Original Article

Effect of Nanosilver on Thermal and Mechanical Properties of Acrylic Base Complete Dentures

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Abstract

Objective: Polymethyl methacrylate (PMMA), widely used as a prosthodontic base, has many disadvantages, including a high thermal expansion coefficient and low thermal conductivity, a low elasticity coefficient, low impact strength and low resistance to fatigue. This study aimed to make an in vitro comparison of the thermal conductivity, compressive strength, and tensile strength of the acrylic base of complete dentures with those of acrylic reinforced with nanosilver.

Materials and Methods: For this study, 36 specimens were prepared. The specimens were divided into three groups of 12; which were further divided into two subgroups of control (unmodified PMMA) and test (PMMA mixed with 5 weight% nanosilver).The results were analysed by Independent t-test.

Results: This study showed that the mean thermal conductivity and compressive strength of PMMA reinforced with nanosilver were significantly higher than the unmodified PMMA ($P<0.05$), while the tensile strength decreased significantly after the incorporation of nanosilver ($P<0.05$).

Conclusion: Considering our results suggesting the favorable effect of silver nanoparticles on improving the thermal conductivity and compressive strength of PMMA, use of this material in the palatal area of maxillary acrylic resin dentures is recommended.

Key words: Polymethyl methacrylate (PMMA); Nanosilver; Thermal conductivity; Compressive strength; Tensile strength

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INTRODUCTION

Appropriate aesthetics and desirable characteristics of acrylic resin make this material a good candidate for prosthodontic applications. This material presents excellent aesthetic properties; it has adequate strength, low water sorption, low solubility and low thermal conductivity and is free from toxicity [1]. It can reproduce surface details accurately and can be easily repaired. Although the properties of this material are not ideal in every respect, the abovementioned desirable features account for its popularity. However, it has limitations including a high thermal expansion coefficient, low thermal conductivity, a low elasticity coefficient, low impact strength, and low resistance to fatigue [2-5].

Several researchers have demonstrated that PMMA can show good fatigue behaviour and impact strength when it is reinforced by carbon fibers [3, 6, 7]. Also, polyethylene and sapphire fibers seem to enhance the physical properties of acrylic resin. Furthermore, physical and mechanical properties of acrylic resin, such as flexural modulus, can also be improved using metal fibers [3, 8]. For instance, the incorporation of silver, copper, and/or aluminium in the form of powder into the resin was found to improve its thermal conductivity, polymerization shrinkage, and water sorption [3, 8, 9]. Recently, autopolymerizing polymethyl methacrylate resin was reinforced with silane-treated glass fibers; which increased the strength of the resin [3].

Flexible resins can be considered as an alternative to conventional acrylic resins in the construction of dentures due to their advantages in terms of aesthetics and comfort. Therefore, numerous studies have been conducted to study the physical and mechanical properties of these materials [1].

Regarding the increasing advancements in nanotechnology in terms of adding nanosilver particles to an acrylic base, the use of nanosilver particles has been preferred to silver powder because the nanoparticles cause better processing and smoother surfaces than the silver powder [10].

To the authors' knowledge, to date there has not been any conclusive study about the effect of the addition of nanosilver particles to the acrylic denture base on its thermal conductivity, compressive strength and tensile strength. This study aims to assess these parameters.

MATERIALS AND METHODS

This experimental study was performed at the Prosthodontic Department of the Tabriz University College of Dentistry. To determine the sample size, we used the results of Ebadian et.al. study [11]. Considering the estimated thermal conductivity of acrylic resin (similar to the acrylic resin used in this study) to be 12.16 ± 0.7, α=0.5, power of 80%, and one unit of thermal difference, the ideal sample size was calculated to be 6 for each group in a total of 18 cases. Each group was then divided into two subgroups:

Group A as the control group, with unmodified PMMA, or pure acrylic resin powder (Triplex, Ivoclar Vivadent AG, Lichtenstein, Germany); and

Group B as the test group, with PMMA mixed with 5 weight% nanosilver (Model number: SP-A00601, Iran).

Although previous studies have been conducted on metal fillers including tin, Al2O3, copper, and silver with weight percentages of 5%, 15%, and 20%, we used 5 weight% of nanosilver in order to minimize the probable unfavourable changes in mechanical and chemical properties of the denture acrylic base. The proportional amounts of acrylic resin powder and nanosilver (model no: SPA00601, Iran), determined by weighing with a digital scale, were mixed in an amalgamator to achieve a homogenous mixture of PMMA and nanosilver powder.

The specimens were prepared by processing and flasking according to the manufacturer's instructions. The specimens were the same size, and were thoroughly processed using Emery paper with very fine particles. The size of all specimens was measured by a micrometer with an accuracy of ±0.01mm.

The specimens had one of two shapes. Some were cylindrical with dimensions similar to those of thermal conductivity measurement apparatus (Figure 1). These cylindrical specimens were used for the assessment of thermal conductivity and compressive strength.

The cylindrical specimens had a length of 38 cm and a diameter of 25 cm (Figure 1). For the preparation of these samples, cast iron flasks with the same shape and internal dimensions as the standard sample were produced.

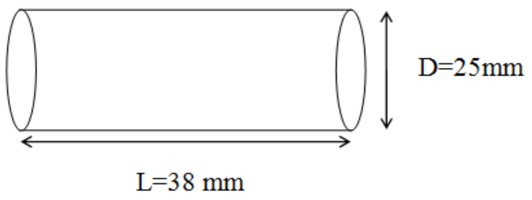

Fig 1. Schematic view of the thermal conductivity measurement apparatus.

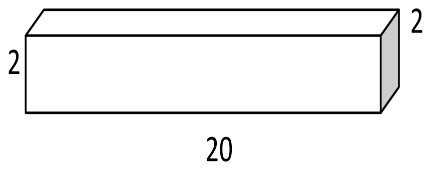

Fig 2. Standard schematic drawing of the tensile strength test measurement apparatus.

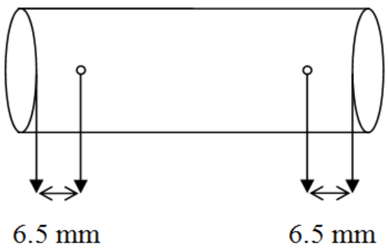

Fig 3. Drilling points of the cylindrical specimens.

To prepare the cylindrical samples, PMMA powder and the heat-cure monomer were mixed.

The inside of the muffle was lubricated with Vaseline. PMMA paste was placed inside the muffle, and it was overfilled a bit. A piece of special cellophane paper was placed on the paste surface, and the muffle door was inserted in place and tightened by screws.

The muffle and PMMA complex were placed under the pressure apparatus, with pressure equalling 1.5 pounds to prevent bubble or void formation within the samples and to establish a PMMA paste with the same interior surfaces as the muffle. Then, the muffle was heated. After cooling, the flask was opened and the sample was removed.

As mentioned, the samples were measured using a high-accuracy (±0.01µm) device. Then, they were processed using Emery paper in order to remove any possible surface roughness or surface bubbles. These samples were used to test thermal conductivity and compressive strength.

The alternatively shaped specimens were rectangular, with dimensions of 2 cm by 20 cm by 200 cm (Figure 2).

These were used to assess the tensile strength. The specimens of this shape were also flasked and heated in prepared muffles, similar to the cylindrical samples.

Stage 1: Measurement of the thermal conductivity rate of the specimens

The cylindrical specimens were drilled by a hand-piece fissure bur to make two holes, each with a diameter of 1 mm, at a distance of 6.5 mm from the two ends (Figure 3).

Then, the samples were inserted in the thermal conductivity measurement apparatus (Cusson's Thermal Conductivity Apparatus, England, Figure 4).

The apparatus had two thermocouple systems that entered into the two holes in the specimens. The water flowed through the two openings of the specimens, and the difference of temperature at the two points was measured by a thermometer attached to the apparatus.

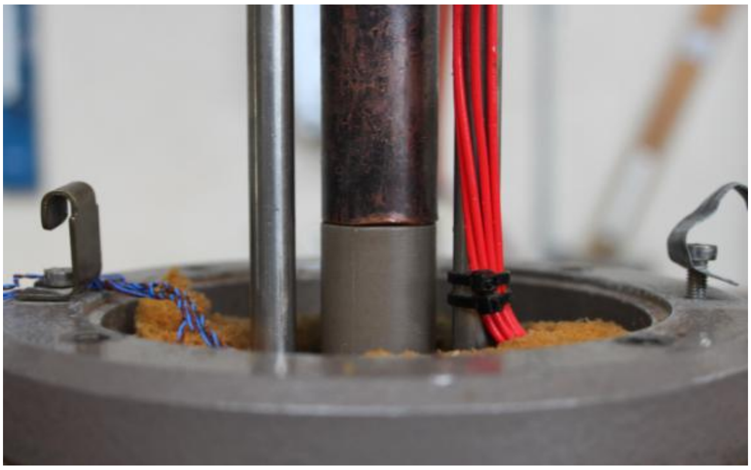

Fig 4. Thermal conductivity measurement apparatus with the cylindrical specimen

Fig 5. The compressive strength measurement apparatus with a cylindrical specimen

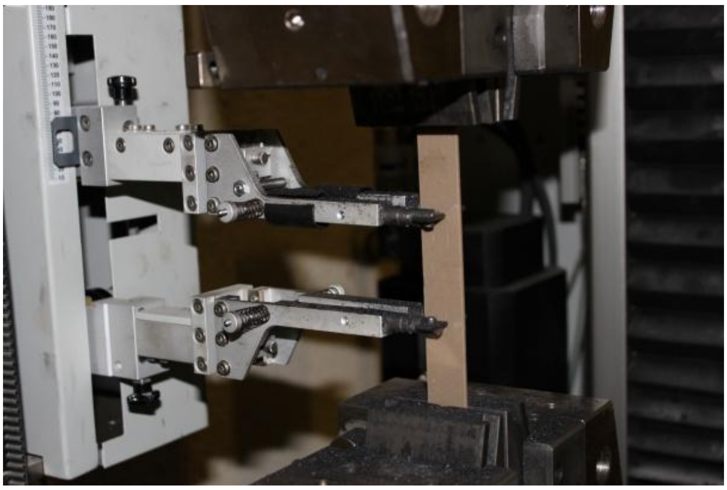

Fig 6. The universal tensile strength measurement machine with a rectangular specimen

Then, according to the measured parameters, the thermal conductivity coefficient (K) of the specimens was calculated using the following formula:

$$K = \frac{j \times M \times L \times (T_2 - T_1)}{A \times t \times (t_2 - t_3)}$$

where t = time of water flow, A = section area, L = length of the specimen, M = water volume, j = mechanical equivalent of temperature which is 0.186 j/kcal, t_2 = temperature of the cold extremity, t_3 = temperature of the warm extremity, T_1= temperature of the water upon entrance, and T_2=temperature of the water upon exit. At this phase, both the control group (PMMA) and the test group (PMMA+ 5% of nanosilver by weight) of the cylindrical samples were tested, and the thermal conductivity coefficient for each group was determined.

All measurements were made at one time in order to reduce the confounding factors. The abovementioned apparatus measured the thermal conductivity coefficient of different materials in relation to standard cylindrical specimens made of copper (Cu).

The standard samples (i.e., those specimens made of copper) were placed in one side, and the measurable samples were inserted in a special site on the other side.

Stage 2: Measurement of the compressive strength of the specimens

The cylindrical specimens were inserted in related points in the compressive strength measurement apparatus, the Dark device, as shown in Figure 5, and were fixed by levers.

The apparatus exerted increasing compressive force on two sides of the specimens until the specimens broke; the force at the time of breakage was transferred to the computer and analysed. The compressive strength of the sample, displayed on the apparatus monitor, was recorded. The samples used in the compressive strength test were cylindrical samples with dimensions of 38 mm by 25mm, just like the samples used in the thermal conductivity test. However, these samples were not perforated.

Stage 3: Measurement of the tensile strength of the specimens

The rectangular specimens were inserted in relative points on a universal tensile strength measurement machine, Zwick Z100, as depicted in Figure 6, and were fixed by levers.

The apparatus exerted increasing tensile force on two sides of each specimen until the specimen broke; and the load at the time of fracture was recorded as it appeared on the apparatus monitor.

Table 1. Comparison of thermal conductivity, tensile and compressive strengths of control and test groups

	Group	N	Mean	Std. Deviation	Independent t-test		
					t	**df**	**P value**
Thermal conductivity	**Control**	6	0.63	0.00	-12.74	10	0.00
	Test	6	0.65	0.00			
Tensile strength	**Control**	6	60.12	0.26	46.53	10	0.00
	Test	6	52.20	0.32			
Compressive strength	**Control**	6	102.16	0.53	-50.64	10	0.00
	Test	6	121.19	0.75			

This machine has one fixed arm and one mobile arm which move to generate force against the sample. The control samples were placed in the machine first, and were fixed at one end. The device exerted increasing tensile force on the other end of the specimen until the specimen broke.

Then, the tensile strength exerted at the time of fracture was recorded as it appeared on the apparatus monitor. After examining the control group samples, the test group samples were studied, and the tensile strength at the time of fracture was also recorded.

RESULTS

Table 1 shows the results of independent t-test for assessing the effect of nanosilver on the thermal conductivity, tensile strength and compressive strength of polymethyl methacrylate. The results showed that:

The test group had significantly higher thermal conductivity than the control group.

The test group had significantly lower tensile strength than the control group.

The test group had significantly higher compressive strength than the control group.

DISCUSSION

Although previous studies have been conducted on metal fillers including tin, Al2O3, copper, and silver with weight percentages of 5%, 15%, and 20%, we used 5% weight of nanosilver in order to minimize the probable unfavourable changes in mechanical and chemical properties of the acrylic base of the denture. Since Polymethyl methacrylate (PMMA) shows excellent appearance, ease in processing, and reparability, it can be considered as an excellent currently available denture base material, which is most commonly used for the fabrication of complete dentures. Therefore, it is used broadly in prosthetic dentistry [2, 3, 12, 13]. However, its application is restricted due to its relatively poor thermal and mechanical properties [13-16]. Some inherent disadvantages of PMMA are its low thermal conductivity (5.7×10-4oc/cm2), which is three times lower than that of metals [17] and patient (especially first-time users) dissatisfaction [3,18]. Furthermore, its high coefficient of thermal expansion causes the release of internal stress, resulting in dimensional inaccuracy and a relatively low modulus of elasticity, leading to rapid deformation at low stress [3]. Mucosal irritation caused by the release of PMMA has also been reported [1, 19].

Three different procedures have been considered in order to improve the impact properties of PMMA.: (1) development of an alternative material to PMMA; (2) chemical modification of PMMA by creating transverse bands or by adding a rubber graft copolymer and (3) reinforcement of PMMA with other materials such as carbon fibers, glass fibers, and ultra-high modulus polyethylene, tin, or aluminium [3,13]. PMMA demonstrates poor strength characteristics. Hence, its low impact and flexural strength should be improved when it is used in the acrylic resin prosthesis [3, 13]. Reinforcing the resin can be assumed as a solution in this regard [12]. A durable repair approach for denture base fracture is desired in order to avoid recurrent fracture [12].According to several research studies, patient acceptance of denture prostheses can be affected by physical properties of denture base materials [12, 13, 17, 20]. Thermal conductivity is an important material property in determining gustatory response. Denture base acrylic resins have low thermal conductivity as compared with denture base metal alloys [20]. The thermal conductivity of the denture base also plays an important role in parotid gland secretory function, and in gustatory and digestive responses to thermal changes of hot and cold foods in the mouth. The secretory function of the parotid gland increases with an increase in palatal tissue temperature [17]. It has been shown that the thermal conductivity of denture base acrylic resin increases by the addition of 15 volume% of thermally conductive sapphire (Al2O3) whiskers [20].

PMMA used in prosthodontics is a relative insulator. Different materials such as metal fillers and ceramics have been used to solve this problem. Mixing the acrylic resin with Al_2O_3 at two different weight percentages (15 wt% and 20 wt%) significantly increased the thermal conductivity and the rate of acrylic base warming [11].

Because of the low thermal conductivity of PMMA (5.7×10^{-4}oc/cm2) and the acrylic resins used in dentures, fillers of various metals including silver (with a thermal conductivity of 1000oc/cm2) [18], aluminium, and copper particles have been used at various weight percentages for increasing the thermal conductivity of acrylic resins [11,21-23]. Sehajpal and Sood [22] showed that the thermal conductivity of PMMA can be increased by 4.53, 4.43, and 4.04 times, respectively when fillers of silver, aluminium, and copper particles at 25% concentration are added to PMMA [22]. Nanosilver particles were applied in the present study to increase the thermal conductivity of the acrylic resin. This choice was initially made because of silver's (Ag) higher thermal conductivity, as mentioned above.

Recently, there have been advancements in the production of heat conductor ceramics such as sapphire (Al_2O_3), silicon nitride, boron nitride, and aluminium nitride, which all have thermal conductivity levels close to those of metals. Therefore, they have been used as fillers in acrylic resin powders, due to their advantages of having high thermal conductivity, as well as low density and white colouring; which have the least effect on denture base appearance [20].

Marei et al. [3] have stated that the thermal conductivity, impact strength, compressive strength, and warping of PMMA could be improved when 5 volume% of these metal powders is added to PMMA. Tin powder was superior to aluminium powder in improving the impact and compressive strength of PMMA; while aluminium powder was superior to tin powder in improving the thermal conductivity of PMMA (44% vs. 31%, respectively) and decreasing its warping. Therefore, it can be concluded that physical and mechanical properties of PMMA will be improved by using metal-filled resin.

Messersmith et al. added sapphire (Al_2O_3) to conventional denture base acrylic resin at 9.35 volume% and 15 volume%. The thermal conductivity and transverse strength of the sapphire-containing composites were significantly higher than those of the unmodified acrylic resin [20]. Thermal conductivity was found to depend on the volume percentage of cylindrical fillers, as well as on the innate conducting properties of Al_2O_3, denying the role of spherical fillers in increasing the thermal conductivity [20]. The findings of the present study suggest that spherical fillers can also significantly increase the thermal conductivity of PMMA, because the nanosilver particles have a spherical shape [21].

Overall, thermal conductivity, as one of the most important characteristics of the denture base, plays a major role in the secretions of salivary glands and enzymes, the taste of the food, and the gustatory response [11, 20].

Adding 5 wt% to 20wt% of aluminium oxide powder (Al_2O_3) filler increases the flexural strength and thermal conductivity of heat-polymerized acrylic resin [11, 23]. The addition of silica to PMMA denture base materials does not produce a significant improvement in the transverse bend or impact strength of the dentures, as compared to conventional heat-cured acrylic resins [24]. According to Nagai [25], transverse strength and the modulus of elasticity in repaired acrylic specimens are improved when reinforcement with glass fibers and pretreatment with methylene chloride are performed. The transverse and impact strengths of heat-polymerized denture base resin were also increased when metal wire and glass fibers were utilized as reinforcements [12, 13]. Moreover, the flexural strength of specimens reinforced with continuous unidirectional glass fibers was significantly higher than that of metal wire or woven fiber reinforcements [12]. However, using zirconium powder as reinforcement for high-impact acrylic resin increased the transverse and impact strengths of the resin significantly [26]. The compressive strength of PMMA increased with the addition of silver, aluminium, and copper fillers, while the tensile strength decreased [22]. The disadvantages of metal-filled acrylic resin include heavy weight, relining problems, decreased tensile strength, increased density, and cosmetic problems [22].

Vallittu [27] and Vallittu and Lassila [28] showed that the bonding of metal wire to acrylic resin enhanced the fracture resistance of specimens; while the different positions of the wires had no effect on the fracture resistance [27, 28].

Some researchers have used various metal wires for this purpose, including aluminium and aramid, and concluded that these additions enhanced the fracture resistance of the acrylic base [11, 20]. Their findings regarding the reinforcement of compressive strength are compatible with our results. Kemp et al. [29] showed that glass fiber reinforcement significantly enhanced both the flexural strength and the flexural modulus of PMMA.

Another restriction of PMMA application is due to its low fracture resistance, which should be improved when it is going to be utilized as denture base material [30]. Various methods have been used to reinforce acrylic denture base material in order to repair fractures in complete dentures. PMMA can be generally reinforced by metal wires and plates. Using metal wires as reinforcement increases the transverse strength of the PMMA. Nevertheless, reinforcement of PMMA by metal plates showed insignificant effect on the transverse strength of the restoration [30-34].

Macroscopic retention of the metal strengtheners to the PMMA had only a minor effect on its strength, in contrast to microscopic retention, which had a marked effect. Chemical bonding between the PMMA and the metal reinforcement has been shown to enhance the strength of the prosthesis, with some exceptions [31]. Heat-polymerizing acrylic resin has been the most common denture base material for more than 60 years.

However, the mechanical strength of acrylic resin is not sufficient to maintain the longevity of dentures. One frequent problem that occurs with denture bases is fracture caused by such factors as poor fit of the denture base, poorly balanced occlusion, and stress on the denture base after years of use [25, 32, 33].

John et al. [30] performed an in-vitro study to determine whether the flexural strength of conventional acrylic resin is less than that of the same resin when reinforced with glass, aramid, or nylon fibers. All reinforced specimens showed better flexural strength than the conventional resin.

Flexural strength was improved when the acrylic resin was reinforced by different fibers. In this regard, acrylic resin showed the highest flexural strength when glass fibers were used as reinforcement in comparison with acrylic resin reinforced by aramid and then nylon. Also, the conventional acrylic resin showed the lowest strength.

The incorporation of nanosilver (antibacterial agent) in denture base resin can inhibit oral pathogens from colonizing on the denture base and keep dentures clean, though it had no significant influence on the mechanical properties of denture base resin [34]. After culturing for 24 hours, 75% of Streptococcus mutans and 49% of Candida albicans were inhibited separately [34].

Considering the use of 5 wt%, 15wt%, and 20wt% aluminium oxide, copper, and silver powder in recent studies [3, 11, 20, 23], this study was performed using 5 wt% nanosilver in order to minimize the probable adverse effects on the mechanical and chemical properties of the acrylic base. We found unfavourable brownish discoloration of the dentures to be the most significant problem with this low percentage of nanosilver powder.

The other reason for choosing such low percentage of nanosilver was to significantly lower the patient costs for the dentures containing nanosilver particles. Adding 5 wt% of nanosilver powder to PMMA improved its thermal conductivity. This improvement was probably due to the uniform distribution of metal particles within the PMMA. To reach this goal, the nanosilver and acrylic powders were poured into an amalgamator mixer to mix the fine particles and produce a uniform mixture. In similar studies, adding 5 wt% of silver, copper, and aluminium to PMMA improved its thermal conductivity, although it decreased its tensile strength [22, 35].

In Sehajpal and Sood's study, adding silver, aluminium and copper droplets by 5 volume% increased the compressive strength of the denture base by up to 2.5%; while increasing the particle ratio to 20% was associated with greater increase in compressive strength [22]. Marei et al. increased the compressive and impact strengths of the denture base by adding metal (aluminium and copper) droplets by 5 volume% [3]. We also obtained similar results. In the present study, adding 5 wt% of nanosilver powder to PMMA improved its thermal conductivity (by 3.3%) and compressive strength (by 18.6%), but decreased its tensile strength (by 13.4%).

CONCLUSION

This study was conducted to evaluate the effect of adding nanosilver particles to PMMA in terms of three properties of acrylic resin. The three tested properties were thermal conductivity, compressive strength, and tensile strength. Results showed that the addition of nanosilver particles significantly increased the thermal conductivity and compressive strength of the acrylic base, while decreasing its tensile strength. Considering the obtained results and the effect of nanosilver particles on increasing the thermal conductivity and compressive strength of the acrylic base, adding these particles to the palatal portion of the acrylic base of a total maxillary denture is recommended.

Since adding nanosilver particles by 5 wt% decreased the tensile strength of the acrylic resin, it is recommended that this study be repeated with different mixtures of various percentages of nanosilver particles, in order to determine the best weight percentage that minimizes this disadvantage.

REFERENCES

1- Goiato MC, Santos DM, Haddad MF, Pesqueira AA. Effect of accelerated aging on the microhardness and color stability of flexible resins for dentures.Braz Oral Res. 2010;24(1):114-9.

2- Zarb GL, Bolender CL, Eckert SE. Prosthodontic treatment for edentulous patients: Complete dentures and implant-supported prostheses,12thed. St. Louis:Mosby; 2004; 6-23.

3- Marei MK, El-Sabrooty A, Ragab AY, El-Osairy MA. A study of some physical and mechanical properties of metal filled acrylic resin. Saudi Dental Journal.1994; 6:69-77.

4- Dixon DL, Breeding LC. The transverse strengths of three denture base resins reinforced with polyethylene fibers.J Prosthet Dent. 1992; 67(3):417-9.

5- Narva KK, Lassila LVJ, Vallittu PK. Flexural fatigue of denture base polymer with fiber-reinforced composite reinforcement. Composites: Part A. 2005; 36:1275–1281.

6- Bertassoni LE, Marshall GW, de Souza EM, Rached RN. Effect of pre- and postpolymerization on flexural strength and elastic modulus of impregnated, fiber-reinforced denture base acrylic resins.J Prosthet Dent. 2008; 100(6):449-57.

7- Bulbul M, Kesim B.The effect of primers on shear bond strength of acrylic resins to different types of metals.J Prosthet Dent. 2010;103(5):303-8.

8- Nakamura M, Takahashi H, Hayakawa I.Reinforcement of denture base resin with

short-rod glass fiber.Dent Mater J. 2007; 26(5): 733-8.
9- Davy KW, Parker S, Ladizesky NH, Ward IM.Denture base poly(methyl methacrylate) reinforced with ultra-thin modulus polyethylene fibers.Br Dent J. 1988; 164(4):109-13.
10- http://www.nanoclub.ir
11- Ebadian B, Parkan MA. Evaluation of thermal conductivity of heat-cured acrylic resin mixed with Al2O3. Jdt. 2002; 15(3):21-28.
12- Vojdani M, Khaledi AAR. Transverse Strength of Reinforced Denture Base Resin with Metal Wire and E-Glass Fibers. Jdt. 2006; 3(4): 167-172.
13- Jagger DC, Harrison A, Jandt KD. The reinforcement of dentures.J Oral Rehabil. 1999;26(3):185-94.
14- Jagger D, Harrison A, Vowles R, Jagger R. The effect of the addition of surface treated chopped and continuous poly (methyl methacrylate) fibres on some properties of acrylic resin. J Oral Rehabil. 2001;28(9):865-72.
15- Jagger D, Harrison A, Jagger R, Milward P. The effect of the addition of poly(methyl methacrylate) fibres on some properties of high strength heat-cured acrylic resin denture base material. J Oral Rehabil. 2003;30(3):231-5.
16- Franklin P, Wood DJ, Bubb NL. Reinforcement of poly(methyl methacrylate) denture base with glass flake.Dent Mater. 2005;21(4):365-70.
17- Kapur KK, Fischer EE.Effect of denture base thermal conductivity on gustatory response.J Prosthet Dent. 1981;46(6):603-9.
18- Powers JM,Sakaguchi RL. Craig's Restorative Dental Materials, 12th ed.St. Louis: Mosby; 2006; 189-212.
19- Taira M, Nakao H, Matsumoto T, Takahashi J. Cytotoxic effect of methyl methacrylate on 4 cultured fibroblast. Int J Prosthodont. 2000;13(4):311-5.
20- Messersmith PB, Obrez A, Lindberg S.New acrylic resin composite with improved thermal diffusivity.J Prosthet Dent. 1998;79(3):278-84.
21- Pulit J, Banach M, Kowalski Z. Nanosilver -making difficult decisions. Ecological Chemistry and Engineering S. 2011; 18(2): 185-196.
22- Sehajpal SB, Sood VK. Effect of metal fillers on some physical properties of acrylic resin.J ProsthetDent. 1989; 61(6): 746-51.
23- Ellakwa AE, Morsy MA, El-Sheikh AM. Effect of aluminum oxide addition on the flexural strength and thermal diffusivity of heat-polymerized acrylic resin.J Prosthodont. 2008;17(6):439-44.
24- McNally L, O'Sullivan DJ, Jagger DC. An in vitro investigation of the effect of the addition of untreated and surface treated silica on the transverse and impact strength of poly (methyl methacrylate) acrylic resin.Biomed Mater Eng. 2006;16(2):93-100.
25- Nagai E, Otani K, Satoh Y, Suzuki S. Repair of denture base resin using woven metal and glass fiber: Effect of methylene chloride pretreatment.J Prosthet Dent. 2001;85(5):496-500.
26- Ayad L, Neveen M, Badawil MF, Fatah AA. Effect of reinforcement of high-impact acrylic resin with zirconia on some physical resin with zirconia on some physical and mechanical properties. Rev Clin Pesq Odontol. 2008; 4(3): 145-151.
27- Vallittu PK. Effect of some properties of metal strengtheners on the fracture resistance of acrylic denture base material construction. J Oral Rehabil. 1993;20(3):241-8.
28- Vallittu PK, Lassila VP. Effect of metal strengtheners' surface roughness on fracture resistance of acrylic denture base material.J Oral Rehabil. 1992;19(4):385-91.
29- Kemp PL, de Wet FA, Botha SJ, Levin J. Flexural properties of denture-base polymer reinforced with glass-fibre polysulphone composite. SADJ. 2004;59(5):190-2, 194, 196.
30- John J, Gangadhar SA, Shah I. Flexural strength of heat-polymerized polymethyl methacrylate denture resin reinforced with glass, aramid, or nylon fibers. J Prosthet Dent. 2001;86(4):424-7.

31- Vallittu PK. A review of methods used to reinforce polymethyl methacrylate resin. J Prosthodont. 1995;4(3):183-7.
32- Vallittu PK, Lassila VP, Lappalainen R. Evaluation of damage to removable dentures in two cities in Finland. ActaOdontol Scand. 1993;51:363-9.
33- Jagger DC, Harrison A, al-Marzoug K. Effect of the addition of poly (methyl methacrylate) beads on some properties of acrylic resin. Int J Prosthodont. 2000;13(5):378-82.
34- She WJ. Basic study of denture base resin with nano-silver antibacterial agent. Accessed from:http://iadr.confex.com/iadr/china04/preliminaryprogram/abstract_49832.htm
35- Brassel GW, Wischmann WB. Mechanical and thermal expansion properties of a particle filled polymer. J Master Sci. 1974; 9:307-314.