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Evaluation of Bond Strength of Acrylic Artificial Teeth with Unreinforced and Nano Silica Reinforced Denture Base Material after Chemical Disinfection

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ABSTRACT

Soaking dentures with disinfection solutions is an effective way of keeping dentures in a healthy status; however, immersions in these solutions have a negative effect on the bond strength of denture base and denture teeth. The aim of this study was to evaluate the bond strength between denture acrylic teeth and heat-cured Poly (methyl methacrylate) denture base material (with and without nano silica) after disinfection with different chemical disinfectants for a simulated period of six months. One hundred specimens of maxillary central incisors attached to PMMA were divided into two groups; 50 specimens of PMMA without nano silica and 50 specimens of PMMA reinforced with 5 wt% of nano silica. Specimens of each group were immersed in five immersion solutions (n=10): distal water (control), Fittydent® cleansing tablets, 4% chlorohexidine, 1% sodium hypochlorite and Dettol personal care solution. Bond strength were carried out in a universal testing machine with crosshead speed of 0.5 mm/min. Data analysis was done using independent sample t-test, one-way ANOVA and Tukey's HSD post hoc test. Results showed that bond strength increased significantly in nano silica groups compared to groups without nano silica. Bond strength decreased in all immersion groups, for both groups of PMMA, but the Dettol group showed the least significant decrease (P>0.05). Reinforcing PMMA denture base with nano silica increased the bond strength with acrylic teeth. Denture tablets, chlorohexidine and sodium hypochlorite decreased the bond strength significantly, while Dettol personal care solution did not significantly reduce bond strength.

Key words: Bond strength, Nano silica, Chemical disinfectants, Immersion

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INTRODUCTION

Denture hygiene plays a fundamental role in the health of the oral soft tissue that supports the denture prosthesis and in keeping the denture in a healthy state. Because dentures are in close contact with oral tissues and food, a biofilm of colonizing microorganisms usually forms causing oral infections and damaging the denture substance as well [1,2].

Patients normally clean and disinfect their dentures for 2 to 4 minutes each day [3]. Immersion of denture in a chemical disinfectant solution for a required period of time is one of the disinfection methods, which is feasible and inexpensive [4]. It has been reported that use of chemical cleansers with mechanical methods was effective in stains removal and in reducing microbial colonization and biofilm formation on the denture surfaces [5,6].

Many types of chemical disinfectants are available such as sodium hypochlorite, chlorhexidine gluconate and commercial tablets. These disinfectants have the capacity to reduce the adhesive of candida on the denture and to inhibit the growth of microorganisms on dental prostheses [7,8].

The daily use of cleansing chemical solutions and mechanical disinfection reduces the service-life of the prosthesis and lead to many problems including weakening the connection between the denture base and denture teeth as disinfection could cause changes in the mechanical and physical properties of acrylic resin denture base and acrylic teeth leading to debonding of teeth [9-11]. For that reason, caution must be taken when selecting the appropriate disinfecting solution to avoid these problems [12].

To minimize the problems of disinfection procedure, many attempts were carried out to improve bonding of denture teeth to denture base material [13]. Mechanical alterations and chemical treatment of the ridge lap surface of the artificial teeth were investigated to

improve bond strength between artificial teeth and denture base [14,15].

On the other hand, an increased attention directed toward the reinforcement of Poly (methyl methacrylate) (PMMA) denture base with metal oxide fillers and fibers to improve its mechanical properties [16-18]. These studies investigated the mechanical aspect of the reinforcement procedure, such as transverse strength, impact strength, hardness and fatigue strength of PMMA.

One study found that adding 5 wt% surface-treated nano silica (SiO_2) to PMMA improved some of its mechanical properties such as transverse strength, impact strength and hardness but there was no mention about bond strength between artificial teeth and denture base [19].

Nano-sized silica has many favorable properties such as its small particle size, active function, its specific surface area is large, and powerful interfacial interaction with polymers, therefore, it has a great potential to improve the properties of polymers [20].

The purpose of this study was to evaluate the bond strength between denture acrylic teeth and heat-cured PMMA denture base material, with and without silane-coated nano silica after disinfection with different chemical disinfectants for a simulated period of six months.

The null hypothesis was neither the addition of nano SiO_2 nor the disinfection would affect the bond strength of teeth with denture base.

MATERIALS AND METHODS

Materials and immersion solutions used in this study are listed in Table 1 and Table 2 respectively.

Study design

One hundred specimens were fabricated in this study. The specimens were divided into two groups:

1. 50 specimens of teeth bonded to acrylic denture base resin without nano SiO_2.
2. 50 specimens of teeth bonded to acrylic denture base resin with 5 wt% nano SiO_2. The weight percentage of nano SiO_2 was selected according to a previous study [19].

Each group was then subdivided into five groups (n=10) according to the immersion solution used:

1. Distilled water (Control).
2. Fittydent® denture cleansing tablets (Tab).
3. Ready supplied 4% Chlorhexidine Gluconate (CHX).
4. Ready supplied 1% Sodium Hypochlorite (NaOCl).
5. Dettol personal care antiseptic (Dettol).

Table 1: Materials used in the study

Product	Manufacturer
Superacryl™ Plus heat-curing denture base resin	SpofaDental a.s., Czech republic
Silicon Oxide nanopowder (silane-coated amorphous SiO_2 nanoparticles of 99.5% purity and average particle size 15 nm)	Mknano, Canada
Major Dent artificial acrylic teeth	Major Dental, Italy
Polywax base plate wax	Bilkim, Turkey
Elite stone (Type 4 dental die stone)	Zhermack, Italy

Table 2: Immersion solutions used in the study

Solution	Manufacturer	Main active ingredients
Distilled water	Almansoor Co. for pharmaceuticals, Iraq	-
Fittydent® super cleansing tablets	Fittydent international GMBH, Austria	Sodium Bicarbonate Sodium Carbonate Peroxyhydrate, Trisodium Phosphate, Potassium Monopersulphate, Sodium Perborate monohydrate
4% Chlorhexidine Gluconate	Almansoor Co., Iraq	Chlorhexidine Digluconate
1% Sodium Hypochlorite	Babel Co. for detergents, Iraq	Sodium Hypochlorite
Dettol personal care antiseptic	Reckitt Benckiser Arabia FZE, UAE	Benzalkonium Chloride, disodium EDTA, Isopropyl Alcohol

Specimen preparation

Specimens were fabricated with dimensions in accordance to the Japanese Standard for acrylic teeth (JIST 6506, 1989) [21]. Maxillary right central incisors with same size and shade were selected for this study. A custom-made mold was used to fabricate the wax pattern [22]. The mold consisted of a metal tube with inner dimension of 12 mm in diameter and 35 mm in height, two plastic rings to fit the outer dimension of the metal tube on both ends and a plastic rod to pass through the plastic rings and meet the inner cylinder of the metal tube at a 45° angle (Figure 1). The inner cylinder was brushed with a separating medium and let aside to dry. Base plate wax was then melted and poured in the inner cylinder and the tooth was imbedded in the wax up to the cervical neck area with the labial surface touching the plastic rod. This ensured that the tooth was embedded in the wax at a 45° angle (Figure 2). Excess wax was removed with a wax knife. Wax pattern was left in the mold to harden at room temperature and then removed (Figure 3).

Wax patterns were invested in metal flasks with dental die stone using conventional flasking technique for complete denture. Elimination of wax was done in a water bath. Stone molds were left to dry and then brushed with a separating medium. For specimens of acrylic resin without nano SiO_2, acrylic powder and

liquid were mixed, packed and polymerized according to manufacturer's instructions. For specimens with nano SiO_2, the silane-coated nano SiO_2 powder was first weighed (1.1 g) and then mixed with the acrylic liquid (10 ml) in an ultrasonic probe (Soniprep 150, MSE (UK) Ltd, United Kingdom) for 3 minutes at 120 W and 60 KHz [23]. The acrylic powder (22 g) was then added to the mixture and the process of packing and polymerization proceeded as recommended by the manufacturer. All specimens were finished, polished and store in distilled water for 48 hours at room temperature.

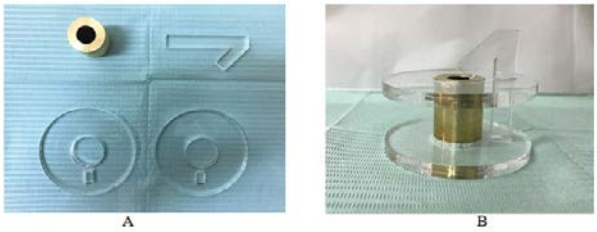

Figure 1: Custom-made mold for wax pattern, (A) unassembled, (B) assembled

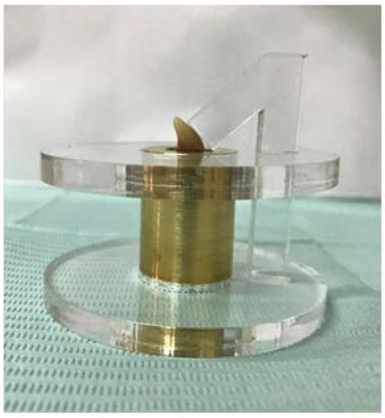

Figure 2: Fabrication of wax pattern

Figure 3: Wax pattern

Immersion procedure

Fittydent® tablets were prepared according to manufacturer's instructions. One tablet was dissolved in a container containing 200 ml of warm water (40°C). Each of chlorohexidine, NaOCl and Dettol solution was poured into a separate container. Specimens were randomly divided and immersed in the disinfecting solutions for 5 minutes. The immersion cycle was repeated for 180 times to simulate 6 months of daily disinfection procedure [24]. After each cycle the specimens were rinsed under running tab water, the disinfecting solutions were discarded, and fresh solutions were prepared for the next cycle. Specimens were stored in distilled water at room temperature if the immersion procedure was not carried out.

Bond strength testing

Before testing procedure, the cross section area at the neck of the tooth was calculated. To simulate occlusal forces, load should be applied on the incisor third of the tooth. To ensure standardization of testing procedure, a line was drawn on the palatal surface of the tooth at a distance of 1 mm away from the incisal edge. Specimens of control group were tested immediately after 48 hours in distilled water. Specimen was mounted on a universal testing machine (WDW-20, Laryee Technology Co. Ltd., China) and load was applied on the drawn line with a crosshead speed on 0.5 mm/min (Figure 4). The bond strength (in MPa) was calculated by dividing the maximum force at break on the cross section area.

Data Analysis was done using independent sample t-test, one-way ANOVA and post hoc Tukey's HSD (honest significant difference). P value of ($P>0.05$) was considered statically non-significant (N.S.), $P \leq 0.05$ was considered significant (S.) and $P<0.01$ was considered as highly significant (H.S.).

Figure 4: Bond strength testing

RESULTS

The mean values of bond strength for all study groups are presented in (Figure 5). All groups with nano silica showed higher mean values than that of groups without nano silica. Control group for acrylic without and with nano silica showed higher mean value than groups

of immersion solutions (7.484 MPa and 8.23 MPa respectively). All immersion groups showed a reduction in mean value of bond strength when compared to the control groups. For acrylic without nano silica group, the lowest mean value was the Tab group (6.474 MPa) while for acrylic with nano silica, the lowest mean value was the CHX group (7.246 MPa).

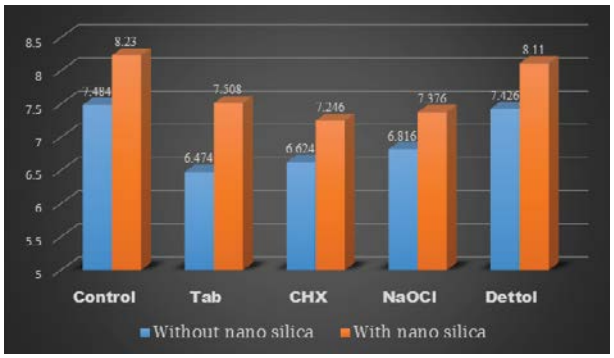

Figure 5: Bond strength mean values of all study groups

Independent sample t-test was performed to determine the significance of the difference between the mean value of acrylic without nano silica and that of acrylic with nano silica in each immersion group. There was a highly significant increase (P<0.01) in mean value of nano silica group compared to that of without nano silica in each immersion solution (Table 3).

For acrylic without nano silica group, One-way ANOVA test showed there was a highly significant difference between immersion groups (P<0.01) (Table 4).

A Post hoc Tukey's HSD (honest significant difference) test was conducted for multiple comparisons between immersion groups within acrylic without nano silica group. There was a highly significant difference between all immersion groups (P<0.01) except for the difference between control group and Dettol group and between Tab group and CHX group which was non-significant (P>0.05), and the difference between CHX group and NaOCl group was significant (P<0.05) (Table 5).

One-way ANOVA test revealed that there was a highly significant difference between immersion groups (P<0.01) within acrylic with nano silica group (Table 6).

Tukey's HSD test for multiple comparisons between immersion groups within acrylic with nano silica group showed that there was a highly significant difference between all immersion groups (P<0.01) except for the difference between control group and Dettol group, Tab group and NaOCl group, and CHX group and NaOCl group was non-significant (P>0.05) (Table 7).

DISCUSSION

According to the results of the study, the null hypothesis was rejected because both nano SiO_2 and chemical disinfection solutions affected the bond strength of artificial teeth with acrylic denture base.

Acrylic resin teeth are more common to use with acrylic denture than porcelain teeth because of their chemical bonding property and the ease of adjustment for occlusal correction [25,26]. Other advantages of resin teeth are high resilience, resistance to thermal changes and less susceptible to impact fracture than porcelain teeth [27]. However, one of the major concerns in clinical prosthodontics is debonding of resin teeth from denture base at the teeth-base interface. It has been reported that about 22% to 30% of repair cases involved teeth detachment, mainly in the anterior region [28,29].

Table 3: Descriptive statistics and independent t-test for all study groups

Immersion solution	Acrylic	N	Mean	Std. Deviation	Std. Error	t-test P value (Sig.)
Control	Without nano silica	10	7.484	0.102	0.045	0.000 (H.S.)
	With nano silica	10	8.23	0.068	0.03	
Tab	Without nano silica	10	6.474	0.101	0.045	0.000 (H.S.)
	With nano silica	10	7.508	0.132	0.059	
CHX	Without nano silica	10	6.624	0.079	0.035	0.000 (H.S.)
	With nano silica	10	7.246	0.101	0.045	
NaOCl	Without nano silica	10	6.816	0.104	0.046	0.000 (H.S.)
	With nano silica	10	7.376	0.086	0.038	
Dettol	Without nano silica	10	7.426	0.082	0.036	0.000 (H.S.)
	With nano silica	10	8.11	0.055	0.024	

Table 4: One-way ANOVA for acrylic without nano silica group

Acrylic		Mean Square	F	P value (Sig.)
Without nano silica	Between Groups	1.077	119.912	0.000 (H.S.)
	Within Groups	0.009		

Table 5: Post hoc Tukey's HSD test for comparison between immersion groups within acrylic without nano silica group

Acrylic	Immersion groups		Mean Difference	Std. Error	P value (Sig.)
Without nano silica	Control	Tab	1.01	0.059	0.000 (H.S.)
		CHX	0.86	0.059	0.000 (H.S.)
		NaOCl	0.668	0.059	0.000 (H.S.)
		Dettol	0.058	0.059	0.866 (N.S.)
	Tab	CHX	-0.15	0.059	0.130 (N.S.)
		NaOCl	-0.342	0.059	0.000 (H.S.)
		Dettol	-0.952	0.059	0.000 (H.S.)
	CHX	NaOCl	-0.192	0.059	0.032 (S.)
		Dettol	-0.802	0.059	0.000 (H.S.)
	NaOCl	Dettol	0.61	0.059	0.000 (H.S.)

Table 6: One-way ANOVA for acrylic with nano silica group

	Acrylic	Mean Square	F	P value (Sig.)
With nano silica	Between Groups	0.996	115.328	0.000 (H.S.)
	Within Groups	0.009		

Table 7: Post hoc Tukey's HSD test for comparison between immersion groups within acrylic with nano silica group

Acrylic	Immersion groups		Mean Difference	Std. Error	P value (Sig.)
With nano silica	Control	Tab	0.722	0.058	0.000 (H.S.)
		CHX	0.984	0.058	0.000 (H.S.)
		NaOCl	0.854	0.058	0.000 (H.S.)
		Dettol	0.12	0.058	0.283 (N.S.)
	Tab	CHX	0.262	0.058	0.002 (H.S.)
		NaOCl	0.132	0.058	0.204 (N.S.)
		Dettol	-0.602	0.058	0.000 (H.S.)
	CHX	NaOCl	0.13	0.058	0.216 (N.S.)
		Dettol	0.864	0.058	0.000 (H.S.)
	NaOCl	Dettol	-0.734	0.058	0.000 (H.S.)

Bonding of resin teeth to denture base depends on the reaction of the polymer at tooth-denture base interface to form an interlaced polymer network [30]. This occurs when monomer from denture base swell into the polymer of resin teeth [31]. Disinfection solutions cause debonding of resin teeth by altering this interface polymer network [10].

Addition of surface treated nano silica to PMMA denture base has showed improvement in the properties of polymer [32]. For this reason, this study was designed to investigate the effect of silane-coated nano silica on bond strength of resin teeth and resin denture base after disinfection procedure.

The results of this study revealed that nano silica highly increased bond strength values in all disinfectants groups. This can be explained by the action of silane coupling agent on the surface of nano silica. Silanes can form a bond between organic and inorganic materials because they have two different functional groups in their chemical structure; one group can react with inorganic substances such as ceramics and the other react with organic materials like resins. A general formula for a functional silane coupling agent is $X-(CH_2)_n-Si-(OR)_3$, where X is an organo-functional group that reacts with an organic resin, $-(CH_2)_n-$ is a linker group, and -OR is an alkoxy group. The alkoxy groups are activated by hydrolysis ($\equiv SiOR \rightarrow \equiv SiOH$) before they react with the surface hydroxyl groups of the substrate [33,34]. This fact increased the chemical bond of the interfacial polymer network thus improving the bond strength of teeth with denture base.

The second possible explanation of the increased bond strength with the addition of nano silica is due to the hydrophobicity of the silane coupling agent which made the polymer absorb less water [35]. Absorbed water acts as a plasticizer in the resin [36,37] and it adversely affects the bond at the interface of resin teeth and resin denture base [38,39].

Based on the results of this study, Fittydent® cleansing tablets, 4% chlorohexidine gluconate and 1% sodium hypochlorite significantly deceased bond strength of artificial teeth with denture base. Chemicals contained in these denture cleansers have plasticizing effect. When dentures are immersed in these chemicals, they are absorbed and diffused into the polymer chains causing loosening of these chains and consequently affect bond strength [40,41].

Fittydent® cleansing tablets contain Sodium Carbonate Peroxyhydrate and Sodium Perborate which decompose in water and form an alkaline peroxide solution. The peroxide solution has mechanical cleaning function through the release of oxygen bubbles when the tablets dissolved in water [42]. This phenomenon could affect the bond strength at toot-denture base interface.

Chorine-containing cleansers, such as sodium hypochlorite and chlorohexidine, cause the release of plasticizers from resin polymers when immersed in these solutions affecting its bond strength with artificial teeth [43,44].

The least effect on bond strength in this study was seen with Dettol personal care antiseptic solution. This could be explained by the chemical inertness of its constituents.

One of the limitations of this study includes the accurateness of wax pattern fabrication procedure. The excess wax at the tooth neck area should be removed with extreme care. Any leftover wax could affect the bond strength value. Another limitation is the mode of debonding (Cohesive or adhesive) was not investigated in this study so further studies must be conducted to analyze the debonding type. As a suggestion for further studies, the effect of mechanical cleaning in addition to immersion disinfection on bond strength can be studied. Other types of reinforcing filler can be considered for future studies.

CONCLUSION

Within the limitations of this study, the following conclusions can be drawn:

1. The addition of silane-coated nano silica powder to PMMA denture base significantly increased the bond strength with acrylic resin teeth.

2. Immersion with Fittydent® cleansing tablets, 4% chlorohexidine gluconate and 1% sodium hypochlorite for a simulated period of six months significantly reduced the bond strength of artificial teeth with denture base (with and without nano silica).

3. Dettol personal care antiseptic solution can be used as a disinfectant for PMMA denture base without jeopardizing bond strength with artificial teeth.

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