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ORIGINAL ARTICLE

Comparison of Tensile Bond Strength of Four Types of Artificial Teeth to Acrylic Denture Base Under In Vitro Conditions

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Abstract

Background: The detachment of artificial teeth from the denture acrylic base is a significant complication among denture users. This study aimed to compare the tensile bond strength of four types of artificial teeth to the acrylic denture base.

Materials and Methods: This in vitro experimental study investigated 36 samples of four types of artificial teeth: Ivoclar composite, Ivoclar porcelain, Yamahachi, and Maroli. Nine maxillary first premolar teeth from each type were selected. Grooves measuring 3 mm in depth and 2 mm in length were created on the occlusal surface of each tooth, and this surface was embedded in self-cure acrylic up to the CEJ level. The smallest cross-sectional area among the samples was selected as the standard, and all specimens were adjusted to match this area. The primary casts were poured, cylindrical wax models were attached to the specimen bases, and flasking was performed. After replacing the wax with heat-cured acrylic, the final samples were subjected to tensile testing on a universal electromechanical testing machine until failure. Data were analyzed using one-way ANOVA and Tukey's post hoc test ($\alpha = 0.05$).

Results: A statistically significant difference in mean tensile bond strength was observed among the four groups ($P < 0.001$), with Ivoclar composite showing the highest mean tensile bond strength, followed by Ivoclar porcelain, Yamahachi, and Maroli. The percentage of adhesive failures in Ivoclar composite, Ivoclar porcelain, Yamahachi, and Maroli samples was 77.8%, 66.7%, 55.6%, and 77.8%, respectively.

Conclusion: The highest tensile bond strength was observed in Ivoclar composite teeth, followed by Ivoclar porcelain, Yamahachi, and Maroli.

Keywords: Tensile Strength; Artificial Tooth; Denture Bases

Introduction

Although significant advancements have been made in prosthodontic materials and techniques, the detachment of artificial teeth from denture bases remains an ongoing challenge. Tooth separation from the prosthetic base may occur due to trauma, excessive or unfavorable occlusal forces, or inaccuracies during denture laboratory processing. Studies indicate that the most common repair in removable prostheses involves the detachment of artificial teeth from the denture base, and this detachment is the leading cause of failure in implant-supported dentures. The physical and chemical properties of artificial teeth greatly affect the bond strength between the teeth and the denture base resin (1, 2).

Due to the disadvantages of porcelain teeth and the development of various types of resin teeth that offer comparable benefits, the use of porcelain teeth has become more limited. A notable advantage of resin teeth is their ability to chemically bond with the

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denture base, whereas porcelain teeth attach only via mechanical retention (3).

Artificial teeth are available in various materials, including methacrylate-based resins, composite resins, and porcelain, each with distinct advantages and drawbacks. Comparisons between acrylic and porcelain teeth indicate that acrylic teeth chemically bond to the prosthetic base and are easier to adjust (4).

Porcelain teeth have several disadvantages, including brittleness, a tendency to fracture, limited bonding strength, and thermal expansion mismatch with the acrylic base material (5). Furthermore, porcelain teeth may cause localized stress concentration beneath the denture base, which is why acrylic resin teeth are more commonly used in removable prostheses (6).

The physical and chemical properties of artificial teeth play a critical role in enhancing their bond to the denture base resin (4). Physical modifications may include incorporating diatorics at the tooth base or creating ridges on the labial or lingual surfaces. Chemical modifications can involve applying monomer to the tooth base during acrylic packing, complete wax elimination, cleaning with detergents, altering polymer structures, promoting polymerization reactions, or using resin cements (7).

Previous studies have reported varying results regarding the bond strength of artificial teeth to denture base resins, depending on the type of resin, tooth material, and testing methodology. Mohamed et al. (8) and Özer et al. (9) reported that composite teeth exhibit higher bond strength to acrylic base materials compared to acrylic teeth. Conversely, Gharebagh et al. (4) found that acrylic teeth showed higher bond strength than composite ones.

Numerous factors affect the bonding strength of artificial teeth. For instance, the type of artificial tooth plays a significant role in determining the tensile bond strength. The presence of methacrylate monomers in acrylic teeth enhances bonding. Additionally, mechanical retention features such as retentive grooves or diatorics can significantly improve bond strength (10).

The material type of both the artificial teeth and the denture base may influence tensile bond strength. Selecting compatible combinations of artificial teeth and base resin can reduce the rate of prosthetic failure and subsequent repairs (11).

Given the vast array of influencing factors, several studies have evaluated the tensile bond strength of different brands of artificial teeth. Therefore, the present study aimed to compare the tensile bond strength of four types of artificial teeth to an acrylic denture base under laboratory conditions.

Materials and Methods

In this in vitro experimental study, 36 maxillary first premolar artificial teeth from four brands were selected: Ivoclar composite (Ivoclar AG, Switzerland), Ivoclar porcelain (Ivoclar AG, Switzerland), Yamahachi (Yamahachi Dental MFG. Co, Japan), and Maroli (Marola Dental Laboratories Ltd, England). All selected specimens had anatomical and morphological features similar to the standard products of their respective manufacturers. The specimens were randomly divided into four groups of nine. Random allocation into four groups (n=9) was performed using computer-generated randomization to ensure unbiased sample distribution.

Only maxillary first premolars that met standard laboratory preparation criteria were included. Any specimens other than first premolars, or those with non-standard morphology, as well as teeth from brands not included in the study or samples that exhibited defects during any laboratory stage, were excluded.

Grooves measuring 2 mm in length and 3 mm in depth were prepared on the occlusal surfaces of the selected teeth using a fissure bur. Plastic cylindrical tubes (17

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mm long and 8 mm in diameter) were prepared and fixed to a glass slab with wax.

The cylinders were filled with self-cure acrylic resin (Acropars, Marlic Dental Industries Co., Iran). Each prepared tooth was then placed into the acrylic from the occlusal surface, embedded up to the cementoenamel junction (CEJ).

After polymerization, the samples were detached from the glass slab and removed from the plastic tubes. To standardize the bonding surface, the specimen with the smallest cross-sectional area was used as a reference, and a template was created. The same bonding surface area was replicated on the remaining samples using the template and adjusted accordingly(Figure 1).

Figure 1. Artificial tooth specimen after removal from the plastic cylindrical tube

For flasking and wax removal, samples were placed in flasks, and the first layer of gypsum was poured onto the standardized bonding surface. Wax cylinders (8 mm in diameter, 10 mm in height) were attached to the specimen bases. A separating medium (biofilm) was applied to the surface, and the second half of the flask was placed and filled with gypsum. All internal flask surfaces were coated with Vaseline.

The entire flask was placed under 200 Pascal pressure using a hydraulic press for 30 minutes. After the second gypsum layer had set, the flask was immersed in a 100°C water bath for 10 minutes, then gently separated. Melted wax was carefully removed. The mold cavity was coated with a separating medium and filled with heat-cured acrylic resin (Acropars heat-cure acrylic, Marlic Medical Industries Co.). The bonding surface of each tooth was lightly coated with acrylic monomer before flask closure. The flask was placed under 200 Pascal pressure in a hydraulic press for 30 minutes. Then, it was immersed in 20°C water, which was gradually heated to 100°C using a low flame. Samples were heat-cured at 100°C for 30 minutes, then gradually cooled to room temperature (20°C). Finally, the samples were removed from the flask (figures 2, 3, 4, 5).

Figure 2. Dental specimens after pouring the primary maxillary cast.

Figure 3. Wax cylinders attached to the base of dental specimens after pouring the primary cast

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Figure 4. Maxillary cast after removal from the 90°C water bath and wax elimination.

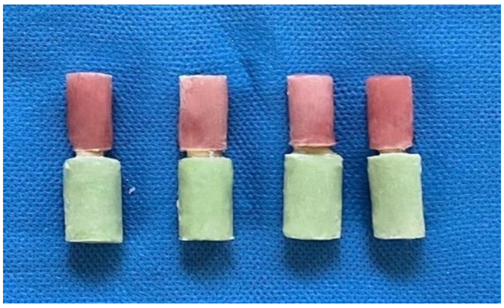

Figure 5. Dental specimens prepared for tensile testing.

The tensile bond strength of the four types of teeth Ivoclar composite, Ivoclar porcelain, Yamahachi, and Maroli—bonded chemically to the heat-cured acrylic base was tested using an electromechanical universal testing machine (K-21046, Walter + Bai, Switzerland). The test was conducted with a 200 N force, a crosshead speed of 1 mm/min, and a preload of 2 N. The device held the lower part of each sample while the upper part, embedded in self-cure acrylic, was subjected to a tensile load. The device stopped automatically upon failure, and for each sample, a force-displacement curve was recorded.

After confirming the normality of the data using the Shapiro–Wilk test, the data were analyzed using one-way ANOVA and Tukey's post hoc test in SPSS version 26. The significance level was set at 0.05.

Results

One-way ANOVA revealed a statistically significant difference in mean tensile bond strength among the four groups ($P < 0.001$). The highest mean tensile strength was observed in the Ivoclar composite group, and the lowest in the Maroli group. The Ivoclar porcelain group ranked second, followed by the Yamahachi group in third place (Table 1).

Table 1. Mean Tensile Bond Strength among the Four Groups

Group	n	Mean±SD (Newton)	P value
Ivoclar Composite	9	194.54±27.21	<0.001
Ivoclar Porcelain	9	180.89±23.41	
Yamahachi	9	112.63±22.69	
Maroli	9	56.71±16.70	

Tukey's post hoc test revealed significant differences between the Ivoclar composite group and the Yamahachi ($P < 0.001$) and Maroli groups, as well as between the Ivoclar porcelain group and both the Yamahachi ($P < 0.001$) and Maroli groups. A significant difference was also observed between the Yamahachi and Maroli groups ($P < 0.001$). However, there was no statistically significant difference between the Ivoclar composite and Ivoclar porcelain groups ($P = 0.528$). (Figure 1)

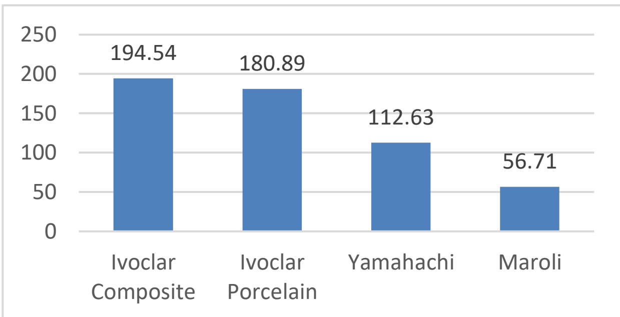

Figure 1. Mean Tensile Bond Strength (Newton)

The distribution of failure modes (adhesive vs. cohesive) among the four groups is shown in Table 2. Fisher's exact test indicated no statistically significant

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association between failure type and type of artificial tooth (P = 0.86).

Table 2. Distribution of Failure Types (Cohesive/Adhesive) Among the Four Groups

Groups	Cohesive Failures n (%)	Adhesive Failures n (%)	P value
Ivoclar Porcelain	3(33.3)	6 (66.7)	0.86
Ivoclar Composite	2 (22.2)	7 (77.8)	
Yamahachi	4 (44.4)	5 (55.6)	
Maroli	2 (22.2)	7 (77.8)	

Discussion

The results of the present study demonstrated that the highest tensile bond strength was observed in Ivoclar composite teeth, followed by Ivoclar porcelain, Yamahachi, and Maroli. Among these, Ivoclar composite teeth exhibited the greatest tensile strength and a higher percentage of cohesive failures, indicating greater structural integrity than the other tested artificial teeth.

The findings of Khaki et al. (12) showed no significant difference in tensile bond strength among the tested samples. In that study, the samples were embedded in acrylic from the lingual surface without standardizing the bonding surface area. Considering that an increased bonding surface area may enhance tensile strength, the lack of significant differences in their study could be attributed to this variation. In contrast, the current study employed standardized bonding surfaces. Additionally, Khaki's samples comprised anterior teeth, whereas the present study used maxillary first premolars, which could have influenced the force application conditions and the resulting outcomes.

Khaki also concluded that due to the lack of significant differences in tensile strength and the prevalence of cohesive failures in all Ivoclar samples, the structural strength of Italian Ivoclar teeth was weakest. In contrast, the current study found higher tensile strength in Ivoclar composite and porcelain teeth than in Maroli and Yamahachi, with cohesive failure rates of 22.2% and 33.3%, respectively. This suggests that Ivoclar composite and porcelain teeth exhibit stronger structural integrity.

In another study by Ghahramani et al. (13), the bond strength of composite and acrylic teeth to both heat-cured and autopolymerized denture bases was evaluated using Ivoclar composite, Ivoclar acrylic, Marjan New, and Glamour brands. Their results revealed no significant differences in bond strength among the groups. Most failures in both types of bases were cohesive, with only 12.5% adhesive. These findings contrast with those of the present study.

One notable procedure in Ghahramani's study was thermocycling, in which specimens underwent 5,000 thermal cycles between 4°C and 55°C, with a 30-second dwell time and a 20-second interval. This process likely enhanced the bond between artificial teeth and the acrylic base, resulting in predominantly cohesive failures. Additionally, they used Selectaplus H heat-cured acrylic (Dentsply, England), whereas the current study used Acropars heat-cure acrylic (Marlic Medical Industries Co.) and did not employ thermocycling.

Schneider et al. (11) assessed the tensile bond strength of four types of artificial teeth to both microwave- and heat-cured acrylic bases. Their results mainly indicated cohesive failures, contrasting with our findings. Schneider (11) conducted testing on the occlusal surface unlike the current study, which tested bonding at the basal surface. Moreover, they applied thermocycling, which might account for these discrepancies. Nevertheless, both studies emphasized that the type of artificial tooth influences bond strength.

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In Kawara et al.'s study (14) on multilithic artificial teeth, all failures were adhesive, which differs from the present findings. The variation may be due to differences in tooth structure and testing methodology. Their results showed that monolithic acrylic teeth had significantly higher bond strength than multilithic teeth, while our study found the opposite.

In another study by Kawano et al. (14), no significant differences were found in bond strength across groups, which is inconsistent with our results.

Rosthamkhani et al. (7) also found no significant differences in tensile bond strength among groups, conflicting with our results. However, the rigorous laboratory preparation, consistent bonding surfaces, and absence of contamination in our study may account for the differences. Conversely, Schneider et al. (11) reported significant differences in tensile strength among groups, aligning with our findings.

According to Jaber Radha et al. (15), integrating SiO_2 nanoparticles into PMMA denture base resin significantly increased tensile bond strength in all concentrations tested (2.5%, 5%, and 7%) in a concentration-dependent manner. The 2.5% concentration was optimal for enhancing shear bond strength and reducing artificial tooth detachment, supporting the role of material modification in improving bond strength.

Conclusion

The type of artificial tooth significantly affects its tensile bond strength to the acrylic denture base. Among the tested specimens, Ivoclar composite teeth exhibited the highest tensile strength, followed by Ivoclar porcelain, Yamahachi, and Maroli. These results indicate that choosing suitable artificial tooth materials can enhance the durability and clinical success of acrylic-based dentures.

Conflict of Interests: The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial, or non-financial in this article

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