Evaluation of shear bond strength of denture base materials to polymer and CoCr RDP framework material

by

Daniel Andrew Pinto, DDS

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Abstract

New removable dental prosthesis (RDP) framework materials are being released that can be fabricated by computer assisted design and manufacturing (CAD/CAM). These materials are proposed to replace traditional cobalt chromium (CoCr) frameworks. However, their properties must be tested to ensure that they are comparable to traditional framework. The ability to bond to veneering resins, is important in the repair of a removable dental prosthesis. CoCr enveloped by poly-methyl methacrylate (PMMA) is traditionally the gold standard for RDP repairs. A new polymer framework material (Ultaire AKP, Solvay Dental 360) was used for a shear bond test to compare both the bond strength of CoCr and AKP to not only PMMA (Probase Cold, Ivoclar Vivadent), but also to a denture composite, in this case Nexco (Ivoclar Vivadent).

Samples of CoCr and AKP were embedded in autopolymerizing PMMA cylinders. PMMA and Nexco were bonded to each substrate using their individual manufacturer instructions. Shear bond test results indicate that PMMA with a metal bonding liner called UBAR (Protech Professional Products, Inc) had the strongest bond in the CoCr samples, while the Nexco composite had the strongest bond within the AKP samples. Further testing must be done to evaluate flexural strength of this material as well as other applications of polymer frameworks.

Section 1: Introduction

History of RDP Design and Fabrication

Band and Clasp

The removable dental prosthesis (RDP) is a treatment modality that utilizes remaining teeth to retain and support replacements for missing teeth. The first known attempt at a partial denture was in 1728, by Pierre Fauchard, the 'father of modern dentistry'. (1) In 1810, Gardette in Philadelphia used bands (Figure 1) to encircle the adjacent teeth and retain the prosthesis. (2) However, these bands impinged on the gingiva, which was improved by the introduction of the occlusal rest in 1817 by Delabarre. (3)

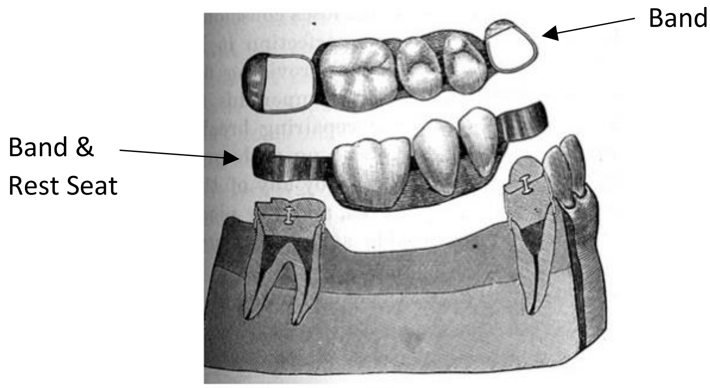


Figure 1- Band-Clasp RDP from Dental Cosmos *1900*

Partial denture technology remained the same until Bonwill described the negative consequences of the current type of partial dentures in 1890. These included soft tissue irritation, mobile teeth, caries, abrasion of teeth, and poor fit. (4, 5) These problems were mainly limitations of the methods of production—soldering together prefabricated parts—and could not be truly resolved until the invention of the lost wax technique by

William Taggart in 1907. (6) Nevertheless, Bonwill (Figure 2) created his own design to improve food impaction and gingival damage using narrower clasps and rest seats.

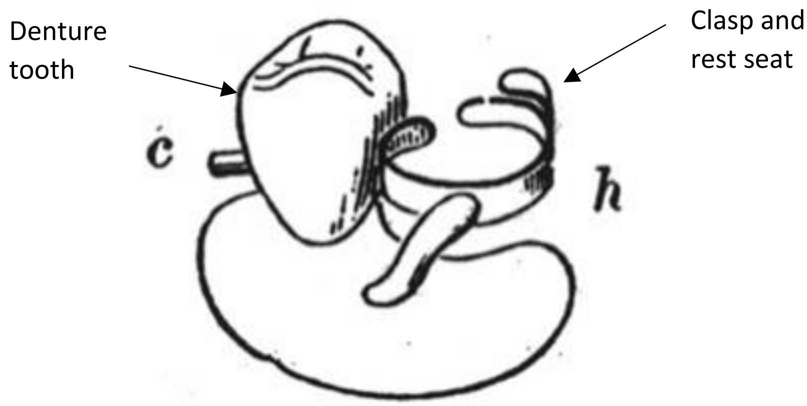


Figure 2 - Initial Design of Bonwill Retention Scheme

The narrower clasp design lending itself to discussion of the rigidity of the clasp.

<u>Lost Wax Technique</u>

Once the lost wax technique was invented by Taggart (6), Norman Nesbett introduced it in the form of cast clasps. (7) Even with the accuracy of the lost wax technique, RDPs still were not cast in one piece. Full arch impression with plaster were difficult, dental stones of

Figure 3 - Cast Clasps - Waliszewski 2010

today did not exist, and the lost wax technique was not refined enough to produce accurate castings. (8) At this time unilateral RDPs were still very popular among dentists.

Figure 4 - Unilateral RDP - Waliszewski 2010

It was possible to fabricate Full-arch RDPs by soldering individual pieces on a definitive cast, but due to the technical difficulties, this was left for the most technically-oriented practitioners. Akers then developed his one-piece casting technique in 1925, and full-arch one-piece RDPs become easier to fabricate. (9) He was met with criticism due to

Figure 5 - Akers Wax Design - Waliszewski 2010

the change in the entire technique of fabrication. However, improvements to refractory materials and casting alloys, with also the promise of time-saving for the dentists, one-piece castings became the standard in a short period of time. (10), (11) The popularity of the Akers' one-piece casting method, and its relative complexity, relegated the task of framework fabrication to the dental laboratory. This time-saving move allowed dentists to provide this treatment to a wider number of patients.

While the Akers method helped in fabrication of full arch RDPs, it was favored by proponents of unilateral RDPs as well. (11, 12) Over time, with improvements in FPD fit and fabrication (7, 13), as well as concerns including potential swallowing of the prosthesis (14), unilateral RDPs fell out of favor, and full arch RDPs became the standard. Unilateral RDPs are rarely a proposed treatment option today. (15)

Framework design

In 1922, Cummer laid out a summary of RDP design to put order to an otherwise unorganized history of RDP nomenclature and technology. (16) His terms included the base, connectors, retainers, and rests. However, with no definitive classification system of RDPs, people argued and were confused on the principles needed to be used on each case—due to the difference in application in different types of clinical scenarios. It was not until 1928 when Edward Kennedy came up with his classification system that some sort of agreement resulted. Kennedy's system was based on the location of the edentulous area and subsequent tooth supporting area. Clinicians would be able to provide context when talking about individual cases and their subsequent designs. Its importance is illustrated by the fact that it remains the main classification system for RDPs in today's textbooks (17), (18).

The development of the surveyor in the 1920s by Weinstein and Roth (13) allowed dentists to plan the contours of teeth. This tool did not become popular until the invention of the hydrocolloid impression material in the 1930s. Prior to this, undercuts were blocked out during impressions. Reversable hydrocolloids allowed these undercuts to be captured. Surveying teeth for the ideal clasp position became possible. Kennedy came up with the term “height of contour”. However, Willis was the one to first describe a technique of dental surveying (13). Establishing a “path of insertion”— the specific direction in which a prosthesis is placed on the abutment teeth (19) –allowed for conservative tooth modification.

Another important principle of RDPs was the fit of the rigid framework, however some gold alloys were known to distort or warp under load. Stress breakers and different clasping methods were just a few techniques attempting to overcome the misfit and distortion of RDPs at this stage (13).

Denture Processing

Methyl Methacrylate

History and Technique

In the 18th century, following Pierre Fauchard, dentures were fabricated mainly from ivory, with some attempts at using porcelain. (20) This remained unchanged until the 1850s with the invention of vulcanite, a hard rubber that was easily adaptable to the patient’s ridge. While esthetically unpleasant, the comfort and function of this material was superior to prior materials. (20, 21) Vulcanite was used as the denture base with individual porcelain teeth fabricated for the patient. This remained the material of choice until the 1930s and the invention of polymethyl methacrylate (PMMA). When PMMA was evaluated it was said to have all the ideal properties of a denture base material. (20) PMMA is currently the main resin used in denture fabrication (22). It has been used over 70 years in both medicine and dentistry (23). Once the framework of the RDP has been fabricated (made of Cobalt Chromium—CoCr), PMMA is used for both teeth and gingival acrylic for replacement of missing teeth in the edentulous spaces. (18)

Traditional denture processing has 3 separate stages: flasking, boil out and wax removal, and polymerization of acrylic (24). Once the tooth setup is tried in, and the gingival design is waxed up to full contour, the denture setup is flasked by pouring dental stone into a flask around the teeth and wax.

Figure 6 - Complete denture deflasked (Left – master cast with record base, Right – Teeth with gingival contour in stone)

Once the stone is set, the flask is opened and all the wax is boiled out, leaving the cast of the tissue surface on one side, and the teeth on the other (Figure 6). For partial dentures, the framework remains on the side with the cast, as shown in Figure 7.

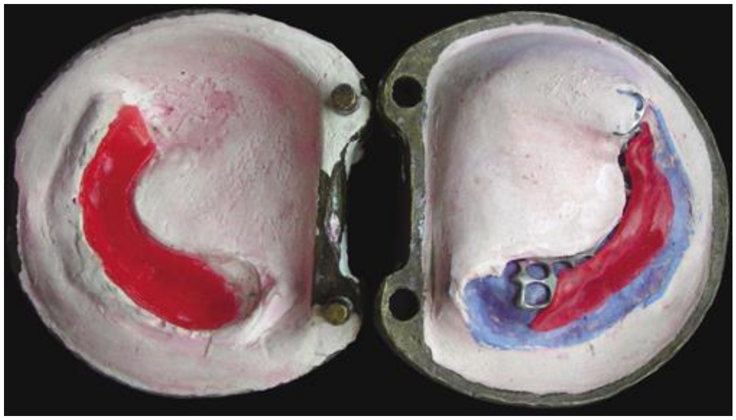


Figure 7 - Partial Denture framework invested prior to processing acrylic (Left – teeth covered by wax, Right – partial framework covered by wax)

Acrylic can be added to the framework either by compression or injection molding (25). Compression molding involves premixing polymer and monomer into a doughy stage, placing it into the denture flask, closing the flask, and applying force using a press to compress the acrylic into the crevices of the stone. (Figure 8) This may have to be done several times for adequate adaptation.

Compression molding involves premixing polymer and monomer into a doughy stage, placing it into the denture flask, closing the flask, and applying force using a press to compress the acrylic into the crevices of the stone. (Figure 8) This may have to be done several times for adequate adaptation.

Figure 8 - Denture Flask Press

Injection molding involves injecting the acrylic through the side of the flask after it is already closed. This requires a wax sprue to be added prior to fully flasking to allow passage for the resin. (Figure 9) Heat is usually applied opposite the injection side to minimize shrinkage. This aspect allows for improved accuracy over compression molding. (25)

Figure 9 – Injection molding flask (Left- Sprued denture, Right - Processed denture with sprue attached)

Bonding

The retention of PMMA acrylic with a CoCr framework is almost entirely macromechanical (physical). However, a monomer called 4-META (4-methacryloyloxyethyl trimellitate anhydride) was found to be able to increase the bond strength of acrylic to partial denture frameworks by introducing a chemical bond. (26)

Advantages

Aside from the discovery in bonding improvements of PMMA to CoCr in the last 20 years, very little else has changed with regards to processing of PMMA in denture fabrication. (27) This can be attributed to its many advantages: biocompatibility and low toxicity, esthetics and polishability, ease of processing, and low cost. PMMA is a relatively inert material that when highly polished can be very compatible with gingival and mucosal tissues. (23) It can be processed in multiple ways, and can be rebased or relined to add deficiencies with changes in ridge dimensions over time. Finally, it is a low cost material that is easy to produce. (27)

Disadvantages

While PMMA has been a staple in denture processing due to its favorable properties, it has a number of shortcomings that could be solved with the development of newer materials in to the method of denture fabrication. These disadvantages include polymerization shrinkage, porosity and cytotoxicity, and monomer inhalation. (27) While polymerization shrinkage causes dimensional changes that could affect proper fit, it has been minimized with heat cured injection molding. Porosity is another side effect of the method of fabrication. This can allow bacteria to reside in these pores and cause denture stomatitis. Another issue is the inhalation of monomer vapors during handling of the material that are thought to be possibly cytotoxic. (28) Most of these disadvantages can be overcome by using milled PMMA for dentures rather than heat processed PMMA. While for complete dentures this has been studied and seems to be successful, its use has been limited so far with traditional RDPs. Therefore, other materials have been studied to improve the RDP from its standard CoCr framework.

Exploration of Alternatives

A different direction of RDP was started with the invention of the nylon-based flexible partial denture material in the 1950s. (29)

Figure 10 - Valplast flexible RDP - Burbank Dental

These injection-molded partials were very convenient; lightweight and comfortable for the patient because of their flexibility, as well as having improved esthetics (Figure 10). (30) Due to a non-rigid framework, rest seats are not possible with these type of resin partials and therefore the lack of support during mastication would damage the gingival sulcus around tissue if not carefully blocked out. For this reason, most clinicians typically only use these flexible partials typically as interim prostheses. (31)

The CoCr framework-based RDP continues to be the gold standard of definitive RDP fabrication. Al Jabbari (32) found that this was due to its favorable properties over commercially pure titanium (cpTi) and type IV gold. Biocompatibility and flexibility of clasps are among some of the favorable characteristics of CoCr. (32)

Kulunk found that surface treatment of CoCr with Al_2O_3 significantly enhanced the shear bond strength of autopolymerizing resin to CoCr frameworks. (33)

While material improvements and technique optimization have continued, the lost-wax one stage RDP framework fabrication method has not credibly changed since the first half of the 20th century. However, with advancements in laser welding and selective laser melting (SLM), removable dental prosthesiss are going in a digital direction (34).

Digitization of the RDP

While the digital revolution started in the 1990s, the removable dental prosthesis was left behind for the single crown. The technology was used for the “crown in a day” protocol invented by CEREC and other CAD/CAM companies. (35) Recently, the milling of resin as well as the SLM printing of metal have expanded the digitization of dentistry to the RDP as well (Figure 11). (34)

The first step in the digitization of RDPs is the data acquisition, as in typical CAD/CAM dentistry. Usually, a conventional impression is made, a cast is fabricated and scanned. (36) This step is required due to the necessity of border molding an impression when a distal extension is present. However, in tooth-bound situations, a digital impression can be taken to directly design the RDP framework. (37) In designing the framework, one must be aware of what material will be used for the framework. In CoCr SLM frameworks, the design can be done traditionally with standard sized clasps and connectors.

Figure 11 - SLM milled RDP framework - 3DRDP.com

The fit of these SLM frameworks is at least as accurate as cast frameworks. Without any casting, SLM fabrication can compensate for operator error and some casting errors that can typically occur. (38) However, even with the digital technology being used for the framework, the acrylic still needs to be processed traditionally. While additive SLM techniques are extremely accurate and well used for metals, additive techniques for resins, such as stereolithography (SLA) and digital light processing (DLP) have limited uses at this time. However, recent research suggests that printed resins can be just as capable as milled or conventional resin. (39)

With regards to tooth replacement, patients typically use RDPs as a last resort restoration, due to financial or dental reasons. (40) Metal colored clasps are not aesthetic, and some patients complain of the weight as well as temperature modulation that happens with hot and cold foods. (40) Many patients will stop wearing their RDPs within 5 years of receiving them because of these issues. While nylon-based flexible resin RDP frameworks are too weak for rest seats, the invention of polyether ether ketone (PEEK) in the 1980s has allowed for its application in dentistry in recent years (41). Coming from the family of polyaryletherketones (PAEK), PEEK is a strong thermoplastic material that can be milled using CAD/CAM technology and used as an RDP framework. (Figure 12)

Figure 12 - CoCr RDP (left) - PEEK-type RDP (right) - Solvay Dental 360 Ultaire AKP

Several companies have released their own versions of the thermoplastic material PEEK for use in RDP frameworks (41). One of these companies is Solvay SA. They have created a dental division called Solvay Dental 360 exclusively for their one dental product: Ultaire AKP. A “high performance” aryl ketone polymer, AKP is a polymer they designed for RDP framework fabrication. While the manufacturer has done internal testing, nothing has been published on the material properties of PEEK-type materials as RDP frameworks. Properties like flexural strength compared to CoCr and bonding to PMMA or composite material are yet to be investigated thoroughly.

The main mechanism of bonding to PEEK-type materials seems to be micromechanical, after microblasting or acid etching. Only two studies found talk about resin bonding to PEEK (42), (43), and differences between PMMA and composite were glossed over. As PEEK-type materials are being used for both fixed and removable purposes, the studies on fixed prostheses focused on composite veneering. As PMMA is typically the material of choice for removable prostheses, it is important to take a closer look at the differences. Kountouras and Pearson looked at ideal veneering materials for overlay partials, which looks at the bond strength after loading. They found that in rigid areas, composite/MDP (10-methacryloxyldecyl dihydrogen phosphate) worked the best due to its high modulus of elasticity, whereas PMMA resin worked better in areas with more flexibility due to its low modulus. (44) It is important to use a primer for composite/metal bonding. (45), (46) Keeping this in mind, repairs are typically performed in areas with less flexibility.

Research Aim and Hypothesis

Do to the scarcity of background information on PEEK, this study focused on Solvay Dental 360's Ultaire AKP ability to bond to PMMA and composite. While RDP frameworks typically use mechanical retention for the acrylic resin, simple repairs depend more on bonding. Also, potential bonding of AKP to resin could allow for development of different RDP designs. The purpose of this study is to compare the shear bond strength of both PMMA and composite resin repair materials for CoCr to the new AKP material. Our hypothesis was that AKP would bond significantly differently to PMMA and/or composite than to CoCr. Our null hypothesis was that there would be no difference in bond strength.

Section 2: Materials and Methods

Table 1 - Equipment Used

- Buehler IsoMet Precision Saw
  - MetLab 5”x0.01” diamond wafering blade
  - Used to cut initial samples
- Resin mold
  - Used to embed samples in PMMA cylinder
- Buehler Handimet Roll Grinder
  - Used to prep surfaces to be uniformly smooth before sample preparation
- Sandblaster
  - Used to roughen surface prior to application of resin
- Ultradent shear bond test mold
  - Used to add test samples to substrate
- Ivoclar Vivadent Bluephase curing light
  - Used to polymerize Nexco composite onto sample
- Triad Curing Unit
  - Used to polymerize Nexco samples definitely
- Pressure Pot
  - Used to cure PMMA onto sample
- Ultradent shear bond universal testing machine

Used to test bond strength of samples

Table 2 - Materials Used

- Ultaire AKP
  - Solvay Dental 360 product
  - Tested thermoplastic material
- Cobalt Chromium
  - Control material
- FasTray PMMA
  - Used to embed samples in cylinder of PMMA
- Nexco composite
  - Ivoclar Vivadent product
  - Gingival shade 5
  - SR Connect bonding agent for resin
  - SR Link bonding agent for metal
- Probase Cold Cure PMMA
  - Ivoclar Vivadent product
- UBAR
  - Protech product
  - Contains 4-META monomer
  - Metal acrylic bonding agent

Specimen Fabrication and Testing

CoCr and AKP are listed as PDM (Partial Denture Material).
Probase, Probase/UBAR, and Nexco are listed as DBM (Denture Base Material)

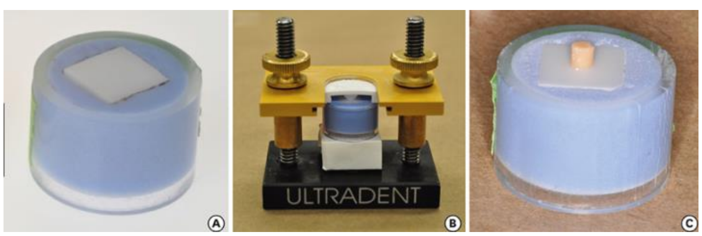
Two groups of partial denture material were tested, CoCr and AKP, with 6 specimens for each group. Each was subdivided into 3 groups of added denture base material of 2 each: Probase alone, Probase/UBAR, and Nexco composite.

Six identical square discs (1cm x 1cm x 2mm) of Ultaire AKP and 6 cylinders of CoCr were formed using a bandsaw along with a precision saw (Buehler IsoMet 1000 Precision Saw). Squares were placed face down into mold in masking tape and PMMA was poured into the molds (Figure 13). Surfaces were smoothened with a dental model trimmer and then finished with a 240-600 grit roll grinder (HandiMet Buehler).

Figure 13 – Top Left -Samples embedded with PMMA in mold, Top Right – Finished samples prior to bond, Bottom – Roll grinder and Dental Model Trimmer

All materials were added to surface using Ultradent mold (Figure 14) for shear bonding testing according to ISO standard 20922:2013. Prior to placement of material, the mold was lubricated with vaseline to allow for easy removal. Surfaces were microblasted with 100 micron Al2O3 at 2 bar at a distance of 20mm for 5 seconds before being surface treated (Figure 17).

For AKP, Probase was added directly to 2 of the specimen (Probase alone). A PMMA bonding agent, UBAR, was applied to another 2 specimen prior to Probase application (Probase/UBAR). Probase PMMA was then applied, and the mold was placed in a pressure pot for 15 minutes to allow for polymerization of the Probase. The same process was followed for the 4 CoCr Probase samples.



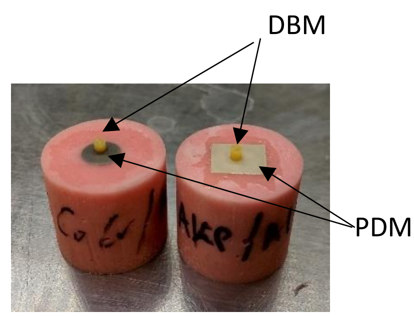


Figure 14 – Left - Example of Ultradent Shear bond mold, Right – Actual Study Samples

For Nexco application on CoCr, SR link was used as a bonding agent and allowed to react for 3 minutes. For Nexco application on AKP, SR Connect was used and light cured for 11 minutes (Bluephase, Ivoclar Vivadent). Nexco was then added to the final 2 specimen for both both AKP and CoCr. The Nexco (gingival shade 5) was cured for 5 minutes per manufacturer instructions. For the ease of removal from the Ultradent mold, specimen were cured for 1 minute with a handheld curing light, and then placed in a Triad curing unit for 4 minutes. Excess resin was trimmed for all specimen, and the specimen were measured to ensure equal length and diameter.

Each specimen was then tested in an Ultradent Universal Testing Machine (Figure 15) and resurfaced with a lathe and roll grinder. All specimen were tested 5 times each for a total of 60 trials. Testing was performed within 24 hours after surface treatment and bonding.

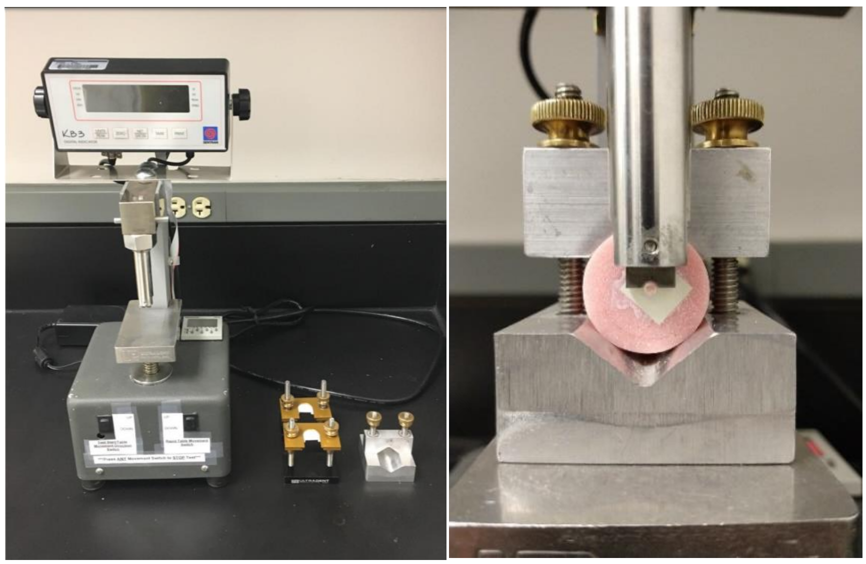
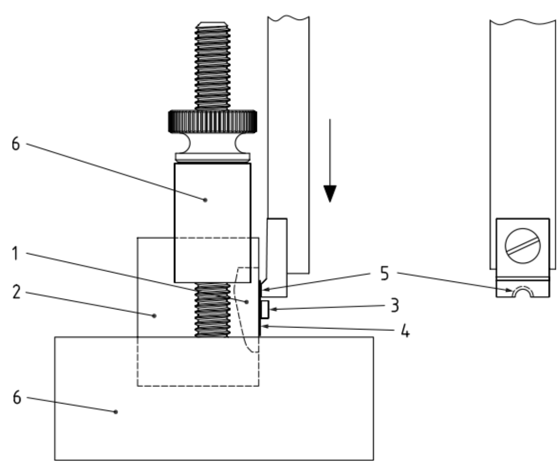


Figure 15 – Top - Ultradent Universal Shear Bond Tester (with sample in place), Bottom – ISO 29022:2013 Notched Shear Bond Testing Diagram



Key

1 tooth
2 cured potting material
3 cured composite button
4 cured adhesive
5 notched-edge shear blade
6 test base clamp

Section 3: Results

CoCr and AKP are listed as PDM (Partial Denture Material).
Probase, Probase/UBAR, and Nexco are listed as DBM (Denture Base Material)

A two-way analysis of variance (ANOVA) was used to determine differences in bond strength by partial denture framework (PDM) and denture base materials (DBM).

The equal variance assumption was not met (p = .01), and efforts to address this by applying various transformations of the data were not successful. A two-way ANOVA was then applied to rank scores. Because these results were nearly identical to those of the original ANOVA, the assumptions for the original analysis were deemed reasonable and are reported.

ANOVA results (Table 3) indicated a significant difference in mean bond strength by DBM, but no significant difference for PDM. There was also a significant interaction effect. Means and standard deviations are shown in Table 4.

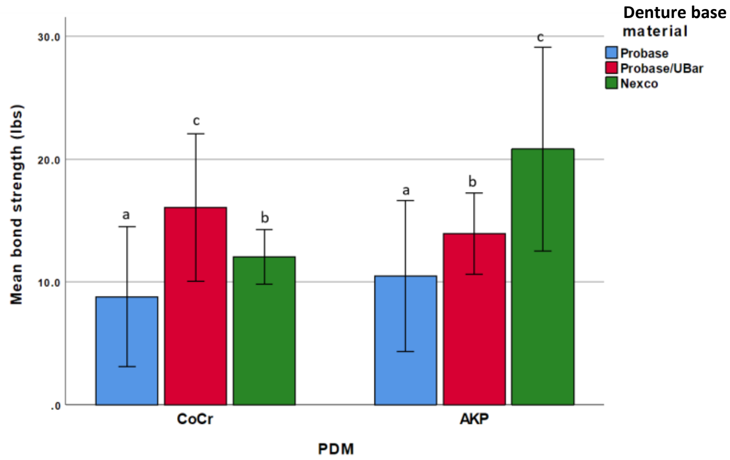
Table 3 - ANOVA results, means by PDM and DBM

Source	df	SS	MS	F	p-value
PDM	1	116.48	116.48	3.662	.061
denture base	2	510.64	55.32	8.028	.001
PDM * denture base	2	304.41	152.21	4.786	.012
error	54	1717.44	31.80		
Total	59	2648.80			

Table 4 - Mean bond strength, in lbs (std dev) by PDM and DBM

PDM	denture base	Mean (SD)
CoCr	Probase	8.81 (5.68) a
	Probase/UBar	16.05 (6.00) c
	Nexco	12.05 (2.22) b
AKP	Probase	10.50 (6.13) a
	Probase/UBar	13.95 (3.32) b
	Nexco	20.82 (8.30) c

Because of the significant interaction between PDM and denture base, post hoc tests (Tukey HSD) examined mean differences among denture bases for each PDM separately. These results also appear in Table 4.



Lbs Converted	To Mpa
	9.64
CoCr	**17.57**
	13.19
	11.49
AKP	15.27
	22.79

Figure 16 - Mean bond strength, in lbs (standard deviation), by PDM and DBM (n=10 per group) (bars with same letter within PDM grouping are not statistically significantly different)*

As illustrated in Figure 16, CoCr results indicated significantly higher mean bond strength for Probase/UBAR than either of the other two materials and significantly higher mean bond for Nexco than Probase. AKP results indicated significantly higher mean bond strength for Nexco than either Probase or Probase/UBAR and significantly higher mean bond strength for Probase/UBAR than Probase.

No analysis was done between the results of AKP and CoCr, and therefore, the Probase/UBAR/CoCr group cannot be compared to the AKP/Nexco group. While the AKP/Nexco group mean is numerically higher, no conclusion can be drawn from a comparison between these two groups.

We can reject our null hypothesis and suggest that there was a significant difference in bonding between PMMA and composite for both CoCr and AKP. For CoCr, Probase/UBAR has the highest bond strength, and for AKP, Nexco has the highest bond strength.

Section 4: Discussion

Surface Preparation

Preparation of the substrate prior to addition of a veneering material has been well studied. Many studies look at different ways to prepare the sample. Microblasting is known to improve bond strength of various materials. (47) Typically, 50-100 microns Al_2O_3 is used at a distance of 10 mm at 2 or 4 bar pressure. (48) However, during preliminary testing, an Al_2O_3 residue was being left behind on the AKP material. The distance to the sample was varied to see if any improvement in appearance could be made. As shown in Figure 17, sandblasting was attempted at both 10 and 20 mm at 2 bar pressure.

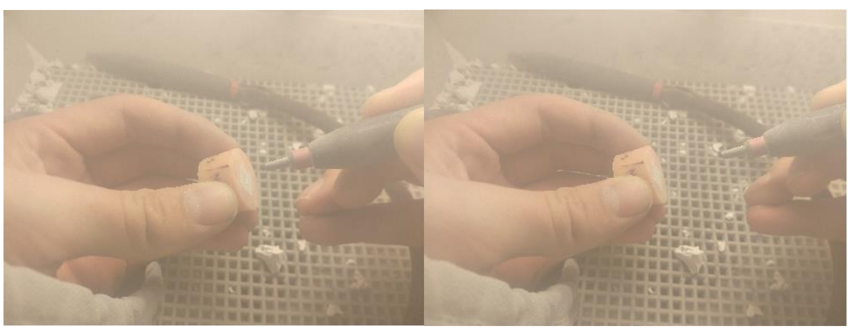


Figure 17 – Sandblasting Al2O3 at distances of 10 and 20 mm

Figure 18 shows the results of the residual particles embedded into the AKP material after microblasting. CoCr appearance is not critical, as metal is accepted as not esthetic. However, since one of the primary goals of using AKP is esthetics, and having greyish residue left on a tooth colored surface is not ideal. In pilot testing, the difference in the distance of the microblasting did not appear to affect the bond strength of either material.

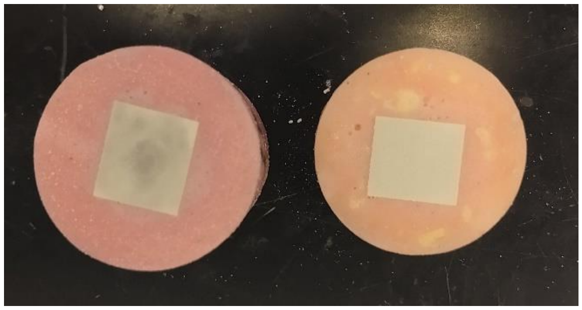


Figure 18 - Microblasting at 10mm (Left), and 20 mm (Right)

Further study of thermoplastic materials needs to be done on surface treatments to receive different veneering materials. Increasing the amount of pressure at the further distance may help retain the tooth colored appearance. Other methods of surface treatment such as acid etching could be evaluated as well.

Implications and Applications

The fact that PMMA with surface treatment of an acrylic-metal primer (UBAR) was the best for CoCr was not a surprise. This has been the gold standard for partial denture frameworks for over 50 years. (13) With regards to AKP, bonding mechanisms to PEEK-type materials are still not fully understood. Both PMMA and composite have been shown to be functional RDP DBM materials in different situations, but no study has recommended a material for PEEK-type—and therefore AKP—materials in RDPs. Under the conditions of this study, composite resin (Nexco, Ivoclar Vivadent) has a stronger mean shear bond strength than PMMA acrylic. (Probase, Ivoclar Vivadent). This study did not address flexural strength of the materials, and it is known that under some elastic pressure, PMMA can perform better. (44) However, as mentioned previously, repaired areas typically are under less flexure than traditional distal extensions. Therefore, based on the results of this study, one could suggest that for an AKP-based denture framework, composite-based repair materials may be the better choice in a clinical situation. Composite materials also have better handling and ease of use than most PMMA-based materials. Light curing tends to be faster than using a pressure pot or processing PMMA. While only one type of composite was tested here, (43) the bonding properties of veneering resins depends on the surface preparation type as well as the bonding agent used. According to Stawarczyk et al., an MMA (multifunctional methacrylate) containing bonding agent seems to work the best. (43) However, future testing of the veneering resins and their bonding agents is necessary before a definitive recommendation is made for any thermoplastic material.

There are several possible applications of new materials such as AKP. While digital dentistry has allowed us to fabricate digital frameworks—whether CoCr or PEEK—the teeth and gingival still need to be processed traditionally. This requires a cast and keeps the denture process analog. Belfiglio suggests the use of a metal base that is adapted to the tissue surface as a method of fabricating well adapted complete dentures. An issue with these dentures, however, is that they are difficult to adjust. (49)

Figure 19 - Metal Base Complete denture

With the accuracy of CAD/CAM dentistry, AKP could be used as a “metal base” and be adapted to the tissue surface. It can fill the entire distal extension area, and all that would need to be added are the teeth. A ridge of retention can be added occlusally on the base, and CAD/CAM teeth can be design, milled and bonded to the base. For this reason, it is important to know which material bonds best to PEEK. As was determined in this study, composite tends to bond more strongly than PMMA to AKP; therefore, composite teeth may be a suitable way to bond a "supra-structure" to this AKP base. An AKP base would overcome a limitation of traditional metal bases, as it was be relatively easier to adjust.

Limitations of Study

The first limitation was a non-uniform amount of time between sample fabrication and testing, varying from a few minutes to a few hours after fabrication. This was mainly due to a schedule and not being available to test immediately every time.

No SEMs were taken of the fractured samples, and this omission may also be considered a limitation. Again, it was not deemed necessary at this initial stage of study, as the intention was merely to figure out if the material was viable. An SEM of the samples should be considered in future studies to determine failure modes.

Finally, although efforts were made to control consistency of the hand grinder polish, proper distances of the microblaster to the sample, uniform thickness of the bonding agent for composite, and proper density and uniformity of the DBM added to the Ultradent mold, some variability may have occurred and may have influenced results—which is standard and to be expected.

Future Studies

One area of potential future research for AKP and other PEEK-type materials is establishing ideal surface treatment of PEEK-type materials. Because of possible discoloration of the material, ideal microblasting conditions should be studied, as well as alternative methods of surface treatment such as acid-etching.

In addition, other types of bonding agents and their corresponding veneering resin should be tested to determine differences in chemical makeups and how that might affect bond strength. CAD resin should also be compared to direct resin in relation to their bond strength to thermoplastics.

Another area of potential inquiry is the flexural strength of these PEEK-type materials, especially as compared to CoCr. Upon initial examination, it is obvious that CoCr is objectively stronger than PEEK-type thermoplastics. However, maximum yield strength is rarely reached in these materials, and therefore it is important to look at the resilience of these materials over many chewing cycles instead; especially after thermocycling—i.e. fatigue loading. PEEK RDP framework clasps, are much thicker than their CoCr counterparts, and determining the limits and possibilities of material shapes and thicknesses is crucial for RDP design.

While not as important as flexural strength or fatigue loading, hardness of the material should be tested as these appliances will be in the mouth for a long period of time, and understanding its wear characteristics and longevity against enamel or other hard surfaces such as zirconia or metal is therefore important.

Section 5: Conclusion

Within the limitations of this study, Nexco composite bonded to AKP polymer has a significantly higher shear bond strength than any other combination of materials used. For CoCr, Probase PMMA has a significantly higher shear bond strength than any other material used. These results support the claim that composite resin is the material that bonds the best to AKP. Clinically, this means that a composite denture repair material would be recommended for repairing an AKP based denture, as this would be comparable to using a PMMA based repair material with a CoCr denture. Future studies are needed to test the viability of using composite material with this new polymer.

Section 6: References

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