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ORIGINAL ARTICLE

Bond of acrylic teeth to different denture base resins after various surface-conditioning methods

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Abstract The study examined the bond between different denture base resins and highly cross-linked acrylic denture teeth with different base surface-conditioning methods. One hundred fifty highly cross-linked resin denture teeth (SR-Antaris, No. 11, Ivoclar-Vivadent, FL) were divided into five groups with different surface-conditioning methods of the base surfaces of the teeth (C=control, no surface conditioning, MM=application of methyl methacrylate monomer, SB=sand blasting, SBB=sand blasting+bonding agent, TSS=tribochemical silica coating+silanization). Teeth were bonded to either a cold-cured denture base resin (ProBase Cold, Ivoclar-Vivadent, FL) or heat-cured denture base resins (SR Ivocap Plus, Ivoclar-Vivadent, FL and Lucitone 199, Dentsply, USA). After 24 h of storage in distilled water, compressive load was applied at 90° on the palatal surface of each tooth until fracture. Median failure load ranged between 103 and 257 N for Probase Cold groups, 91 to 261 N for Lucitone 199, and 149 to 320 N for SR Ivocap Plus. For Probase Cold, significant highest failure loads resulted when teeth were treated with SB, SBB, or TSS. For Lucitone 199, significant highest failure loads has been found with MM and TSS treatment. For SR Ivocap Plus, highest failure loads resulted using SBB and TSS. Conditioning of the base surfaces of the teeth prior to denture base processing is highly recommended. Tooth bond is significantly affected by the surface-conditioning method and applied denture base resin. Tribochemical silica coating+silanization method can be recommended for pre-treatment of teeth applying either heat-cured or cold-cured denture base resin.

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Introduction

Loss of adhesion between denture teeth and denture base is a common clinical problem [1–4]. Studies that have evaluated the frequency of various denture repairs have found that 22–30% of denture repairs involve tooth debonding [5]. The International Organization for Standardization (ISO) specification no. 22112 defines standards concerning the bond strength between artificial acrylic teeth and denture base resins and a bond test method [6]. One attempt to improve the bond of denture teeth to an acrylic base resin is mechanical modification of the base surfaces of denture teeth as for instance grinding or surface grooving. Other methods are chemical treatments such as application of monomer, nonpolymerizable solvents, dissolved polymethyl methacrylate, tribochemical silica coating+silanization or combinations of the above [4, 7–10]. A study [11] determined that painting unmodified base surfaces of acrylic resin teeth with monomer, unfilled resin, or bonding agent demonstrated the highest bond strength. Takahashi et al. [8] found that the preparation of a diatoric and application of dichloromethane on the base surface of the teeth significantly improved the bond strength. Zuckerman [12] concluded that mechanical modification to the acrylic teeth produced a stronger bond with denture base resin. Saavedra et al. [9] investigated the bond strength between a heat-polymerized acrylic resin and acrylic teeth and found higher bond strength using methyl methacrylate-based bonding agent and tribochemical silica coating+silanization.

Denture teeth generally bond better to heat-cured denture base resin than to autopolymerizing resin [8, 13–17].

Higher polymerization temperature of heat-cured resins enhances the diffusion of monomers into the denture teeth, thus increasing the bond strength [14].

The EN ISO 22112 [6] bond strength test is not a clinically realistic test and induces cohesive fractures. Therefore, the present study used a more realistic alternative method. The purpose of this study was to determine whether a perfected combination of a particular surface-conditioning method and a particular denture base acrylic resin material could result in optimal bond strength. The first part of the research hypothesis was that heat-polymerized acrylic resins show higher bond to highly cross-linked acrylic denture teeth than cold-curing denture base resins. The second part was that different surface-conditioning methods of the base surfaces of the teeth can influence the bond between tooth and denture base resin.

Materials and methods

With the aid of a silicon mold and according to the manufacturers' directions, 150 highly cross-linked methyl methacrylate resin denture teeth (SR-Antaris, No.11, Ivoclar-Vivadent, FL) were bonded to three types of acrylic resin: a cold-curing denture base resin (ProBase Cold, Ivoclar-Vivadent, FL), an injection pressing heat-curing denture base resin (SR Ivocap Plus, Ivoclar-Vivadent, FL), and a conventional water-bath, heat-curing acrylic resin (Lucitone 199, Dentsply, USA). Teeth were embedded in resin with a 1-mm high cervical area (Fig. 1).

Beforehand, five different surface-conditioning methods were applied to the base surfaces of the teeth. Therefore, they were divided into five groups (n=10) for each denture base resin:

1. C: Control, no surface conditioning.
2. MM: Application of methyl methacrylate monomer (ProBase Cold, Ivoclar-Vivadent, FL) for 1 min.
3. SB: Sand blasting (250-μm aluminium oxide, 2 bar; distance=10 mm; 20 s)
4. SBB: Sand blasting (250-μm aluminium oxide, 2 bar; distance=10 mm; 20 s)+methyl methacrylate-based bonding agent (Palabond, Heraeus Kulzer, G), allowed to dry for 30 s.
5. TSS: Sand blasting (110-μm aluminium oxide (Rocatec Pre, 3 M ESPE, G) followed by tribochemical coating with 30-μm silica-modified aluminium oxide (Rocatec soft, 3 M ESPE, G), 2.8 bar; distance=10 mm; 20 s). Thereafter, a silane-coupling agent (ESPE-Sil, 3 M ESPE, G) was applied and allowed to dry for 5 min.

All specimens were stored at 37°C for 24 h in distilled water. Then, the fracture test was carried out in a testing machine (Zwick 1446, G). The load was applied at 90° from the long axis of each denture tooth on the palatal surface at a crosshead speed of 1 mm/min until fracture (Fig. 2).

Fracture force, median, and percentiles were calculated (Fig. 3; Table 1) and the Mann–Whitney U test (Table 2) was performed using the program SPSS 15 for Windows (SPSS Inc., USA) [18]. The level of significance was set at α=0.05. Fracture forms were determined optically and classified into adhesive, cohesive, or mixed adhesive/cohesive failure mode.

Fig. 1 Tooth–resin assembly

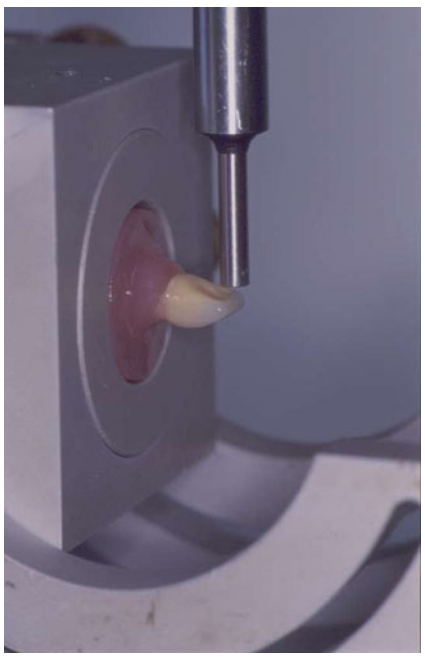

Fig. 2 Method of holding and loading test specimens

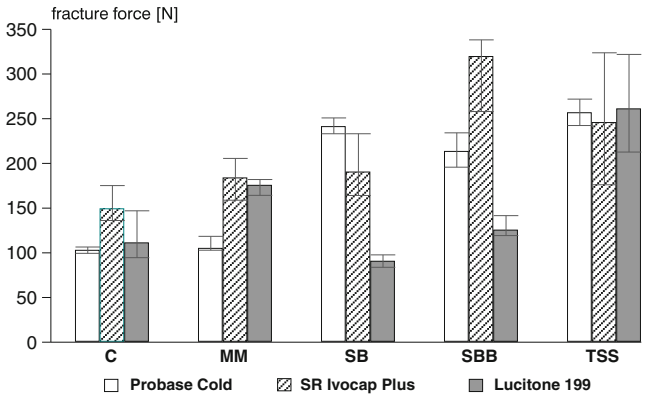

Fig. 3 Results of the fracture test: median, 25% and 75% values of bond

Results

Mann–Whitney *U* test revealed that there were significant differences caused by the effect of surface treatment for each of the three denture base materials ($p \leq 0.05$).

Probase Cold

For Probase Cold, the five different surface-conditioning methods showed mean values between 103 and 257 N. In comparison with control group or MM group, pre-treatment with SB, SBB, or TSS increased bond significantly ($p = 0.000$). No statistically significant differences were shown among surface-conditioning methods SB, SBB, and TSS. Also, there was no statistical significant difference between control group and MM group.

SR Ivocap Plus

SR Ivocap Plus revealed bond values between 149 and 320 N. Pre-treatment of teeth with SBB significantly improved bond compared with control group ($p=0.000$), MM group ($p=0.003$), or SB group ($p=0.005$), and TSS significantly improved bond compared with control group ($p=0.038$). Otherwise, there were no statistically significant differences.

Lucitone 199

Lucitone 199 showed bond values between 91 and 261 N. Surface-conditioning method TSS significantly improved bond over control ($p=0.002$), MM ($p=0.01$), SB ($p=0.00$), and SBB ($p=0.001$). Pre-treatment of the teeth with monomer significantly improved their bond compared with control ($p=0.05$), SB ($p=0.00$), or SBB ($p=0.05$), and SBB showed significant higher bond values than SB ($p=0.001$).

Surface-conditioning method SBB in combination with SR-Ivocap Plus showed highest bond values (320 N). For each denture base material treatment of the teeth with TSS resulted to significantly higher bond values compared to control group. All specimens showed a mixed adhesive/cohesive failure mode (Fig. 4).

Discussion

As discovered by other authors [19], the EN ISO 22112 [6] is not a realistic method for testing bond strength between denture teeth and denture base resin. It measures bond strength in relation to the strength of the denture tooth material and induces cohesive fractures. Therefore, teeth with less mechanical strength pass the test successfully, but only if the fracture form is at least partly adhesive, a valid measurement can be assumed. Therefore, the present study used a more realistic design which leads to a mixed adhesive/cohesive failure mode.

The results of this study showed that bond between denture teeth and denture base resin depends on the used denture base resin and surface-conditioning method. Denture tooth modifications can result in significant differences in bond when highly cross-linked denture teeth are processed with either Probase Cold, Lucitone, or Ivocap acrylic resins.

Without surface conditioning of teeth, the heat-curing denture base resin SR Ivocap Plus showed highest bond values. Injection pressing and high polymerization temperature enhances the diffusion of monomers into the denture teeth, thus increasing the bond strength [8]. Slices from test samples dyed with monomer-solvent dye (Sudan red G) indicate that the monomer of heat-curing polymers penetrates into the expanded tooth material, samples fabricated of cold-curing polymer demonstrate no penetration signs. Using sand blasting+bonding agent or sand blasting with tribochemical coating, SR Ivocap Plus exhibited significantly higher bond. To enhance a possible chemical bond between teeth and denture base resin, the

Table 1 Results of the fracture test: median (25%/75%) values of bond

Fracture force [N]	C	MM	SB	SBB	TSS
ProBase Cold	103 (99/107)	105 (103/118)	241 (233/251)	213 (196/234)	257 (242/272)
SR Ivocap Plus	149 (136/175)	184 (159/206)	190 (164/233)	320 (258/338)	246 (176/324)
Lucitone 199	111 (95/147)	176 (164/182)	91 (84/98)	125 (119/142)	261 (212/322)

Table 2 Mann–Whitney *U* test, *p* values of bond data ($p \leq 0.05$, *=significant differences)

	Probase Cold				SR Ivocap Plus				Lucitone 199			
	MM	SB	SBB	TSS	MM	SB	SBB	TSS	MM	SB	SBB	TSS
C	0.442	0.000*	0.000*	0.000*	0.130	0.065	0.000*	0.038*	0.05*	0.105	0.382	0.002*
MM		0.000*	0.000*	0.000*		0.798	0.003*	0.234		0.000*	0.05*	0.01*
SB			0.279	0.234			0.005*	0.279			0.001*	0.000*
SBB				0.105				0.234				0.001*

tooth surface is enlarged by sand blasting and treated with monomer-based bonding agent. This dissolves part of the PMMA of the tooth and provides free double bonds that may copolymerize with the PMMA of the denture base [20].

Sand blasting with tribochemical coating and silanization leads to a chemical bond between the inorganic silanized surface and an organic resin, corresponding to the chemical bonding of silanized fillers in composites.

The conventional water-bath heat-curing acrylic resin Lucitone 199 showed lowest bond values for the control group and the surface-conditioning method sand blasting and sand blasting+bonding agent. The reason could be because the dough of Lucitone 199 is quite dry, and only poor MMA is available for soaking. As a result, bond increases when monomer is used for surface conditioning of teeth and significantly highest bond was found using sand blasting with tribochemical coating and silanization.

Using the cold-curing denture base resin, Probase Cold surface conditioning with monomer did not increase bond. Due to lack of pressure and low polymerization temperature, there is no diffusion of monomers into the denture teeth; as a result, there is no increase of bond strength. Therefore, mechanical roughening is absolutely required and sand blasting, sand blasting+monomer-based bonding agent and sand blasting with tribochemical coating+silanization improved bond significantly.

The tribochemical silica coating+silanization method displayed equally significant high bond values compared to untreated base surfaces of teeth for all denture base materials. The tribochemical silica coating+silanization method [21] is a well-known state of the art in dental retention-free adhesive bonding technology. Metal, resin, and ceramic surfaces can be coated with a silicatized adhesive layer which ensures durable retention-free bonding to resins. Saavedra et al. [9] also studied bond strength of acrylic teeth with Lucitone resin and determined that tribochemical silica coating+silanization increased bond strength.

Type of denture teeth used can affect the bond when processed to acrylic resins [8, 22]. The denture teeth used in this study were highly cross-linked acrylic resin polymer denture teeth with an added filler of colloidal silica to add strength. Cross-linking is added to the methyl methacrylate denture teeth for strength and abrasion resistance but also results in a decreased chemical bond as compared with acrylic resin denture teeth without cross-linking [13, 23]. Clancy and Boyer [13] reported that heat-cured plastic teeth were 40% higher in bond strength than highly cross-linked methyl methacrylate resin denture teeth.

Conclusions

Within the limits of this in vitro study, the following conclusions were drawn:

1. The failure load of bonding highly cross-linked denture teeth to acrylic resin can be significantly influenced by modifications to the base surfaces of teeth before processing. The highest bond values were observed for the heat-curing resin SR-Ivocap Plus in combination with conditioning method sand blasting+bonding agent.
2. Tribochemical silica coating and silanization method revealed significantly higher bond on each tested denture base material and can be recommended for pre-treatment of teeth applying either heat-cured or cold-cured denture base resin.

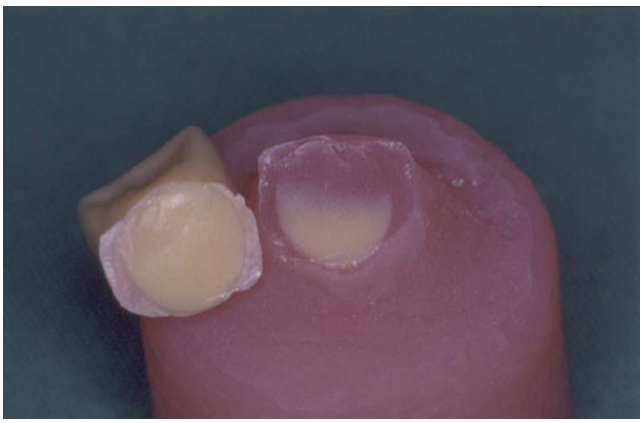

Fig. 4 Mixed adhesive/cohesive failure mode

Conflict of interest The authors declare that they have no conflict of interest.

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