ORIGINAL ARTICLE

Effects of Microwave and Light Emitting Diode as Disinfection Methods on the Dimensional Stability of Polymethyl Methacrylate and Polyamide Denture Base Resin

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ABSTRACT

Objective: To compare the effects of microwave and light emitting diode disinfection on the dimensional stability of two denture base materials; polymethyl methacrylate and polyamide.

Study Design: In-vitro study

Place and Duration of Study: Peshawar Dental College and Material Research Laboratories, University of Peshawar from 10th June 2021 to 8th December 2021.

Materials and Methods: Fifteen specimens each for polymethylmethacrylate and polyamide were divided into three groups, control, microwave & light emitting diode. The specimens for microwave group were irradiated at 1000W for 3 minutes, thrice a week. The specimens for light emitting diode group were disinfected in a device for 30 minutes, thrice a week. The control group specimens were placed in distilled water for 4 weeks. Dimensions were measured before disinfection, and four weeks after the assigned disinfection. The mean and the standard deviation of the differences between three groups were statistically analyzed using one-way ANOVA and after obtaining significant values, through post hoc Tukey HSD.

Results: For polymethylmethacrylate highest dimensional difference (-9.02mm) was noted for microwave disinfected group while the control group showed the lowest value (-6.99mm). For polyamide, the highest dimensional changes were recorded for light emitting diode group (8.66mm) and the lowest (-7mm) for the control group. Statistical analysis showed that the differences were significant for both polymethylmethacrylate and polyamide when compared with the control ($p<0.05$) but insignificant when microwave disinfected group was compared with light emitting diode group ($p>0.05$)

Conclusion: No significant difference in dimensional stability of both the denture base resins was observed after disinfection with microwave and light emitting diode.

Key Words: *Dimensional stability, Disinfection, Denture base resin, Light emitting diode, Microwave, Polymethyl methacrylate, Polyamide.*

Introduction

Polymethyl methacrylate (PMMA) is widely used for the fabrication of partial and complete dentures. Even though implant treatments are on the rise, but still there is a vast majority of cases that need removable dentures in developed as well as developing countries.[1] Therefore, the use of PMMA in prosthetic dentistry remains substantial as it shows adequate material properties and ease of application.[2] However, concern has been expressed with the adverse effects due to monomers present in acrylic materials among patients and medical staff.[3] In addition, the aesthetics of PMMA based removable partial denture can be impaired by the appearance of metallic components. A viable or possible alternative to PMMA can be polyamide.[4] Polyamides (PA) are preferred for persons allergic to methyl methacrylate, bone undercuts, in thin mucosa and excessive resorption of bone, in production of temporary dentures after implants placement surgeries.[5]

Due to poor oral and denture hygiene, removable prostheses provide a source for microbial growth[6], and thus causing denture related stomatitis.[7] Denture hygiene is achieved both through chemical and mechanical methods which affect the physicomechanical properties of materials used to make removable prosthesis.[8] To overcome the

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complications, microwave radiation has been advocated as an easy, safe, and effective way for denture disinfection.[10] In a recent review, microwave disinfection has been claimed as an efficient antifungal therapy for the treatment of denture stomatitis.[11] Microwave disinfection is mostly carried out in wet conditions[12] where the denture base is placed in water in the microwave oven, this may cause further polymerization of the resin.[13]

Despite the effectiveness of microwave as denture disinfectant, researchers have reached contradictory findings regarding its harmful effects on some properties. These detrimental effects may be due to the heating of material during irradiation, which could affect the structure of polymer.[14] The consequences of microwave disinfection of denture base materials have been vastly studied, but no consensus could be developed regarding the deleterious effects of microwave on prosthodontic materials[11]. Some of these studies showed notable dimensional changes of upto -1.12%[15], & 3%[16] after disinfection with microwave.

Blue LED light in the visible spectrum of wavelength (405nm), has been found to have bactericidal/ fungicidal effects.[18] Blue LED light of this wavelength inhibits the candida biofilm production on prosthesis and can also disinfect denture surfaces swiftly than conventional disinfection methods. Therefore, blue LED light can be a promising technique for denture disinfection. However, there is very limited information available for the effects of LED for disinfection of both PMMA and PA denture base resins on their dimensional stability. Similarly, no data is available to compare the effect of microwave and LED disinfection of two denture base materials on their dimensional stability. The aim of this study was to compare the effects of microwave and LED disinfection on the dimensional stability of polymethyl methacrylate and polyamide denture base resins.

Materials and Methods

This was an in-vitro, study conducted from 10th June 2021 to 8th December 2021, in Peshawar Dental College and Material Research Laboratories, University of Peshawar.

A total of thirty specimens were made, fifteen each for the two materials used; Polymethyl methacrylate (Engropolymer, Meadway, UK) and Polyamide (Vertex Dental B.V, Netherland). The specimens for each material were further subdivided into three groups: Group (A) Control (without treating either with MW or LED), group B microwave (MW) and group C light emitting diode (LED) disinfected containing five specimens each (n=5)[19] (Table I). Each specimen measuring 25×25×5mm was made in a stainless-steel split mold. Four holes, measuring 0.5mm in depth, were engraved in the metal mold as index marks.

After fabrication of specimens, wax patterns were invested in curing flask with dental stone type III. The flasks were put in boiling water for about 10 minutes. After removal of wax, sodium alginate was applied to the mold. Heat cure acrylic powder was mixed with its monomer in a ratio of 2.5:1 w/v[20] and was packed into the molds. The flasks were gradually heated to 100°C in a period of one and a half hour. This temperature was maintained for 30 minutes. The flasks were bench cooled overnight. The specimens were taken out and immersed in water for 48 hours. The specimens were then trimmed, using belt emery paper (400-800 grit). Further refined with grade 1200 and finished with grade 2400 emery paper. Final polishing was done with a motor driven revolving disc, with a velvet polishing cloth.

Wax patterns for PA specimens were made in stainless steel molds and invested in the flasks with dental stone (type III), following the procedure adopted for PMMA specimens. Wax sprues were then attached to the wax patterns. The investment was coated with petroleum jelly. The flasks were then filled with dental stone and placed in boiling water. After dewaxing, the flasks were placed in the hydraulic injector for flexible denture base resin. Molten polyamide was forced into the flask by using polyamide injection system at a pressure of 5 bars for 3 minutes. The flasks were bench cooled before deflasking[15]. Following deflasking, finishing was performed with 600 and 800 grit silicon carbide paper, and then polished with white cotton yam wheel polishing brush.

Measurements were recorded with a digital caliper (Mitutoyo, Mfg Co., Japan), using elevated indentations labeled by letters A, B, C & D. Six dimensions (distances AB, BC, CD, AD, AC and BD) were documented for each specimen. Five measurements were recorded for each of the six

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dimensions before calculating the mean. The algebraic norm was calculated by taking the square root of sum of squares of individual dimensions.[21]

Norm[22] = $[AB^2+BC^2+CD^2+AC^2+AD^2+BD^2]^{1/2}$

For control group (A) specimens, after initial measurement were kept in distilled water at room temperature and the water was changed corresponding to the water change for the interventional groups (B & C). For group B, after taking the initial measurements, individual specimens were placed in 200ml of distilled water at room temperature in a microwave oven (Dawlance, model: DW-162H, Korea) and then subjected to disinfection at 1000W for 3 minutes, thrice a week for 4 weeks. For group C (LED disinfection), after the initial measurements, the specimens were subjected to irradiation for 30 min, 3 times a week for 4 weeks.

Water for sample immersion was changed after conducting 2 disinfection protocols for groups B & C and after every 4th day for group A. After completing 12 disinfection cycles, specimens were measured for final measurement. The percent difference was determined as follow[21]:

Percent Difference = final measurement - initial measurement / initial measurement × 100

Mean and standard deviation values for the linear dimensions were determined. Data collected before and after disinfection with microwave and LED, were statistically analysed by one-way ANOVA and post hoc Tukey's test using SPSS version 26. P value less than 0.05 was considered as significant.

Results

The mean values of the initial, final measurements and their differences for all the groups of PMMA are given in Table I. Group B1 (disinfected using microwave) exhibited the highest change in dimensions (-9.02mm) while the control group (A1) displayed the lowest change in dimensions (-6.99mm) (Table I). One way ANOVA showed highly significant difference (*p*=0.002) among the groups after disinfection protocol (Table I). Post hoc Tukey's test for multiple comparison showed significant difference for both the groups B1&C1 when compared to control (A1) (*p*=0.004) &(*p*=0.006) respectively while the difference between group B1 & group C1 was insignificant (*p*=0.964) (Table II).

The mean values of the initial, final measurements and their differences in mm with standard deviations for each group of PA are given in Table III. It can be seen from the Table III that group C2 exhibited the highest (-8.66mm) while the control group, displayed the lowest change in dimensions (-7.0mm). One way ANOVA showed statistically significant difference among the three groups ((*p*=0.013). Post hoc Tukey's test showed statistically significant difference between group B2 and the group A2, similarly the difference between group C2 and group A2 was significant (*p*=0.042). The difference between the group B2 and group C2 was also statistically insignificant (*p*=0.835).

Table I: Comparison of Dimensional Changes In PMMA* Using One Way ANOVA

Group	Initial Measurements mm (Mean)	Final Measurements mm (Mean)	Difference mm (Mean) ± Std Dev	% Difference	F	*p*
A1 (control)	56.81	49.81	-6.99±0.64	-12.32	10.65	0.002
B1 (M/W)**	57.03	48.01	-9.02±1.03	-15.82		
C1 (LED)***	56.68	47.78	-8.89±0.56	-15.69		

* PMMA: Polymethylmethacrylate,
** M/W: Microwave,
*** LED: Light Emitting Diode.

Table II: Post Hoc Analysis (Tukey's HSD) of Dimensional Changes In PMMA

Multiple Comparison Tukey HSD				
Dependent Variable	Groups (I)	Groups (J)	Mean Difference (I-J)	Significance *(p)*
Dimension PMMA	Control (A1)	M/W	2.02	0.004
		LED	1.89	0.006
	M/W (B1)	Control	-2.02	0.004
		LED	-0.13	0.964
	LED (C1)	Control	-1.89	0.006
		M/W	-0.13	0.964

Table III: Comparison of Dimensional Changes in PA Using One Way ANOVA

Group	Initial Measurements mm (Mean)	Final Measurements mm (Mean)	Difference mm (Mean) ± Std Dev	% Differences	F	*P*
A2 (control)	57.04	50.04	-7.0±0.42	-12.27	6.39	0.013
B2 (M/W)	56.90	48.53	-8.37±1.08	-14.71		
C2 (LED)	57.02	48.37	-8.66±0.69	-15.17		

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Table IV: Post Hoc Analysis (Tukey HSD) of Dimensional Changes in PA

Multiple Comparison Tukey HSD				
Dependent Variable	Groups (I)	Groups (J)	Mean Difference (I-J)	Significance *(p)*
Dimension PA	Control (A2)	M/W	1.40	0.042
		LED	1.65	0.015
	M/W (B2)	Control	-1.37	0.042
		LED	0.28	0.835
	LED (C2)	Control	-1.65	0.015
		M/W	-0.28	0.835

*PA: Polyamide

Discussion

Dimensional stability of denture bases during service is of great importance as it helps in retention of the dentures and cuspal interdigitation.[23] Therefore, any effects of the adopted disinfection techniques on the dimensions of denture bases may pose problems. There are no standard specifications for measuring linear dimensions of denture bases. Wolfaardt et al[24] stated, that many factors affect the dimensional changes of denture bases such as size and shape etc. It has been recommended to test specimens of simple shapes for dimensional measurements.[21] Therefore, square shaped specimens were used in the present study.

Statistically significant difference was observed, when the interventional groups were compared with the control group whereas comparison of the MW with LED showed insignificant results. Therefore, the null hypothesis of this study was partially rejected as significant differences were observed for both the resins after disinfection with MW and LED when compared with control.

The contraction of resin for the control groups of this study could be attributed to the thermal contraction during storage and due to release of stresses that were induced during polymerization.[25] The storage of resin in water helps in residual monomer dispersion in PMMA.[26] This elution of monomer continues for a few days of storage in water.[27] Such loss of monomer from the polymerized specimens can be accredited for the shrinkage or decreased dimensions of specimens of control groups of PMMA, after storage in water for four weeks.[25]

The shrinkage in PA control group was recorded to be around 7mm. Dimensional accuracy of PA is technique sensitive and require more precise and careful processing. It has been reported in literature that storage of nylon (PA) in water has shown decrease in dimensions after about 24 hours.[28] However, an increase in dimensions of the same PA used in the present study after storage in water has also been reported by Chuchulska & Zlatev [29], which contrasts with the results of this study. This might be due to aging of the specimens for 5000 thermocycles.

The change in dimensions of both denture base resins can be explained by the fact that microwave irradiation causes increase in temperature of the specimens.[17] Despite all the precautions taken and careful processing of PMMA, some monomer content is left unreacted in the final product.[30] This increase in temperature can cause reaction of the unreacted monomer at reactive sites of the polymer and thus cause further shrinkage due to thiolymerization.[15] Resins can experience a plasticizing effect after their Tg is exceeded, which causes rearrangement of the polymer chains[31] and thus this change in dimensions could be due to the plasticizing effect of resins above their Tg.

The highly significant result for MW disinfected PMMA group in comparison with the control group of this study is in accordance with results reported by Wemken et al.[17] Polychronakis et al[15] reported shrinkage of 0.35mm for heat cure PMMA and 0.09mm for Valplast after wet microwaving at 450 W for 3 minutes. This can be considered in accordance with the present investigation, as they had measured only the length of the specimens, while in this study, means were calculated for the six measurements of each specimen and the algebraic norm was calculated.

Polyzois et al[32] contradicts the results of the present study as disinfection of acrylic base resin specimens with a 500W MW for 3 minutes and 15 minutes manifested linear shrinkage of - 0.005%. Although the changes were significant statistically but were of no clinical importance. It can be noted in the arguments presented so far that the microwaves

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used for disinfection of denture base resins specimens were of low powers. The power levels of MW ranged between 450W and 700W, with most studies conducted with 650W. This observation is consistent with a critical review by Brondani & Siqueira.[33] The microwave used in the present study had power of 1000W which is a normal domestic microwave device found in our part of the world. Due to unavailability of studies on LED disinfection in the literature, we were not able to compare the results of our study with other studies.

Conclusion

Within the limitations of this study, it is concluded that the dimensional stability of PMMA and PA can be affected by disinfection with MW and LED, and the dimensional changes observed for both materials are comparable, therefore, one disinfection procedure cannot be preferred over the other.

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CONFLICT OF INTEREST

Authors declared no conflicts of Interest.

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DATA SHARING STATMENT

The data that support the findings of this study are available from the corresponding author upon request.

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