Suitability of the new Aryl-Ketone-Polymer indicated for removable partial dentures: Analysis of elastic properties and bond strength to denture resin

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Elastic properties of Aryl-Ketone-Polymer (UAKP) and tensile bond strength (TBS) to denture resin (PalaXpress) were tested. Indentation modulus (EIT) and indentation hardness (HIT) were measured via Martens hardness (n=10 specimens) with 4.2±0.6 kN/mm² and 261±8 N/mm² respectively. TBS was tested in dependence of different adhesives (visio.link (VL), Adhese Universal (AU), All-Bond Universal (ABU), CLEARFIL UNIVERSAL BOND (CUB), G-Premio BOND (GPB), iBOND Universal (IBU), ONE COAT 7 UNIVERSAL (OCU), Scotchbond Universal (SBU) and without adhesive (CG), n=18/group) and the application of opaquer (n=9/group) after thermocycling (5°C/55°C, 10,000×). TBS was affected by the adhesive (η =0.715, p=0.001) followed by the opaquer (η =0.335, p=0.001). VL and CG showed highest TBS followed by AU and ABU, IBU and GPB resulted in lowest TBS. Opaquer increased TBS for all adhesives (p<0.05), except VL and CG (p=0.258). Elastic properties are well-suited for the indication of removable partial dentures. Bonding to denture resin is no limiting factor.

Keywords: High-performance thermoplastics, Aryl-Ketone-Polymer, Denture resin, Removable Partial denture, Tensile bond strength

INTRODUCTION

As the awareness of dental and oral health increases, partial edentulism is an important area of focus in this discussion. The replacement of missing teeth by removable partial dentures (RPD) is wildly used in clinical practice¹ and enables the improvement of four oral functions: esthetics, mandibular stability, mastication, and speech². The most popular and established material of choice for RPD frameworks is cobalt-chromium (CoCr). However, RPD frameworks made of CoCr are less desirable for esthetic reasons as one major design problem is selecting a RPD that avoids the unsightly display associated with conventional clasp assemblies³,⁴. Furthermore, RPD’s made of CoCr do not comply with the modern dentistry tracing towards metal-free restorations and digital technologies. Thus, current literature claims that there is a need for clinical innovation for RPDs to advance the materials and technologies associated with these devices. It is mentioned that polymers are of special interest because of ease of machineability and desirable properties⁵.

To meet this challenge, high-performance thermoplastics of the polyaryletherketone (PAEK) group have been recently introduced to dentistry. These materials are beneficial as they provide high stability⁶-⁸ and the color esthetically matches the teeth and/or mucosal tissue⁹. The good heat resistance of high-performance thermoplastics can offer autoclave disinfection of prostheses¹⁰, which complies with the requirement of preventive cleaning methods¹ⁱ. Generally, PAEK materials are more stable to discolorations in selected media than other denture resins⁵, and showed the lowest solubility and water absorption¹². On this account, high-performance thermoplastics are indicated for removable as well as fixed dental prostheses¹³,¹⁴ and first case reports are published¹⁵,¹⁶,¹⁷. From a clinical perspective, PAEK-based prostheses have shown positive early results with respect to appearance¹⁸, fit¹⁹,²⁰, and retention²¹.

Despite the advances of PAEK-based prosthetics, meeting the demand for development of new materials that satisfy the key design requirements for RPDs¹⁰ has remained elusive. Recently, a new high-performance thermoplastic qualified as Aryl-Ketone-Polymer (UAKP; Ultaire⁷³AKP, Solvay Dental 360, Alpharetta, GA, USA) was launched to the dental market. According to the manufacturer, it is specifically designed for the indication of RPDs as it provides the relevant characteristics and meets distinct and beneficial requirements such as adequate strength and the desired balance between flexibility and rigidity¹¹.

For the successful implementation of a new material to the dental prosthetics market, a few key performance parameters must be rigorously understood, specifically the mechanical properties and the ability to adhere other materials (i.e. PMMA, etc.) to it. If a prosthetic material, specifically RPD base material, does not have the right mechanical property or adhesion profile, the chances of its success in the clinical environment is low. Thus, this investigation focuses on UAKPs performance in these two key areas. For the mechanical properties, although readily available by the manufacturer, the elastic properties of the new high-performance thermoplastic UAKP have not been explored in scientific literature so far. For this reason, the investigation
herein characterized the indentation modulus (\(E_{IT}\)) as well as the indentation hardness (\(H_{IT}\)) of UAKP by Martens hardness measurements. As the \(E_{IT}\) is an intrinsic material property that approaches the Young’s modulus, and the \(H_{IT}\) is a measure of plasticity, valuable information for the application as RPD might be obtained. As RPD frameworks are exposed to a dynamic set of stress/strain environments — insertion/removal stresses on clasps, mastication forces on rests and the frame, etc. — validating the level of elastic behavior and ductility of a material key to knowing if it could succeed for the RPD indication.

On the adhesion properties, the present investigation also focused on the bond strength between the UAKP and denture resin, which has historically been challenging due to the characteristic inert surface character of high-performance thermoplastics\(^{22}\). Even though current scientific evidence has thoroughly dealt with bonding characteristics between high-performance thermoplastics to polymer-based materials like veneering resins\(^{25-28}\) and resin composite\(^{29-42}\), data on the bonding behavior to denture resin is truly scarce\(^3\). The most important findings are that a surface pretreatment combined with appropriate specific conditioning step is necessary to realize a sufficient bonding to dental composites. Most proven is the combination of air-particle abrasion using alumina oxide (\(\text{Al}_2\text{O}_3\)) together with the adhesive viscio.link\(^{25,26,28,41}\) and selected universal adhesives\(^{40,43}\). The additional application of opaquer was observed to increase bond strength values\(^{24,25}\). The goal of this investigation is to evaluate the validity of this general bonding protocol between UAKP and denture resin.

Summed up, the present investigation tested the suitability of UAKP for its dental application as RPD by analyzing the elastic properties (\(E_{IT}\) and \(H_{IT}\)) as well as the bond strength between UAKP and denture resin after appropriate surface treatment. The null hypotheses tested that neither the different adhesives nor the application of opaquer show an impact on the results of tensile bond strength (TBS).

**MATERIALS AND METHODS**

**Fabrication of specimens**

A total number of 172 substrates were prepared from UAKP (Dentivera Milling Discs, UltaiTeTM AKP, Solvay Dental 360, Alpharetta, GA, USA). First, milling blanks were cut into bars using a handpiece and further separated into square shaped specimens with an approximate surface area of 16 mm\(^2\). Then, specimens were embedded in acrylic resin (ScandiQuick A+ScandiQuick B, ScanDia, Hagen, Germany), polished up to P1200 with silicon carbide paper (SiC Foil, Struers, Ballerup, Denmark) for 20 s under permanent water cooling using an automatic polishing device (Tegramin 20, Struers).

Afterwards, specimens were ultrasonically cleaned in distilled water (L&R Transistor/Ultrasonic T-14, L&R, Kearny, NJ, USA) and air-dried. The specimen surface was air-abraded (basis Quattro IS, Renfert, Hilzingen, Germany) using alumina particles (\(\text{Al}_2\text{O}_3\)) with a mean particle size of 50 µm (Orbis Dental, Münster, Germany), a pressure of 0.2 MPa and 10 mm at 45° between nozzle and specimen surface. After renewed ultrasonically cleaning for 60 s in distilled water, 10 specimens were put aside for Martens hardness measurements, while remaining 162 specimens were further divided for TBS measurements.

**Measurements of Martens hardness parameters**

Martens hardness measurements (\(n=30\)) were realized in a universal testing machine (ZHU 0.2/22.5, Zwick Roell, Ulm, Germany) with 3 measurements per specimens (\(n=3\)) in dry atmosphere at room temperature. The diamond indenter pyramid (\(\alpha=136°\)) was vertically pressed into the specimen surface with a load of 9.807 N for 10 s. The intertender displacement represented the total amount of elastic deformation on the surface along with the plastic depth of the impression. Indentation modulus (\(E_{IT}\)) and indentation hardness (\(H_{IT}\)) were calculated (testXpert V12.3 Master, Zwick) according to the equations listed in the standards (DIN EN ISO 14577):

\[
E_{IT} = \left(1 - \nu_i^2\right) \left(1 - \frac{1 - \nu_i^2}{E_i} \right)^{-1} \times \frac{1}{F_{\text{max}}} \times \frac{\sqrt{A_p}}{\bar{a}_{\text{p}}}
\]

\[
H_{IT} = \frac{F_{\text{max}}}{A_p}
\]

\(E_{IT}\) in kN/mm\(^2\) with \(\nu_i\) (Poisson ratio of specimen), \(\nu_i\) (Poisson ratio of indenter), \(E_i\) (reduced modulus of the indentation contact), \(E_p\) (modulus of indenter), \(c\) (compliance of the contact), \(A_p\) (projected area of contact), and \(H_{IT}\) in N/mm\(^2\) with \(F_{\text{max}}\) (maximum applied force).

To better contextualize the determined values of \(E_{IT}\) and \(H_{IT}\) for UAKP additional measurements of Martens hardness were supplemented for Tizian Blank PEEK (unfilled PEEK, Mani Schütz, Rosbach, Germany), Dentokeep PEEK Disc (particle filled PEEK, nt-trading, Karlsruhe, Germany), breCAM BioHPP dentin-shade (particle-filled PEEK, bredent, Senden Germany), Pekton ivory (particle-filled PEKK, Cendres Métaux, Biel/Bienne, Switzerland) and the denture resin PalaXpress (PMMA, Kulzer, Hanau, Germany).

**TBS measurements**

For TBS measurements, remaining 162 specimens were subsequently divided into 9 subgroups according the conditioning with different adhesives (\(n=18\)/subgroup). The subgroups of varying adhesives comprised viscio.link (positive control group) and seven universal adhesives, namely Adhese Universal, All-Bond Universal, CLEARFIL UNIVERSAL BOND, G-Premio BOND, iBOND Universal, ONE COAT 7 UNIVERSAL and Scotchbond Universal (Table 1). The last group of specimens stayed without the application of adhesive (control). For all adhesives, a thin layer was applied on the substrate surface for 10 s using a microbrush and dispersed with oil-free compressed air, if recommended by the manufacturer. The layer of universal adhesive was
Table 1 Summary of used materials

| Product name                  | Manufacturer                          | Lot No.       |
|------------------------------|---------------------------------------|---------------|
| UAKP Dentivera Milling Discs | Solvay Dental 360, Alpharetta, GA, USA | 1641189007    |
| UltraTTM AKP                 |                                       |               |
| Opaquer Universal Opaque A30 | Shofu, Kyoto, Japan                   | 121619        |
| visio.link                   |                                       |               |
| Adhese Universal             | Ivoclar Vivadent, Schaan, Liechtenstein | U52628        |
| All-Bond Universal           | Bisco, Schaumburg, USA                | 1700000951    |
| CLEARFIL UNIVERSAL           | Kuraray Noritake Dental, Kurashiki, Japan | CN0022        |
| G-Premio BOND                | GC Europe, Leuven, Belgium            | 1608301       |
| iBOND Universal              | Kulzer, Hanau, Germany                | 10026         |
| ONE COAT 7 UNIVERSAL         | Coltene, Altstätten, Switzerland      | H39695        |
| Scotchbond Universal         | 3M, Seefeld, Germany                  | 648274        |
| Denture resin                | PalaXpress                            | Liquid 010513 |
|                              | Kulzer                                | Powder R010028|

polymerized for 10 s (Elipar S10, 3M, Seefeld, Germany) with a distance of 5 mm. To guarantee sufficient polymerization, the light intensity of the polymerization unit (1,250 mW/cm²) was examined with a precise radiometer (Bluephase Meter II, Ivoclar Vivadent, Schaan, Liechtenstein) in regular intervals. Visio.link was immediately polymerized for 90 s (bre.Lux Power Unit) as recommended by the manufacturer. The last group stayed without the application of adhesive. For half of the specimens of each subgroup (n=9/subgroup) a thin opaquer layer (Universal Opaque A30, Shofu, Kyoto, Japan) was applied on the conditioned specimen surface. The application was made in lines from two directions, horizontal and vertical, to guarantee an even distribution of the paste-like opaquer. The opaquer was polymerized for 180 s (Solidilite V, Shofu). The other half of specimens of each subgroup (n=9) was left without the application of opaquer. Then, a transparent acrylic cylinder (SD Mechatronik, Feldkirchen-Westerham, Germany) with an inner diameter of 2.9 mm was placed in the center of each pretreated specimen surface and filled with denture resin (PalaXpress, Color: pink, Kulzer). The denture resin was freshly mixed from polymer powder and liquid in a certain ratio (10 g: 7 mL) for 15 s until a homogenous, non-porous dough was achieved. To avoid shifting of the acrylic cylinder on the specimen surface during filling with denture resin, a clamp-like mechanical fixation was used on each specimen separately. With this construction, small groups of specimens (n=4–5) were put in a waterfilled pressure pot at a pressure of 0.2 MPa and a temperature of 55°C for 30 min.

After curing, all specimens were stored in distilled water for 24 h at 37°C (HeraCee 150, Heraeus, Hanau, Germany) followed by additional thermal aging for 10,000 cycles between 5°C and 55°C (Thermocycler THE 1100, SD Mechatronik). After artificial aging and relaxation for 2 h at room temperature (24°C), TBS measurements were conducted. For this, specimens were positioned successively in the test device (Fig. 1) in a universal testing machine (Zwick 1445 RetroLine, Zwick) with the specimen surface perpendicular to the applied stress. TBS (N/mm²=MPa) was measured at a crosshead speed of 5 mm/min and calculated after fracture of the bonding area as follows: fracture load (N)/bonding area (mm²).

Fracture type analysis
The corresponding fracture type was examined using a stereomicroscope at a magnification of 20× (Carl Zeiss Axioskop 2 MAT, Zeiss, Jena, Germany). To assign the fracture type following categories were defined: (i) adhesively —without adhesive or opaquer left on UAKP

Fig. 1 Specimen positioned in test setup for TBS measurements.
surface, (ii) adhesively —with adhesive left on UAKP surface (iii) adhesively —with opaquer left on UAKP. Cohesive fracture types in UAKP or denture resin on UAKP surface were not observed.

**Statistical analyses**

Descriptive statistics were calculated. Normality of data distribution was tested using the Kolmogorov-Smirnov test. One-way and two-way ANOVA together with partial eta squared ($\eta^2_p$) followed by Tukey-B post-hoc test was computed to determine the significant differences among the tested groups. Additionally, non-parametric Kruskal-Wallis and Mann-Whitney $U$ test were performed. Relative frequencies of fracture types together with the corresponding 95%CI according to the Ciba Geigy tables\(^{44}\) were provided. A Chi$^2$-test was used to detect differences in frequencies of fracture types between groups. The Pearson correlation coefficient test evaluated the effect of the TBS and fracture types. The statistical tests were performed with SPSS Version 23.0 (SPSS, Chicago, IL, USA). $p$-Values smaller than 0.05 were considered statistically significant in all tests.

**RESULTS**

For the mechanical property measurements, the mean $E_{IT}$ of UAKP was 4.2±0.6 kN/mm$^2$ and the mean $H_{IT}$ was 261±8 N/mm$^2$. The values for both $E_{IT}$ and $H_{IT}$ were not normally distributed. UAKP showed the lowest $E_{IT}$ for high-performance polymers, followed by Tizian Blank PEEK (unfilled) as well as Dentokeep PEEK Blank and bre.CAM.BioHPP (both particle-filled). Pekkton ivory (PEKK) showed the highest $E_{IT}$ (Fig. 2). Regarding $H_{IT}$ a similar tendency was observed. UAKP showed significantly lower $H_{IT}$ values than all PEEK-based materials, while PEKK showed the highest value (Fig.
For both parameters ($E_t$ and $H_t$), the denture resin PalaXpress (PMMA) provided values in the same range than UAKP.

For the TBS results, the highest influence was exerted by the adhesive (partial eta squared $\eta^2=0.715$, $p<0.001$), followed by the application of an opaquer.

Table 2  Descriptive statistics of TBS (N/mm$^2$) listed by means with standard deviations (SD), 95% confidence interval (CI), minimum, median and maximum

| Opaqueer | Adhesive                      | means±SD  | 95%CI      | Min/Median/Max |
|----------|-------------------------------|-----------|------------|----------------|
| with     | visio.link                    | 33.0±12.1  | 22;43      | 9.9/36.8/53.9  |
|          | Adhese Universal              | 26.2±8.7   | 18;33      | 14.7/28.3/35.7 |
|          | All-Bond Universal            | 24.5±2.5   | 21;27      | 21.2/25.4/27.1 |
|          | CLEARFIL UNIVERSAL BOND       | 18.3±4.0   | 14;22      | 11.1/19.2/25.0 |
|          | G-Premio BOND                 | 10.3±5.9   | 4;15       | 0/11.5/17.4    |
|          | iBOND Universal               | 6.3±7.5    | 0;13       | 0/2.9/22.6     |
|          | ONE COAT 7 UNIVERSAL          | 20.7±2.8   | 17;23      | 15.6/21.2/23.9 |
|          | Scotchbond Universal          | 26.2±2.3   | 23;28      | 22.7/25.9/29.5 |
|          | without                       | 26.4±4.5   | 22;30      | 19.5/26.2/34.8 |
|          | Adhese Universal              | 17.4±6.5   | 11;23      | 4.7/18.2/25.6  |
|          | All-Bond Universal            | 13.0±5.7   | 7;18       | 4.5/13.6/22.6  |
|          | CLEARFIL UNIVERSAL BOND       | 9.2±6.8    | 2;15       | 0/10.4/18.5    |
|          | G-Premio BOND                 | 3.0±4.9    | 0;7        | 0/0/13.3       |
|          | iBOND Universal               | 0          | 0          | 0              |
|          | ONE COAT 7 UNIVERSAL          | 10.3±8.2   | 2;17       | 0/13.8/18.6    |
|          | Scotchbond Universal          | 16.1±3.5   | 12;19      | 12.6/14.5/22.9 |
| without  | without                       | 30.8±6.1   | 25;36      | 20.6/31.3/42.2 |

* indicating non-normal distributed groups
A-E indicating significant differences between adhesives within one group

Table 3  Relative frequency of fracture types with 95% CI

| Opaqueer | Adhesive                      | without adhesive or opaquer left on UAKP | with adhesive left on UAKP | with opaquer left on UAKP |
|----------|-------------------------------|------------------------------------------|---------------------------|---------------------------|
| with     | visio.link                    | 67 (30;93)                               | 0 (0;34)                  | 33 (7;70)                 |
|          | Adhese Universal              | 89 (50;100)                              | 0 (0;34)                  | 11 (0;48)                 |
|          | All-Bond Universal            | 100 (63;100)                             | 0 (0;34)                  | 0 (0;34)                  |
|          | CLEARFIL UNIVERSAL BOND       | 100 (63;100)                             | 0 (0;34)                  | 0 (0;34)                  |
|          | G-Premio BOND                 | 100 (63;100)                             | 0 (0;34)                  | 0 (0;34)                  |
|          | iBOND Universal               | 100 (63;100)                             | 0 (0;34)                  | 0 (0;34)                  |
|          | ONE COAT 7 UNIVERSAL          | 100 (63;100)                             | 0 (0;34)                  | 0 (0;34)                  |
|          | Scotchbond Universal          | 100 (63;100)                             | 0 (0;34)                  | 0 (0;34)                  |
|          | without                       | 100 (63;100)                             | 0 (0;34)                  | 0 (0;34)                  |
| without  | visio.link                    | 56 (20;87)                               | 44 (12;79)                | 0 (0;34)                  |
|          | Adhese Universal              | 100 (63;100)                             | 0 (0;34)                  | 0 (0;34)                  |
|          | All-Bond Universal            | 89 (50;100)                              | 11 (0;48)                 | 0 (0;34)                  |
|          | CLEARFIL UNIVERSAL BOND       | 100 (63;100)                             | 0 (0;34)                  | 0 (0;34)                  |
|          | G-Premio BOND                 | 100 (63;100)                             | 0 (0;34)                  | 0 (0;34)                  |
|          | iBOND Universal               | 100 (63;100)                             | 0 (0;34)                  | 0 (0;34)                  |
|          | ONE COAT 7 UNIVERSAL          | 100 (63;100)                             | 0 (0;34)                  | 0 (0;34)                  |
|          | Scotchbond Universal          | 100 (63;100)                             | 0 (0;34)                  | 0 (0;34)                  |
|          | without                       | 100 (63;100)                             | 0 (0;34)                  | 0 (0;34)                  |
layer ($\eta^2=0.335$, $p<0.001$). The effect of the binary combination of the two parameters was not significant ($\eta^2=0.048$, $p=0.506$) and thus showed no impact on the TBS results.

Of all tested groups, 88.9% demonstrated a normal distribution of TBS. In terms of the adhesives, the significant lowest TBS was achieved when either iBOND Universal or G-Premio BOND was used. Adhesives exhibiting relatively moderate TBS values were CLEARFIL UNIVERSAL BOND, ONE COAT 7 UNIVERSAL and All-Bond Universal. Visio.link and specimens without adhesive (control) showed the highest TBS values, followed by Adhesive Universal und Scotchbond Universal (Table 2). For visio.link and specimens without adhesive (control), no impact of the opaquer on the results of TBS was found ($p<0.258$). For all tested universal adhesives, namely Adhesive Universal, All-Bond Universal, CLEARFIL UNIVERSAL BOND, G-Premio BOND, iBOND Universal, ONE COAT 7 UNIVERSAL and Scotchbond Universal, the application of opaquer resulted in higher values of TBS ($p<0.05$). No correlations between TBS and fracture types (Table 3) were observed ($p>0.05$).

DISCUSSION

Generally, a materials ductility is inversely proportional to its $E_{IT}$, while a materials elastic behavior is inversely proportional to its $H_{IT}$. The respective values of $E_{IT}$ and $H_{IT}$ for UAKP appear to align well with performance needs for materials used for RPDs, i.e. a strong balance of both elasticity and ductility. The behavior corresponds to the current literature recommended requirements for the RPD indication, namely rheometric properties that allow for elastic deformation and recovery with the application and removal of stress and thus resistance to permanent deformation. Within PEEK-based materials, their respective $E_{IT}$ and $H_{IT}$ values define a stiffer, more brittle material, thus less ideal for the deflections needed for RPD clasps than UAKP. The PEEK-based materials only exhibited differences within the $E_{IT}$ values between the unfilled material and the particle-filled materials. This observation seems plausible, since the addition of filler particles intended to increase the mechanical properties. Obviously, the indentation hardness ($H_{IT}$) remained unaffected by the addition of filler particles. PEKK might be interpreted as material with the highest rigidity, and less appropriate for the performance needs of RPD clasps. The higher stiffness might arise from the ratios of ketone groups related to ether groups. The more ketone groups, the higher the stiffness of the polymer chain as it is the case for PEKK in comparison to PEEK.

The observed differences between UAKP and all other tested high-performance thermoplastic materials might also indicate certain differences in the core chemistry and structure. But also, differences in the manufacturing process are to consider, as certain processing steps, such as quenching and annealing, affect the crystallinity of polymers, hence the mechanical properties such as Young’s modulus. This emphasizes the importance not to lump all high-performance thermoplastics together into one category of materials and indications, but to consider them individually regarding characteristic properties.

The first key finding is that the well-established bonding protocol for PEEK and PEKK based materials, comprising air-particle abrasion and conditioning using MMA-based adhesives like visio.link, can be transferred to UAKP and denture resin.

Regarding bond strength between UAKP and denture resin, the incipiently proposed hypotheses that neither the adhesive nor the application of opaquer affects the TBS to denture resin is to reject. The present results and previously published data combine to show that the presence of methyl methacrylate monomers (MMA) plays a significant role in the bond strength between the inert surface of high-performance thermoplastics and other polymer-based materials. The present results point to an enhanced bonding behavior of high performance polymers to MMA-based polymers compared to dimethacrylate (DMA)-based polymers. This is concluded because visio.link is the only adhesive in the present study based on MMA, which resulted in the highest TBS, comparable to that of pure denture resin (PMMA). The high bond strength of denture resin to UAKP is proposed to be driven by two factors; high monomer conversion during polymerization and better relative mechanical properties at the UAKP/PMMA interface compared to other materials.

Given the relative similarity of the Martens hardness measurements between PMMA and UAKP compared to that of PMMA and the other high-performance polymers tested, it can be confidently proposed that residual stress in the interface of UAKP and denture resin are low. This would improve overall mechanical compliance under applied stress of the PMMA/UAKP interface, and result in a stronger, longer lasting bond between the two materials. This assumption might be supported by the observation found in a previous investigation. Here, a more favorable tensile stress distribution between resin composite and dentin was found for a resin composite that showed the greatest similarity in the biomimetic properties to dentin. Since this observation came along with the highest TBS results between resin composite and dentin, a higher resistance of the adhesive interface to the tensile stress is assumed when mechanical properties are comparable.

Denture resins differ from the adhesives or the opaquer, as they are not light cured but thermally cured, i.e. the polymerization reaction is initiated or at least accelerated by temperature and pressure. PMMA polymerization reactions are typically highly reactive, obtaining high conversion efficiencies, and thus not leaving a large amount of residual monomer after the reaction is completed. This results in a more robust interaction with the opposing substrate, which could be diminished with the presence of monomer at the interface.

In contrast to the chemical curing of denture resin,
all adhesives used in the present study are light-cured. Here, the successful polymerization depends on the light curing device that should be matched to the photo initiator system. The polymerization of the adhesives was performed according to the manufacturer’s instructions, but an essential difference between visio.link and all universal adhesives is important to mention. Visio.link contains a type 1 photo initiator (diphenyl(2,4,6 trimethylbenzoyl)phosphine oxide; TPO) while all universal adhesives, except G-Premio BOND, contain a type 2 photo initiator system (camphor quinone; CQ). Therefore, visio.link was polymerized using a different light curing device (bre.Lux Power Unit, 370–500 nm) than all universal adhesives (Elipar S10, 430–480 nm). Since visio.link is already proven to achieve reliable high bond strength values between high-performance thermoplastics and further polymer-based materials that were neither affected by different pressures during air-particle abrasion nor by the application of opaquer, the polymerization reaction for visio.link seems robust. Visio.link robust bonding to UAKP was confirmed by the analysis of fracture types, since it was the adhesive that revealed the significantly highest frequency of cohesive fracture types, i.e. those with remnants of visio.link left on UAKP surface, with or without the application of opaquer.

CONCLUSIONS

Within the limitations of the present investigation, the following conclusions can be drawn:

1. UAKP showed the significant lowest values in indentation modulus and indentation hardness compared to other high-performance thermoplastic materials.
2. Regarding elastic properties, UAKP seems well-suited being indicated for RPDs.
3. The application of an adhesive is not necessarily needed for sufficient bond strength to denture resin.
4. Visio.link resulted in highest TBS comparable to the TBS without adhesive.
5. Universal adhesives, such as Scotchbond Universal, Adhese Universal and All-Bond Universal should be applied in combination with opaquer.

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