Journal of Dental School 2014; 32(3): 139-144 Original Article

Does Addition of Silver Nanoparticles to Denture Base Resin Increase Its Thermal Conductivity?

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Abstract

Objective: Studies have demonstrates that physical properties of denture base affect patient satisfaction and acceptance. Thermal conductivity is among the most important properties of denture base influencing the sense of taste and gingival health. The conventionally used acrylic resin has a low coefficient of thermal conductivity. This study aimed to improve the thermal conductivity of acrylic resin by adding small concentrations of nanosilver.

Methods: In this laboratory experimental study, 0.2wt% and 2wt% silver nanoparticles measuring 10-100 nm were mixed with the conventional denture base acrylic powder. Cylindrical samples were fabricated and thermal conductivity was measured. One-way ANOVA and Scheffe's post-hoc test were used to compare the mean thermal conductivity of different groups. Data were analyzed using SPSS 15 and $p<0.05$ was considered statistically significant.

Results: The thermal conductivity of resins reinforced with nanosilver was significantly higher than that of the conventional resin. By increasing the amount of nanoparticles in the acrylic powder, thermal conductivity further increased.

Conclusion: Addition of small amounts of nanosilver to denture base acrylic resin increases its thermal conductivity.

Key words: Acrylic resin, Denture, Nanoparticles, Polymethyl methacrylate, Silver filler, Thermal conductivity.

Please cite this article as:
Ghafari T, Hamedi Rad F, Ezzati B. Does Addition of Silver Nanoparticles to Denture Base Resin Increase Its Thermal Conductivity? J Dent Sch 2014; 32(3): 139-144.

Received: 31.08.2013 Final Revision: 17.05.2014 Accepted: 26.05.2014

Introduction:

Since the introduction of polymethyl methacrylate (PMMA) by Wright in 1937, it has been used as the main polymer for the fabrication of denture base (1). This material is not ideal, but has optimal properties such as its low cost, low weight and acceptable esthetics that are responsible for its popularity. Several researchers have attempted to improve the mechanical properties of denture base by adding different metal and non-metal fillers (2-5). However, one major limitation of this material is its physical properties especially its very low thermal conductivity (6); which has not been paid much attention.

Thermal conductivity is the property of a material to conduct heat. Since foods and beverages have different temperatures, quicker conduction of this heat by the denture base highly affects overall patient satisfaction (7, 8). In 1981, Kapur and Fischer confirmed that thermal conductivity of denture base has a significant effect on parotid gland secretions and subsequently sense of taste. When the temperature of palatal soft tissue increases, parotid secretion increases as well. If metal bases are used, such increase in secretion occurs. But, in case of using acrylic bases, parotid secretions do not increase (7). In addition to patient satisfaction, lack of thermal conduction to the underlying tissue decreases its thickness and compromises the health of denture-bearing mucosa under occlusal loading (9, 10).

The coefficient of thermal conductivity of PMMA is approximately 0.2 W/min°K; this rate is almost one-third of the coefficient of thermal conductivity of most metals. Due to this difference, in some studies, acrylic denture base has been replaced with metal base (7, 11). However, using a metal base has its own disadvantages including increased weight, difficult border molding, difficult relining, poor esthetics and high cost (12). Considering the shortcomings of metal bases, production of an acrylic-based material with a more favorable thermal conductivity has always been a goal. For this purpose, different materials like silver (13), alumina (14) and tin (15) have been added to the acrylic resin.

Silver is a metal with high conductivity; its antimicrobial properties have been reported in several studies when added to the denture base in the form of nanoparticles (16-18). Chladek, *et al*. in 2011 demonstrated that silver nanoparticles significantly inhibited Candida albicans and their addition to denture base decreased the prevalence of oral diseases in edentulous patients (16). Moreover, silver nanoparticles have greater antibacterial efficacy than silver powder with particles larger than 100nm (for instance in combination with Zeolite) due to increased metal surface area (17). Several investigatorsused silver nanoparticles to improve the mechanical properties of acrylic resin and demonstrated that at low concentrations, nanoparticles increased denture strength (19, 20). Although incorporation of 25% silver powder into acrylic resin causes 4.5 folds increase in thermal conductivity, the tensile strength of the material is decreased by 35%; making the denture susceptible to fracture (13). This study aimed to assess the effect of incorporation of 0.2wt% and 2wt% nanosilver as metal filler into PMMA acrylic resin to increase the thermal conductivity of denture base.

Methods:

This laboratory, experimental study was conducted in Dental Materials Laboratory of Tabriz University of Medical Sciences, School of Dentistry. First 0.2wt% and 2wt% silver nanoparticles (SP-A00601, Top Nano Technology Co., Ltd., Iran) measuring 10-100 nm was mixed with heat-cure denture base acrylic powder (PMMA, SR Triplex Hot, Ivoclar-Vivadent, Liechtenstein, Germany). The two powders were mixed in a mortar and then in an amalgamator (YDM, China) for two minutes to achieve a mixture with uniform color.

A total of 54 specimens were fabricated for this study. Specimens were divided into three groups of 18 each. Group 1 included PMMA with no additive and comprised the control group. Group 2 included PMMA with 0.2wt% nanosilver and group 3 included PMMA with 2wt% nanosilver.

For thermal conductivity testing, cylindrical specimens were fabricated according to P5687 standard dimensions (recommended by the manufacturer) for the thermal conductivity measurement apparatus (Cussons Thermal Conductivity Apparatus, UK). The specimens measured 25mm in diameter and 38 mm in height. Samples were conventionally flasked and baked. Figure 1 shows a schematic view of specimen dimensions.

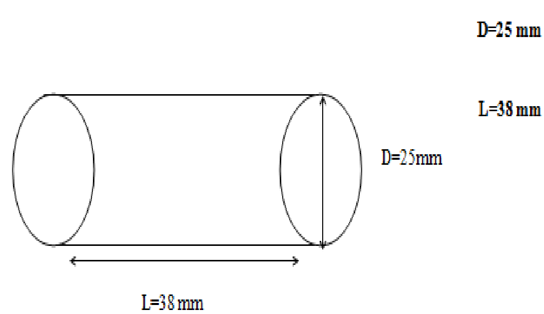

Figure 1- Specimen dimensions for thermal conductivity testing

In brief, aluminum cylinders with the respective dimensions were placed in the flask along with white dental stone (Semnan Dental Stone, Semnan, Iran). After setting of dental stone, aluminum cylinder was removed and the created cavity in the dental stone was used as a mold for the fabrication of specimens. Acrylic powder was mixed with monomer (5 gr of powder with 3.5 ml of monomer); the mixture was placed in the mold when reached dough phase. After flasking, specimens were baked according to the manufacturer's instructions. The flask was subjected to 200 Pascal load for one hour followed by 7 hours of baking at 70°C and 3 hours of baking at 100°C in water bath. Flasks were allowed to cool off in the water; then, acrylic specimens were carefully removed from the flasks and polished with fine grit Emery paper. Dimensions of specimens were measured by a digital caliper to ensure accuracy (Guilin Guanglu, Germany). Errors within ±0.01 mm were disregarded. Specimens remained in water bath at 37°C for complete saturation until the experiment. Specimens were removed from the water one hour prior to thermal conductivity testing and were allowed to dry at room temperature.

Thermal conductivity testing was done by the Thermal Conductivity Measurement Apparatus according to P5687 standard. First, two holes were created at 6.5 mm distance from the margins of specimens (Figure 2).

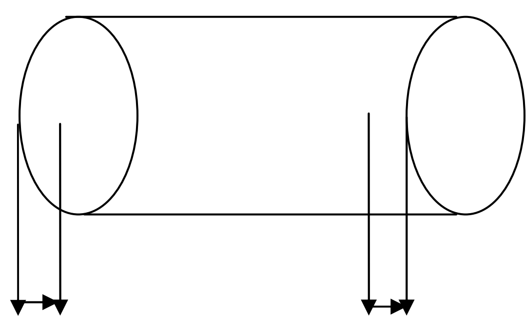

Figure 2- Creation of holes in specimens

Next, copper thermocouples of the apparatus were inserted into these holes to record thermal changes. The two ends of the specimen were subjected to zero and 70°C water flow [based on possible thermal changes in the oral cavity (21)] for 10 minutes. The coefficient of thermal conductivity 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:

J=Mechanical equivalent of heat =0.186 j/Kcal

M=Water mass L=Length of specimen

A= Cross sectional area t= Time of water flow

T2=Temperature of output water

T1=Temperature of input water

t2= Temperature at the cold end

t3= Temperature at the hot end

Data were expressed by descriptive statistics (mean and standard deviation) in each group. One-way ANOVA followed by Scheffe's post-hoc test were applied to compare the mean thermal conductivity of different groups. Data were analyzed using SPSS 15. p<0.05 was considered statistically significant.

Results:

Distribution of data was checked using Kolmogorov-Smirnov test; which was calculated to be 0.818 (p=0.515). Thus, data had normal distribution. Levene's test revealed the equality of variances in each group (p=0.913) (Table 1).

Table 2 shows the thermal conductivity of different groups. ANOVA found a significant difference in thermal conductivity among groups (p=0.001). According to Scheffe's post-hoc test, the difference in mean thermal conductivity of groups was statistically significant.

Table 1-Equality of variances

	Levene Statistics	df_1	df_2	p-value
Thermal conductivity	0.092	2	9	0.913

Table 2- Thermal conductivity of acrylic resin reinforced with different concentrations of nanosilver

	Number	mean (SD)	95% CI		Minimum	Maximum	ANOVA	
			Minimum	Maximum			F	p-value
Control	6	2.89 (0.13)	2.6817	3.0986	2.70	3.01		
0.2wt% nanosilver	6	3.46 (0.105)	3.2944	3.6304	3.31	3.54	54.28	0.001
2wt% nanosilver	6	3.70 (0.37)	3.5421	3.8643	3.56	3.78		

The mean thermal conductivity was 2.89 (0.13) in the control group; which was significantly lower than the rate in group 2 reinforced with 0.2wt% nanosilver (3.46 (0.105)) (*p*<0.001). Thermal conductivity of group 3 with 2wt% nanosilver was significantly higher than that of other groups (3.70 (0.37)) (*p*<0.001). Comparison of the thermal conductivity of conventional acrylic resin with that of reinforced specimens is shown in Diagram 1.

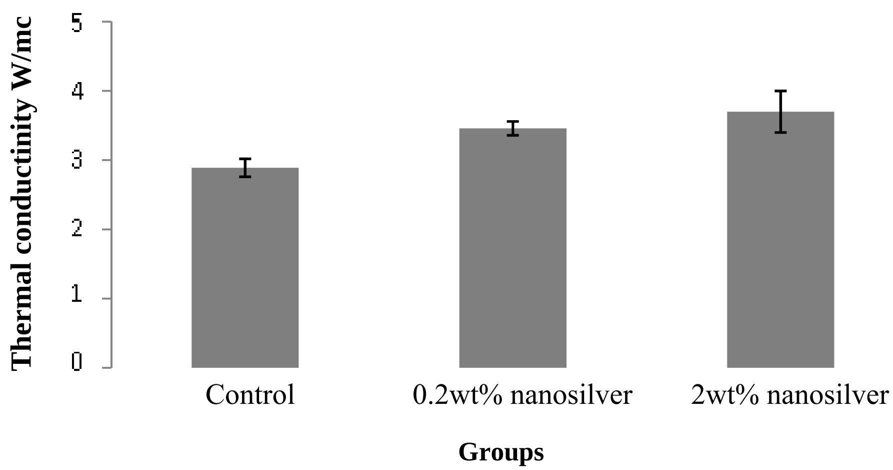

Diagram 1- Comparison of the thermal conductivity of conventional acrylic resin with those reinforced with different concentrations of nanosilver

Discussion:

Many researchers have attempted to improve the properties of acrylic denture base by adding different materials. Review of the literature reveals that the majority of studies have focused on improving the mechanical properties of PMMA by adding different particles like carbon fibers (4), glass fibers (4, 5, 22), silver particles (6, 13) and alumina (15). One major drawback of acrylic denture is its low thermal conductivity (6). But only a few studies have assessed the effect of materials used to reinforce denture structure on its physical properties like thermal conductivity of acrylic resin. Thus, we investigated the effect of addition of low weight percentages of nanosilver on thermal conductivity of acrylic resin.

Selection of silver as a filler in our study was because of several reasons. The first reason was the high thermal conductivity of silver that could improve the low thermal conductivity of denture. Moreover, it has been demonstrated that silver has no harmful effect on oral mucosa (10), and can even decrease the adhesion of Candida albicans and exert antimicrobial effects (16-18). Silver nanoparticles have been successfully used to improve the mechanical properties of acrylic resin (19, 20). Selection of low concentrations of nanosilver in this study decreases the final cost imposed on patients and reduces the need for excess monomer to be combined with acrylic powder while preserving the mechanical properties of denture (23, 24). Addition of higher weight percentages of silver, aluminum and copper fillers to acrylic resin causes a stepwise reduction in tensile strength (13).

Another factor is the size of particles that ranged from 10 to 100 nm in this study. It has been demonstrated that larger fillers further decrease the tensile strength (13). Also, in case of using low concentrations, small particle sizes must be chosen for better distribution among the PMMA particles. These particles keep a connection with one another and like a bridge conduct heat from one side to the other side (13, 14). Thus, silver nanoparticles were used in this study to achievemore favorable thermal conductivity at lower concentrations.

This study showed that addition of silver nanoparticles significantly increased thermal conductivity. Similarly, it was demonstrated that addition of 5-30% nanoparticles with a mean size of 10 μm to acrylic resin increased the coefficient of thermal conductivity by 1.67 to 4.53 folds (13). However, such filler content decreased the tensile strength of acrylic resin by 35%.

One disadvantage of metal fillers is changing the color of acrylic resin that limits its application in the esthetic zone. The method used in our study was simple and quick; technicians can easily add small percentages of silver nanoparticles to the acrylic resin of the palatal area and increase patient satisfaction. As demonstrated by Yadav, *et al*. (2012) addition of metal filler only to the acrylic resin of the palatal area of denture significantly enhances thermal conduction and improves patient's sense of taste (6). Our study had an *in-vitro* design and the effect of many confounders present in the oral cavity was not considered. Further studies are required to assess any improvement in properties of acrylic resin in the oral cavity and in long-term attributed to the addition of silver nanoparticles.

Conclusion:

Within the limitations of this study, it can be concluded that addition of nanosilver to conventional denture base acrylic resin increases its thermal conductivity. The magnitude of this increase depends on the percentage of nanoparticles.

Conflict of Interest: "None Declared"

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