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Effect of Monomer Content in the Polymer-Monomer Ratio on the Displacement of Maxillary Teeth and Dimensional Accuracy of the Maxillary Denture Base in Microwave and Conventional Polymerization - An in Vitro Study

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Abstract

The purpose of the study was to verify the linear displacement of teeth and dimensional accuracy in maxillary complete dentures influenced by different monomer- polymer ratios - according to the manufacturer's instructions, with 25% excess or 25% less monomer content - in the conventional and microwaved polymerization techniques. Wax base plates and wax planes were made on edentulous maxillary stone casts according to traditional method. The set was assembled in semi-adjustable articulator with a lower toothed stone cast as guide to mounting of the maxillary artificial teeth. Impressions were taken from this tooth arrangement with silicone and the mold was used to standardize the mounting of the teeth of all dentures. Referential points were made on the artificial teeth for linear measurements with optical microscope before processing of the dentures and after deflasking. Denture bases were conventionally packed with acrylic resin according to the monomer-polymer ratio protocol. Tooth displacement data were submitted to ANOVA and Tukey test (a=0.05). There were statistically significant differences between the subgroup with monomer content recommended by the manufacturer and groups with 25% more and 25% less monomer, in both conventional and microwaved polymerizations although no statistically significant results were found in comparison of the two groups. Excess or less monomer in the monomer-polymer ratio and polymerization types did not change the linear distance and dimensional accuracy between teeth.

Keywords: Monomer Content; Dimensional Accuracy; Maxillary complete dentures; Microwave and Conventional Polymerization.

1. Introduction

Polymethyl methacrylate has been the most popular and widely used denture base material since the late 1930s despite the polymerization shrinkage [1]. Polymethyl methacrylate used for denture bases incurs dimensional changes during processing and use. Many variables influence dimensional change occurring in a denture and these factors need to be considered during the processing phase [2].

Optimal proportion of the polymer and monomer is very important. Proportions with higher polymer content will result in insufficient monomer to wet all particles of the polymer and promote a dry mixture due to lack of monomer. Conversely, the excess content of monomer will result in increased residual monomer leading to a higher contraction due to excessive polymerization and consequent loss of retention quality and denture stability in oral use [3].

The accuracy of the fit of the prosthesis is, likewise, important for the success of the prosthesis in the oral cavity. The distortion resulting from the cooling and removal of the base from the stone cast leads to the release of stress induced during the processing [4].

Some techniques of processing have been suggested for replacement of the traditional long cycle of hot water, such as the use of microwave energy, which may reduce some variables that may affect base stability [1]. There is little data available regarding the effect of different polymer: monomer ratios on the linear dimensional stability and accuracy of fit of the prosthesis. Therefore, the purpose of the study was to evaluate the effects of

25% more and 25% less monomer on the linear displacement of the maxillary teeth and the dimensional accuracy of the maxillary denture base by conventional and microwave polymerization techniques.

2. Material and Methods

For the present in vitro study, a special maxillary and mandibular edentulous metal die was fabricated. An appropriate stock tray was selected to make impressions from the metal edentulous die and poured with Type III dental stone (Kalabhai, India). Following this method, a total of 121 maxillary dental casts and one mandibular dental cast were made and out of these, one maxillary dental and mandibular dental cast were used for construction of a maxillary denture and subsequent indexing.

On each cast, record bases and occlusal rims were fabricated one of the maxillary casts was mounted with the mandibular cast in class I maxillomandibular relationship on Hanau articulator H2 series using the average values and teeth (Acrypan, Ruthinium Dental Products Pvt. Ltd., India) were arranged. After completing the wax up, the flasking and curing was done in standard water bath polymerization. After retrieval, finishing and polishing of the maxillary denture was done.

A silicone matrix was fabricated on the maxillary denture to make an index of the teeth arrangement to act as a guide and to standardize the teeth arrangement of the subsequent maxillary dentures (Fig. 1).

Figure 1: Silicon Index.

To quantify the movement of the teeth, the linear distances between following reference points (Fig. 2) were measured with travelling microscope:-

1. Median region of right central incisor to median region of left central incisor.

2. Buccal cusp tip of the right first premolar to buccal cusp tip of the left first premolar.

3. Distobuccal cusp tip of right second molar to distobuccal cusp tip of left second molar.

4. Median region of right central incisor to distobuccal cusp tip of right second molar.

5. Median region of left central incisor to distobuccal cusp tip of left second molar.

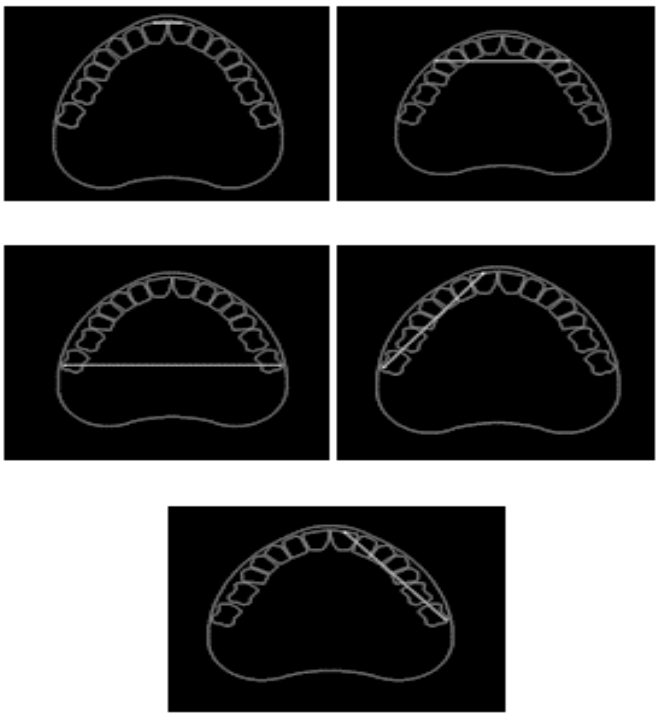

Figure 2: Reference points and the distance mearsurements.

The reference points were made by making holes with round bur (BR-45, Mani Burs, India) in the median region of the incisal edge of both the left and right central incisors, buccal cusp tip of the right first premolar and left first premolar and distobuccal cusp tip of the right second molar and left second molar. The holes were filled with dental amalgam. After the recording of linear distances in all 120 maxillary dentures, the samples were randomly divided into 2 groups with 60 samples in each group.

- **Group I** – Conventional heat cure polymethyl methacrylate resin (Pyrax, India) was used for fabrication of maxillary dentures with different polymer-monomer ratios and hot water bath were used for polymerization. All samples were subjected to flasking procedure by three pour technique in a manner similar to that of the first maxillary denture. After dewaxing, the samples were subdivided into 3 subgroups of 20 samples each:-
- **Group I (a)** - The conventional heat cure acrylic resin polymer and monomer were mixed as per manufacturer's instructions in 3:1 ratio that is 30 parts of powder to 10 ml of monomer.
- **Group I (b)** - Content of the monomer in polymer-monomer ratio being 25% more than manufacturer's recommendation that is 30 parts of powder to 12.5 ml of monomer.
- **Group I (c)** - Content of the monomer in polymer-monomer ratio being 25% less than manufacturer's recommendation that is 30 parts of polymer to 7.5 ml of monomer.
- **Group II** – Microwave polymethyl methacrylate resin (VIPI WAVE, VIPI dental products Co., Brazil)

and special plastic flasks (mufla-STG, VIPI dental products, Brazil) were used for fabrication of maxillary dentures and microwave oven (IFB, India) was used for polymerization.

Following the conventional flasking procedure, boil out was carried out wherein the flasks were kept in microwave oven (IFB, India) for 2 min. The flasks were opened and wax was drained out. Any residual wax was cleaned with hot water rinse. After dewaxing, the samples were subdivided into 3 subgroups with 20 samples each.

- **Group II (a)** - Polymer-monomer ratio was 30 parts of powder to 10 ml of monomer.

When the material reached dough stage, material was packed followed by tightening with screws to remove any flash. The flasks were kept for bench curing. The polymerization of the samples was done in a domestic microwave oven (IFB, India) with maximum potency of 800 W according to manufacturer's recommendation (initial stage: 20 min at medium-low potency, and final stage: 5 min at medium potency). After bench cooling, the flasks were opened, dentures retrieved and finished and polished.

- **Group II (b)** –Content of the monomer in polymer-monomer ratio being 25% more than manufacturer's recommendation that is 30 parts of powder to 12.5 ml of monomer.
- **Group II (c)** - Content of the monomer in polymer-monomer ratio being 25% more than manufacturer's recommendation that is 30 parts of powder to 7.5 ml of monomer.

After processing of all the samples (conventional and microwave), the dentures were seated on their casts and the distances between reference points were again assessed for any movement in the teeth with travelling microscope.

Thereafter, processed maxillary dentures were sectioned in the area posterior to second molar region. The gap between the denture base and the underlying cast was examined under stereomicroscope (Magnus, Olympus) (Fig. 3) in three regions: - on the crest of the ridge on both sides and in center of the palate (Fig. 4) and measured to assess the dimensional accuracy of the denture bases.

Figure 3: Stereomicroscope

Figure 4: Points for dimensional accuracy measurement

The data obtained was statistically analyzed.

3. Results

The mean distance between right central incisor to left central incisor was 0.764 cm in subgroup Ia and 0.763 cm in subgroup IIa. The mean distance between right 1st premolar to left 1st premolar was 3.791cm in subgroup Ia and 3.792 cm in subgroup IIa. The mean distance between right 2nd molar to left 2nd molar was 5.298 cm in subgroup Ia and 5.297 cm in subgroup IIa. The mean distance between right central incisor to right 2nd molar was 4.468 cm in subgroup Ia and 4.470 cm in subgroup IIa. The mean distance between left central incisor to left 2nd molar was 4.470 cm in subgroup Ia and 4.470 cm in subgroup IIa.

The mean distance between right central incisor to left central incisor was 0.762 cm in subgroup Ib and 0.762 cm in subgroup IIb. The mean distance between right 1st premolar to left 1st premolar was 3.789 cm in subgroup Ib and 3.791cm in subgroup IIb. The mean distance between right 2nd molar to left 2nd molar was 5.295 cm in subgroup Ib and 5.296 cm in subgroup IIb. The mean distance between right central incisor to right 2nd molar was 4.466 cm in subgroup Ib and 4.467 cm in subgroup IIb. The mean distance between left central incisor to left 2nd molar was 4.467 cm in subgroup Ia and 4.467 cm in subgroup IIa.

The mean distance between right central incisor to left central incisor was 0.766 cm in subgroup Ic and 0.766cm in subgroup IIc. The mean distance between right 1st premolar to left 1st premolar was 3.794 cm in subgroup Ic and 3.794 cm in subgroup IIc. The mean distance between right 2nd molar to left 2nd molar was 5.301cm in subgroup Ic and 5.301cm in subgroup IIc. The mean distance between right central incisor to right 2nd molar was 4.468 cm in subgroup Ic and 4.471 cm in subgroup IIc. The mean distance between left central incisor to left 2nd molar was 4.470 cm in subgroup Ic and 4.471 cm in subgroup IIc.

There was statistically significant difference when the values were compared within the group I and group II after changing the monomer content (Table 1, Fig. 5) but there was no significant differences between the conventional and microwave polymerization when the two groups were compared for the linear dimensional

change (Table 2).

Table 1: Difference of mean values for the linear dimensional change between the groups with conventional (Group I) and microwave (Group II) polymerization.

Distance	Mean Difference Between Ia and IIa	P value	Mean Difference Between Ib and IIb	P value	Mean Difference Between Ic and IIc	P value
Right Central Incisor- Left Central Incisor	0.0009	0.129	0.0009	0.129	0.0001	0.537
Right 1st Premolar- Left 1stPremolar	0.0017	0.005	0.0017	0.005	0.0001	0.592
Right 2ndmolar- Left 2ndmolar	0.0006	0.203	0.0006	0.203	0.0015	0.395
Right Central Incisor- Right 2ndmolar	0.0016	0.121	0.0016	0.121	0.0013	0.005
Left Central Incisor- Left 2ndmolar	0.0003	0.586	0.0003	0.586	0.0008	0.003

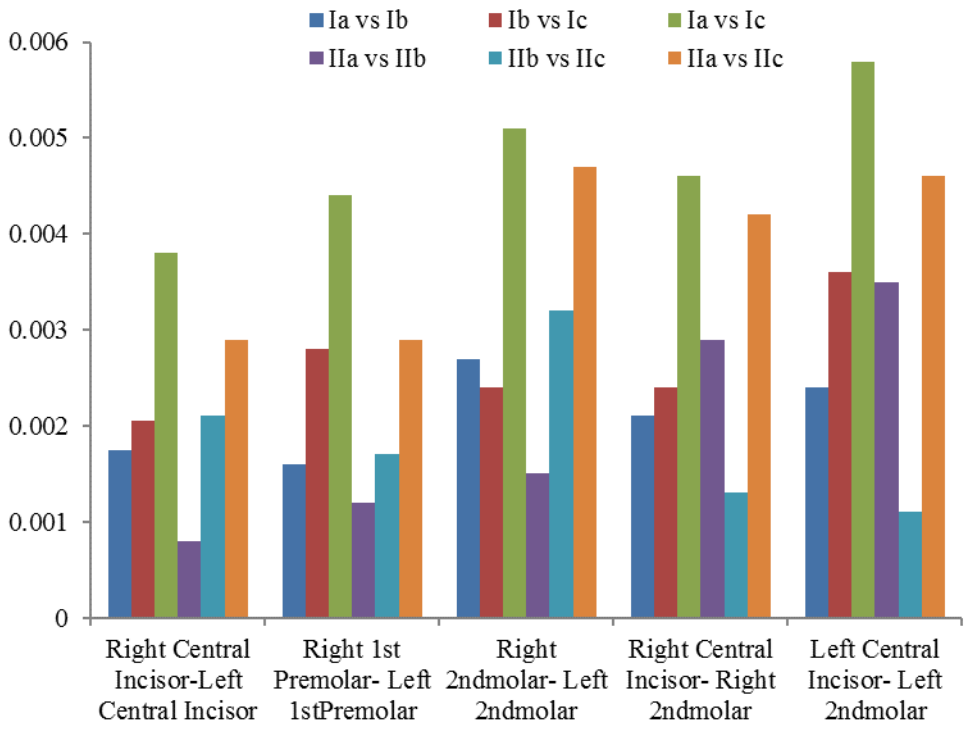

Figure 5: Analyses of the linear dimensional change between the groups with conventional (Group I) and microwave (Group II) polymerization.

Table 2: Difference of mean values for the linear dimensional change within the group with conventional (Group I) and microwave (Group II) polymerization.

Distance	Mean Difference between Ia and Ib	Mean Difference between Ib and Ic	Mean Difference between Ia and Ic	Mean Difference between IIa and IIb	Mean Difference between IIb and IIc	Mean Difference between IIa and IIc
Right Central Incisor-Left Central Incisor	0.00175	0.00205	0.00380	0.008	0.0021	0.0029
Right 1st Premolar-Left 1stPremolar	0.0016	0.0028	0.0044	0.0012	0.0017	0.0029
Right 2ndmolar- Left 2ndmolar	0.0027	0.0024	0.0051	0.0015	0.0032	0.0047
Right Central Incisor-Right 2ndmolar	0.0021	0.0024	0.0046	0.0029	0.0013	0.0042
Left Central Incisor-Left 2ndmolar	0.0024	0.0036	0.0058	0.0035	0.0011	0.0046

The mean value for the dimensional measurement for the group Ia was found to be 0.871. The mean value for the group Ib was found to be 0.887mm. The mean value for the group Ic was found to be 0.873. The mean value for the group IIa was found to be 0.869. The mean value for the group IIb was found to be 0.888. The mean value for the group IIc was found to be 0.868. (Table 3, Fig. 6).

Table 3: Mean values for the dimensional accuracy values between groups with conventional (Group I) and microwave (Group II) polymerization.

Sub group	No	Mean	Standard deviation	Standard Mean	95% Confidence Interval for Mean			
					Lower Bound	Upper Bound	Minimum	Maximum
Ia	20	0.8714	0.0046	0.0010	0.86924	0.87356	0.862	0.879
Ib	20	0.8872	0.0041	0.0009	0.88526	0.88914	0.880	0.897
Ic	20	0.8731	0.0049	0.0011	0.87076	0.87544	0.865	0.882
IIa	20	0.8688	0.0042	0.0009	0.86689	0.87081	0.862	00.877
IIb	20	0.8881	0.0041	0.0009	0.88625	0.89005	0.882	0.896
IIc	20	0.8683	0.0036	0.0008	0.86666	0.87004	0.863	0.876
Total	120	0.8761	0.0093	0.0008	0.87449	0.87786	0.862	0.897

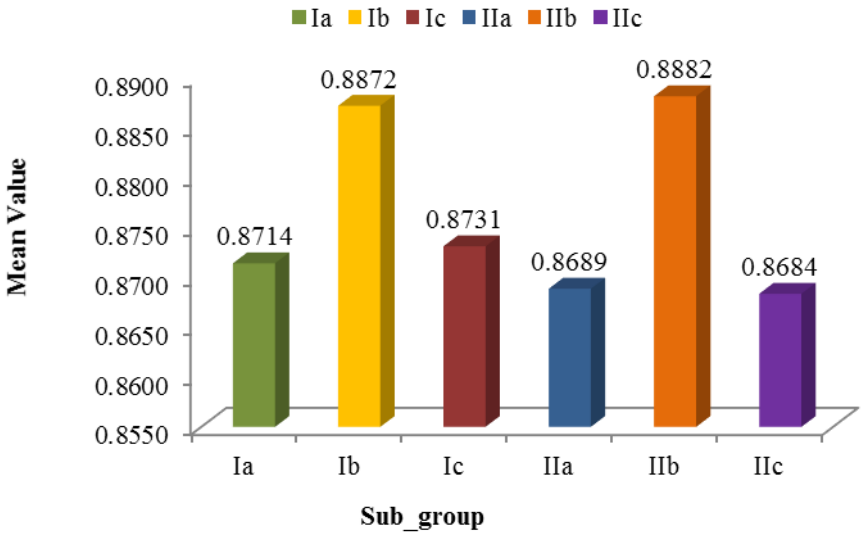

Figure 6: Mean of the distances calculated between cast and the overlying maxillary denture with stereomicroscope in subgroups Ia, Ib, Ic, IIa, IIb, IIIc.

4. Discussion

During the polymerization reaction of the acrylic resins, the conversion of monomer into polymer is not complete and varying amounts of free or unreacted monomer remain in the polymerized resin. Residual monomer is a well-known plasticizer and affects the physical and mechanical properties of the acrylic resins [5].

Because the acrylic denture base serves to ensure the fixing and stabilizing of artificial teeth, as well as for distributing masticatory forces to the entire area of the alveolar ridge, dimensional alteration of the acrylic resin and the movement of the artificial teeth during complete prosthesis manufacture will have a profound effect on the finished prosthesis [6]. Therefore, this study was undertaken to evaluate the linear displacement of the maxillary teeth and the fit of the maxillary denture bases with different monomer polymer ratios and different polymerization techniques (conventional and microwave).

The results of the study indicated maximum displacement the subgroups with 25% more monomer content (Ib and IIb) followed by the subgroups with normal monomer content (Ia and IIa) and minimum displacement in subgroup with 25% less monomer content group (Ic and IIc). Because the curing conditions within group were constant, it is the residual monomer content which influenced the polymerization shrinkage which is highest in case of subgroup Ib and subgroup IIb resulting in maximum displacement. This is understandable when one considers the molecular events that occur during the polymerization process. Each methyl methacrylate molecule possesses an electrical field that repels nearby molecules. Consequently, the distance between molecules is significantly greater than the length of a representative carbon-to-carbon bond. When the methyl methacrylate molecules are chemically bonded, a new carbon-to-carbon linkage is formed. This produces a net decrease in the space occupied by the components resulting in a projected volumetric shrinkage of 7% and a linear shrinkage of less than 1%. When the powder and liquid components are mixed in the proper proportions, a dough like mass results. The accepted polymer-to-monomer ratio is 3:l by volume which provides sufficient

monomer to thoroughly wet the polymer particles, but this ratio does not contribute excess monomer that would lead to increased polymerization shrinkage. Therefore, as the residual monomer content increased, the amount of linear tooth displacement also increased being maximum in subgroup Ic and IIc [7].

The results are in conformity with the study conducted by *Negreiros WA* and his colleagues [8, 9]

When the two groups (Group I and Group II) were compared on basis of linear teeth displacement, it was found that there was no statistically significant difference of tooth difference between subgroup Ia and IIa, between Ib and IIb, and between Ic and IIc. This suggests that different polymerization cycles did not influence tooth displacement and residual monomer is inevitable for all PMMA-based products regardless of the polymerization conditions used. The results are in conjunction with the studies of *Lopes MC* and his colleagues [3] and *Negreiros WA* and his colleagues [9].

Conventional hot water bath and microwave polymerization technique were also compared for dimensional accuracy of the maxillary samples. No significant differences were found by comparison of dimensional accuracy of complete denture bases polymerized by conventional hot water bath and microwave polymerization. Gap formation between the denture base and cast are generally attributed to polymerization shrinkage of the resin material and a tendency of cooling shrinkage toward the central area of the denture base, as well as to subsequent distortion caused by confinement of the surface topography of the alveolar ridge. Therefore, the greatest gap was observed in the central portion of the posterior border, while the contact state around the ridge crest remained stable [10]. These findings were similar with the results reported by Consani and his colleagues [10], *Turck MD* and his colleagues [11] and *Shlosberg SR* and his colleagues [12].

Based on these results, it was possible to assume that though the change in the monomer values affected the linear displacement of teeth and the dimensional accuracy of the maxillary denture bases but the polymerization techniques didn’t have any significant influence on the linear displacement and the dimensional accuracy of the maxillary samples.

4.1 Recommendations

The current study and its results are very significant in relation to the practical implication of the polymerization technique and time needed for the same. Today, in the era of implant dentistry, hybrid prosthesis constitute a major means of prosthodontic rehabilitation where in acrylic is used in combination with metal framework. Use of microwave polymerization for the fabrication of this prosthesis will reduce the laboratory time for fabrication to a great extent. Secondly, it is a very clean method as regards laboratory work is concerned. In addition, any correction if required intraorally can take the final shape in no time thereby saving on additional patient appointments and dentist’s time. Therefore, the use of microwave polymerization is highly recommended as it provides same accuracy with short time.

4.2 Limitations

1. The armamentarium for the flasks is expensive as compared to conventional method.

2. The flasks used in the microwave polymerization have a particular shelf life after which they need replacement.
3. The method is more technique sensitive as compared to convetional method.

5. Conclusion

Studies focusing on acrylic resin properties and laboratory steps for complete denture processing are common in the dental literature. Hence, this study was conducted to compare the effects of monomer content and type of polymerization (microwave and conventional hot water bath) on the teeth movement and the dimensional accuracy of maxillary denture bases. Within the limitations of the study, it was concluded that the monomer content affected the movement of artificial teeth but the different polymerization techniques didn't seem to have a significant effect on the dimensional accuracy and artificial teeth movement.

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