding system. As a proven fact, resinous materials for the veneers of fixed prosthesis commonly require mechanical retention on metal substructures, because there is no chemical adhesion. Conversely, mechanical retention does not restrict creation of a marginal gap at resin metal interface, which can cause discoloration or detachment of resinous material. They concluded that bonding of resin to metal substructure was stable despite prolonged wet storage and intensive thermocycling. NaBadalung *et al*.,[20] conducted a study to evaluate tensile bond strength of three denture base resins (Trutone, Lucitone 199, and Triad) to treated Ni-Cr-Be alloy. A total of 180 samples of truncated cone shape were prepared and treated with three surface treatments, that is, sandblast, acid etch, and Rocatec with or without primers. They concluded that Trutone groups when primed showed the highest bond strength than nonprimed group. Met-Etch and Rocatec treated groups produced higher bond strengths than the sandblasted groups. Rothfuss[21] also compared the shear bond strength of composite to metal with two commercially available chemical bonding systems: A silicoating system (Silicoater) and a nitrogenous heterocycleacrylonitrile system (Kevloc). After storage at 35° C for 15 days, and thermocycling at 5°C and 55°C for 1200 cycles, the bonds were fractured in shear on a universal testing machine and concluded that mean bond strength for the silicoated sample was 10.93 MPa and for the heterocycle-acrylnitrate system 11.44 MPa. Visual inspection of the fracture surfaces revealed that failure was adhesive at the resin-to-metal surface in almost all the specimen. Yoshida[22] studied adhesive primers for bonding Co-Cr alloy to resin and for that, he evaluated the effect of five adhesive primers on the shear bond strength of a self cure resin to Co-Cr alloy. A brass ring which was placed over the casting alloy disk surface nonprimed or primed with each primer was filled with the self curing PMMA resin. The specimens immersed alternately in water baths at 4°C and 60°C for 1 min each for up to 50000 thermal cycles before shear mode testing at a crosshead speed of 0.5 mm/min all of the primers examined, except Metacolor Opaque Bonding Liner (MOBL), improved the shear bond strength between the resin and Co-Cr alloy compared with nonprimed samples prior to thermocycing. Regardless of which primer was used, the shear bond strength significantly differed between thermal cycles 0 and 50000. They concluded that Cesead Opaque Primer (COP) and Metal Primer II (MPII) are effective primers to obtain higher bond strength between resin and Co-Cr alloy. Sharp *et al*.,[23] evaluated the efficiency of metal surface treatments in controlling microleakage of the acrylic resin-metal framework interface. They literally designed their study to determine the effects of various metal surface treatments on microleakage and bond strength between the metal alloy and acrylic resin used in the fabrication of a removable partial denture. They concluded that air abrasion, alone and in conjugation with other surface treatments, resulted in a significant reduction in microleakage between the metal alloy and acrylic resin. Tinplating also resulted in reduction of microleakage although to a lesser degree than with air abrasion. Azad *et al*.,[24] genuinely estimated the tensile bond strength of denture base resins to surface pretreated cobalt chromium base metal alloys. A total of 60 tensile bar specimens were prepared and one half of the bar was cast in Co-Cr alloy and the other half made of denture base resins attached to the alloy following surface pre-treatment. Two denture base resins and five surface pretreatments were used which were sandblasting, acid etching, and use of metal adhesive primers and combination of above mentioned modes. The study results indicated that the bond strength in those specimens wherein a combination of sandblasting, acid etching, and priming was done as surface pretreatment showed the maximum values as compared to other groups.

Yanagida *et al*.,[25] further evaluated the adhesive properties of metal conditioners when used for bonding between autopolymerizing methacylic resins and a titanium alloy. They concluded that the use of one of the three conditioners (Alloy Primer (ALP), COP, and MP II) in combination with the SB resin is recommended for bonding the Ti-6Al-7Nb alloy. Shimizu *et al*.,[26] conducted a study to evaluate the shear bond strengths of an autopolymerizing denture base resin to cast Ti-6Al-7Nb and Co-Cr alloys using three metal conditioners. Ti-6Al-7Nb alloy and Co-Cr alloy discs were cast. The disc surfaces were air-abraded with 50 mm alumina particles and treated with three metal conditioners (Alloy Primer; Cesead II Opaque Primer; Metal Primer II). An autopolymerizing denture base resin was applied on the discs within a hole punched in a piece of sticky tape and a Teflon ring to define the bonding area. The authors achieved significant improvements in bond strength of the autopolymerizing denture base resin to cast Ti-6Al-7Nb alloy and Co-Cr alloy through the application of Alloy Primer, Cesead II Opaque Primer, and Metal Primer II. Banerjee *et al*.,[2] evaluated the tensile bond strength of denture repair acrylic resins to primed base metal alloys (Ni-Cr and Co-Cr).

Three different metal primers viz. Alloy Primer, UBar, MR Bond were used. A total of 128 samples were prepared, half of them were bench cured and other half was pressure pot cured. Samples were tested in Instron testing machine to evaluate the tensile bond strength. Significant differences in bond strength were observed, between combination of primer, curing methods and alloys. They concluded that primed sandblasted specimens that were pressure pot cured had significantly higher bond strengths than primed sandblasted bench cured specimens. The results of the study suggested that MR. Bond (MRB, Tokuyama) metal primer can be used to increase bond strength of autopolymerized repair acrylic resin to base metal alloys and curing autopolymerized acrylic under pressure potentially increases bond strength. Kim *et al.,*[27] evaluated the shear bond strengths of a heat cure denture base resin to CP titanium, and a Co-Cr alloy using two adhesive primers (Alloy primer, MR bond). The study discs of CP titanium, Ti-6Al-4V alloy and a Co-Cr alloy were made. A hexagonal shape wax was attached to disc to fabricate apart of resin tap apart. Samples were invested in conventional way. They concluded that alloy primer, which contains phosphoric acid monomer, MDP, was clinically more acceptable for bonding a heat cure resin to titanium than a MR bond, which contains the carboxylic acid monomer. Bulbul and Kesim[28] evaluated the effect of metal primers on the shear bond strength of acrylic resins to three different types of metals. In this total of 432 disk-shaped wax patterns were cast in a Ti alloy (Tritan), base metal (Co-Cr alloy, Wironit), or noble metal (Au-Ag-Pt alloy, Mainbond EH). They concluded that the metal primers were associated with an increase in the adhesive bonding of acrylic resins to metal alloys. Though among metal alloys, the shear bond strength of the acrylic resin to the base metal alloy was significantly higher than the shear bond strength to the noble and titanium alloys. Lim *et al*.,[29] compared the shear bond strength and failure types of a PMMA denture base resin to CP titanium, Ti-6Al-4V alloy, and Co-Cr alloy using a metal surface conditioner. The PMMA denture base resin was cured onto disks, 10 mm in diameter and 2.5-mm thick. The shear bond strength of the PMMA resin with the surface conditioner was significantly higher than that without. There was no significant difference between the types of metal. Ali[30] conducted a study to evaluate the effect of primers on the shear bond strength of two types of acrylic resin to Co-Cr partial denture alloy. Fifty Co-Cr ingot and fifty cast specimens were fabricated and embedded in resin. The bond strength between primed specimens improved significantly compared with the control group. It was shown that primers enhanced the bond strength of acrylic resin and cast Co-Cr alloy. Kawaguchi *et al*.,[31] conducted a study to evaluate the effect of surface preparation on the bond strength of heat-polymerized denture base resin to commercially pure titanium and Co-Cr alloy. The alloy specimens were divided into five groups: (1) airborne-particle abraded with 50 µm alumina (SAND), (2) Rocatec tribochemical silica coating system (RO), (3) air-abraded followed by application of Epricord Opaque Primer (EP), (4) air-abraded followed by application of Super Bond C and B liquid (SB), (5) air-abraded followed by application of alloy primer (AL). Heat-polymerized denture resin was applied to the bonding area and polymerized according to the manufacturer's instructions. The halves of all specimens were thermo-cycled up to 10,000 cycles. Before thermocycling, SB and AL showed significantly higher shear bond strengths than SAND, RO, EP for both metals. The shear bond strength of AL group after thermocycling was significantly higher than that of the other groups.

Discussion and conclusive remarks

The reliability of the bond at the PMMA-to-metal interface is essential for the service longevity of prosthesis. Even if current literatures emphasis emerging trends in implant supported prosthesis and fixed partial dentures, the conventional removable partial dentures using Co-Cr framework remain a viable treatment option especially for conditions not available to fixed replacement.[4] In spite of many disadvantages of PMMA, such as polymerization shrinkage, thermal expansion, and risk of debonding, it is one of the most popular denture base materials most often used for conventional removable and implant-supported prosthodontics. Majority of predictable methods for the retention of denture base resin are beads, posts, an open lattice, a mesh, or some other macroscopic retentive design.[31]

The most commonly used acrylic retentive designs are open lattice, preformed mesh, and a metal base with bead retention. The lattice design has a high susceptibility to permanent deformation, and the open lattice design produces the greatest amount of retention for acrylic resin. External and internal finishing lines should be placed on the cast metal framework of all three types of acrylic retentive designs, wherever the acrylic resin joins the cast framework.[3,4,32,33] If there is a separation between the acrylic resin and the metal framework, especially at the finishing line, cracks or crazing may occur in the acrylic resin, leading to microleakage that is accompanied by staining. Furthermore, microleakage from the metal-PMMA interface can lead to discoloration, deterioration of the resin, and the creation of a reservoir for oral debris and microorganisms.[34,35] Any insufficiency of the chemical bond can directly affect the metal-resin interface. However, the difference in the coefficients of thermal expansion between the metal and the resin might create a gap at the interface, leading to microleakage.[36-39] In addition the polymerization shrinkage of heat polymerized denture base resin affects the stress at the resin metal interface. So far, none of the study has explained the exact bonding and its longevity on the prosthesis. Therefore, the need of the hour is to have some long-term authentic studies which could define the exact role of various surface treatments and bonding techniques to build more comprehensive understanding in this perspective.

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