Evaluation of Effect of Different Cooling Methods on Denture Base Adaptation of Rapid Heat Cured Acrylic Using a Three Dimensional Superimposition Technique

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Abstract-

Background: There are several factors affecting the adaptability of prosthesis. These factors include nature of the acrylic resin used in denture fabrication, type of the curing cycle used and the process of water uptake. Type of procedure employed for cooling of the flasks during the acrylization process is another vital factor in the preservation of precision of dimensions of the dentures. Prolonged cooling helps in reducing the lingering interior stress in the flasks developed due to heat activated process. As a result there is minimum damage to the denture while deflasking.

Aim: This study was conducted with an ambition to analyse the effect of various methods of cooling over the adaptation of denture base of 2 fast setting heat activated polymethyl methacrylate denture base materials easily available in market using three dimensional superimposition technique.

Materials and Methods: Sixty stone models were prepared. Type IV dental stone was used for pouring of the duplication mould. These sixty study models were divided into five categories X1, X2, X3, X4, X5 with each category consisting of 12 study models according to the method of cooling and material used. A pattern of wax was prepared througout the cast of reference. Then there was superimposition of STL file of every intaglio surface of the denture base with the corresponding STL file of the master cast. This was carried out to analyse the degree of of adaptation of denture base in each specimen. Four anatomical landmarks were choosen for matching in the superimposition of denture base scanned image over the master cast scanned image

Results: Broad area of green colour in the palate was observed in the specimens of X1, X2 and X3 categories. Specimens belonging to X4 and X5 categories showed greater red coloured areas at the location of post dam area and palate area. On the basis of statistical analysis it was found that there were no statistical significant differences between group X1 and X2 specimens. It reflected that there was similarity in the accuracy of both X1 specimens and X2 specimens. It was also observed that differences were statistically significant between specimens of X2 category and X3 category. Besides there was a significant difference between X2 and X5 specimens.

Conclusion: From these results it was inferred that specimens which underwent bench cooling showed better dimensional accuracy in comparison with the rapidly cooling techniques used in the study.

Key words- Polymethyl methacrylate, cooling methods, denture base adaptation, three-dimensional superimposition technique.

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INTRODUCTION

The introduction of polymethyl methacrylate in field of prosthodontics took place in year 1937 with a purpose of preparing removable dentures. It had some important features making it material of choice for acrylization of removable dentures. These features were reduced cost, proper mechanical power, and encouraging working properties. In recent times significant research is being carried out over this acrylic material to decrease time in preparation and insertion of removable dentures. [1,2]There has been introduction of fast twenty minute heat activated polymethy methacrylate recently. Since then several research have been carried out to give an indication that dimensional differences between fast twenty minute heat activation cycle and the conservative extended heat activation cycle.[3,4]

Some of the vital outcomes of adequately adapted prosthesis include improved comfort to patients, better chewing competence and inhibition of hyperplastic pathologies. There are several factors affecting the adaptability of prosthesis. These factors include nature of the acrylic resin used in denture fabrication, type of the curing cycle used and the process of water uptake.[5,6] Type of procedure employed for cooling of the flasks during the acrylization process is another vital factor in the preservation of accurateness of dimensions of the dentures. Prolonged cooling helps in reducing the lingering interior stress in the flasks developed due to heat activated process. As a result there is minimum damage to the denture while deflasking. However, the process of traditional cooling method is time taking process making it unsuitable for emergency conditions, community health programmes in villages, and older patients where main focus is reduced denture insertion time.[7,8]

Therefore, need of the hour is to evaluate the condition of establishment of adequate dimensional accuracy with good adaptation of denture base using cooling of shorter duration. Several methods have been established to study the role of shorter cooling curing cycle in the dimensional accuracy of the denture base material in fabrication of prosthesis. These methods are quantification of space through silicone weight and linear extent between 2 points. However, lot of time is consumed in these methods.[9,10] These methods are also subjected to error by operator because they are technique sensitive methods. Nowadays three-dimensional superimposition techniques has been introduced. These

methods are believed to more clinically relevant to assess adaptation of denture base as well as adjustment of fixed prosthesis.[11,12]

As per the knowledge of the authors there has been no study conducted till now to assess the role of various cooling methods in adaptation of denture base using fast heat activated acrylic. This study was conducted with an ambition to analyse the effect of various methods of cooling over the adaptation of denture base of 2 fast setting heat activated polymethyl methacrylate denture base materials easily available in market using three dimensional superimposition technique.

METHODS AND MATERIALS

Preparation of cast for reference and scanning procedure.

Once there was approval from ethical committee, research was started as in vitro study. Next step was the preparation of a cast to be used as reference in this study. Class 1 type A edentulous maxillary cast as per the guidelines of the American College of Prosthodontists was choosen as the reference cast model. Silicone based material was used for duplication of the reference cast. Sixty stone models were prepared. Type IV dental stone was used for pouring of the duplication mould. These sixty study models were divided into five categories X1, X2,X3,X4,X5 with each category consisting of 12 study models according to the method of cooling and material used. (Table1). Every cast of the study was labelled properly. Each cast was left as such before scanning for twenty four hours for drying. Then there was scanning and digitization of each cast was carried out with the help of 3 Shape E1 dental laboratory scanner.

Table 1: Types of procedure for cooling used in the study

Category	Details about the method of cooling
X1	Thirty minutes process of bench cooling followed by twenty minutes of immersion in water bath at room temperature of 23°C
X2	Process of bench cooling in anticipation of complete cooling
X3	Thirty minutes process of bench cooling followed by fifteen minutes of immersion in water bath at room temperature of 23°C
X4	Five minutes process of bench cooling followed by five minutes treatment in flowing water.
X5	Five minutes immersion into water bath feeded with flowing water at room temperature.

Preparation of specimens of denture base

A pattern of wax was prepared throughout the cast of reference. The thickness of wax pattern was kept at 2.0 millimetre. In order to standardize thickness of wax pattern in all study specimens, a matrix of silicone was utilized to replicate the specimens. Compression moulding technique was used for flasking of each specimen of the denture base. Then there was curing based on heat. It was carried out in hot water tab. The temperature used for heat activation process was 100°C while the duration was of twenty minutes.

Cooling process of the denture base & analysis in three dimensional plane

There were sixty study specimens. They were categorised in five categories on the basis of the cooling method employed according to Table 1. After cooling of the specimens there was hydration in the distilled water. This hydration was carried out before scanning process for duration of twenty four hours. Then the scanner was used to carry out scanning of the intaglio side of every denture base specimen. In order to have similar position for scanning process silicone putty was used. All specimens were kept in identitical position for scanning process. (STL) Standard Tessellation Language format was used to save the data obtained after three dimensional scanning of the denture base specimens. Then the data was transferred to well acclaimed software (3-matric, Belgium).

All unrelated scanned sides were removed virtually. Then there was superimposition of STL file of every intaglio surface of the denture base with the corresponding STL file of the master cast. This was carried out to analyse the degree of of adaptation of denture base in each specimen. Four anatomical landmarks were chosen for matching in the superimposition of denture base scanned image over the master cast scanned image. These landmarks were fovea palatine, incisive papilla and buccal frenum. It was taken care that there was complete superimposition between the complete tissue surfaces associated with denture base and the corresponding area in the master cast.

Differences in the dimensions of both denture base surface and the corresponding surface of the master cast were evaluated. It was accompanied with generation of colour maps of surfaces. These colour maps helped in the qualitative evaluation visually. Following parameters were used for assessment of the colour maps. If there is perfect adaptation between the master cast and denture there colour map will appear as complete green and the measurement will be zero. If there is change in colour from yellow to red then it corresponds to deviation with positive values. It will indicate incomplete adaptation with gapping. If there is change in colour from cyan to blue then it corresponds to deviation with negative values. It will specify compression of tissues. This indicates towards impingement of master cast with the denture base. (Figure 1 and 2)

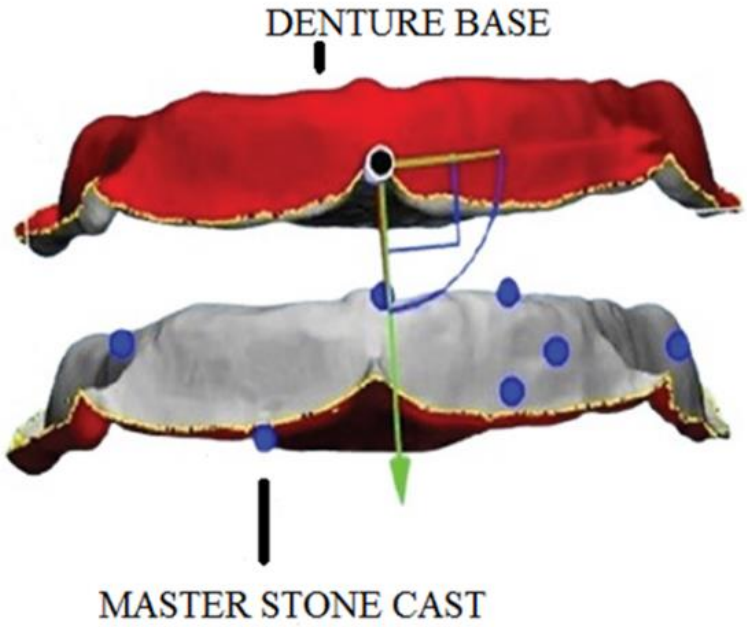

Figure 1: Representative figure of superimposition of scanned image of denture base over the master stone cast

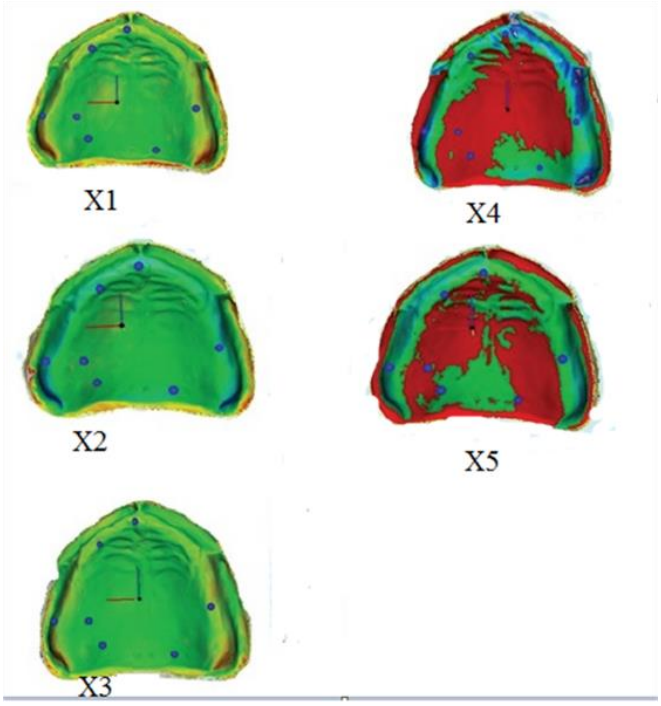

Figure 2: Representative photograph showing the colour maps reflecting the differences in the adaptability of denture base and master cast.

Statistical analysis

All the data was collected and put in the MS excel sheet. Then statistical analysis was carried out with the SPSS software of latest version. One way ANOVA, Turkey Hoc test, Chi square test and Bonferroni Hoc analysis were used in the statistical analysis.RMS (root mean square) values, mean, median and IQR (Interquartile range) values were analysed. P value ≤0.05 was kept as statistically significant.

RESULTS

Maps showing deviation in colours specifying the adaptation of denture base with the master cast of each group is reflected in the figure 2. Broad area of green colour in the palate was observed in the specimens of X1, X2 and X3 categories. Specimens belonging to X4 and X5 categories showed greater red coloured areas at the location of post dam area and palate area. When the deviations was measured between the scanned surface of master cast and scanned surfaces of denture bases then the mean±SD in category X1 was -0.004±0.008 mm, IQR in mm in X1 was 0.154mm, median in X1 was 0.416 mm and RMSE in X1 was 0.426mm. The mean±SD in category X2 was 0.393±0.009 mm, IQR in X2 was 0.137mm, median in X2 was 0.411 mm and RMSE in X1 was 0.291mm. The mean±SD in category X3 was 0.403±0.011 mm, IQR in X3 was 0.146mm, median in X3 was 0.403 mm and RMSE in X3 was 0.403 mm. The mean±SD in category X4 was 0.437±0.131 mm, IQR in X4 was 0.182mm, median in X4 was 0.414 mm and RMSE in X4 was 0.403 mm. The mean ± SD in category X5 was 0.414±0.008 mm, IQR in X5 was 0.169 mm, median in X5 was 0.414 mm and RMSE in X5 was 0.423 mm.(Table 2). On the basis of statistical analysis it was found that there were no statistical significant differences between group X1 and X2 specimens. It reflected that there was similarity in the accuracy of both X1 specimens and X2 specimens. It was also observed that differences were statistically significant between specimens of X2 category and X3 category. Besides there was significant difference between X2 and X5 specimens. (Table 2)

Table 2: Measurements of deviations of surface between scanned maxillary arch and scanned denture base

Mean	Calculated Mean±SD (mm)	Calculated IQR (mm)	Calculated Median (mm)	Calculated RMSE (mm)
X1	–0.004±0.008	0.154	0.416	0.426
X2	0.393±0.009	0.137	0.411	0.291
X3	0.403±0.011	0.146	0.403	0.403
X4	0.437±0.131	0.182	0.414	0.416*
X5	0.414±0.008	0.169	0.281	0.423*

From these results it was inferred that specimens which underwent bench cooling showed better dimensional accuracy in comparison with the rapidly cooling techniques used in the study.

DISCUSSION

Enhanced patient comfort, improved chewing competency, and suppression of hyperplastic diseases are all important results of well adapted prosthesis. The flexibility of a prosthesis is influenced by a number of factors. These variables include the type of acrylic resin utilised in denture production, the curing cycle used, and the water uptake process. Another important component in maintaining the accuracy of denture dimensions is the chilling mechanism used for the flasks throughout the acrylization process.[13,14]

Longer cooling reduces the lingering interior stress in the flasks that develops as a result of the heat triggered process. As a result, the denture is only slightly damaged during the deflasking process. Traditional cooling methods, on the other hand, are time-consuming, making them inappropriate for emergency situations, community health programmes in villages, and senior patients whose primary goal is to shorten denture implantation time. In 1937, polymethyl methacrylate was introduced into the realm of prosthodontics with the aim of preparing detachable dentures.[15,16]

It has some key characteristics that made it an excellent candidate for acrylization of detachable dentures. Reduced cost, sufficient mechanical power, and stimulating operating properties were among these features. Significant research has recently been conducted on this acrylic material in order to reduce the time required for the preparation and insertion of removable dentures. Recently, a rapid twenty minute heat activated polymethy methacrylate was introduced. Since then, a number of studies have been conducted to show that there are significant differences between the quick twenty-minute heat activation cycle and the cautious protracted heat activation cycle.[17,18]

According to the authors' knowledge, no study has been undertaken to date to evaluate the role of various cooling methods in denture base adaption utilising quick heat activated acrylic. The goal of this study was to see how different cooling procedures affected the adaption of two fast-setting heat-activated polymethyl methacrylate denture base materials that are readily accessible on the market.[19,20]

In the X1, X2, and X3 categories, there was a broad area of green colour in the pallet. Specimens in the X4 and X5 groups have more red coloured regions in the post dam area and the palate area. According to statistical analysis, there were no statistically significant differences between group X1 and group X2 specimens. It showed that the accuracy of both X1 and X2 specimens was similar. It was also shown that there were statistically significant variations between specimens from the X2 and X3 categories.

Aside from that, the X2 and X5 specimens differed significantly. From these findings, it was deduced that specimens subjected to bench chilling had superior dimensional precision than those subjected to the study's quick cooling techniques. Several approaches have been developed to investigate the impact of a shortened cooling curing period on the dimensional accuracy of denture base material during prosthesis production. Quantification of space using silicone weight and linear distance between two places are two of these ways. However, these approaches take a lot of time.

The technique of three-dimensional superimposition has recently been introduced. These methods are thought to be more clinically useful for assessing denture base adaptation as well as fixed prosthesis modification. Virtually all

unconnected scanned sides were eliminated. The STL file of each intaglio surface of the denture base was then superimposed on the matching STL file of the master cast.[21,22] This was done to determine the degree of denture base adaption in each specimen. In the superimposition of the denture base scanned picture over the master cast scanned image, four anatomical landmarks were chosen for matching. The fovea palatine, incisive papilla, and buccal frenum were the landmarks. It was made sure that the whole tissue surfaces associated with the denture base and the matching area in the master cast were completely superimposed.Differences in the dimensions of the denture base surface and the master cast's matching surface were measured. It was accompanied by the creation of surface colour maps.[23,24]
Visually, these colour maps aided in the qualitative evaluation. The colour maps were evaluated using the parameters listed below. If the master cast and denture are perfectly adapted, the colour map will appear completely green, and the measurement will be zero. When the colour changes from yellow to red, it indicates a deviation with positive values. It will imply gapping and incomplete adaption. When the colour changes from cyan to blue, it indicates a deviation with negative values. It will specify tissue compression.[25,26]
This indicates that the master cast is in contact with the denture base. According to statistical analysis, there were no statistically significant differences between group X1 and group X2 specimens. It showed that the accuracy of both X1 and X2 specimens was similar. It was also shown that there were statistically significant variations between specimens from the X2 and X3 categories. Aside from that, the X2 and X5 specimens differed significantly. From these findings, it was deduced that specimens subjected to bench chilling had superior dimensional precision than those subjected to the study's quick cooling techniques.[27,28]
There were some flaws in this research. The effects of saliva and mouth opening on the outcomes were not examined in this in vitro study. The analysis was performed by a professional, and the technique was tough to use and comprehend. The study's sample size was tiny in this case.[29,30,31] As a result, future investigations using in vivo conditions and a bigger sample size should be conducted.

CONCLUSION

From these results it was inferred that specimens which underwent bench cooling showed better dimensional accuracy in comparison with the rapidly cooling techniques used in the study.

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REFERENCES

1. Chander NG. Polymethyl metha acrylate denture base: An overview. J Indian Prosthodont Soc 2018;18:87.
2. Ali AA, John J, Mani SA, El-Seedi HR. Effect of thermal cycling on flexural properties of microcrystalline cellulose-reinforced denture base acrylic resins. J Prosthodont 2019;29:611-6.
3. Firtell DN, Green AJ, Elahi JM. Posterior peripheral seal distortion related to processing temperature. J Prosthet Dent 1981;45:598-601.
4. de Negreiros WA, Consani RL, Verde MA, da Silva AM, Pinto LP. The role of polymerization cycle and post-pressing time on tooth movement in complete dentures. Braz Oral Res 2009;23:467-72.
5. Polychronakis N, Yannikakis S, Zissis A. A clinical 5-year longitudinal study on the dimensional changes of complete maxillary dentures. Int J Prosthodont 2003;16:78-81.
6. Kimoto S, Kobayashi N, Kobayashi K, Kawara M. Effect of bench cooling on the dimensional accuracy of heat-cured acrylic denture base material. J Dent 2005;33:57-63.
7. Consani RL, Domitti SS, Mesquita MF, Consani S. Influence of flask closure and flask cooling methods on tooth movement in maxillary dentures. J Prosthodont 2006;15:229-34.

8. Keenan PL, Radford DR, Clark RK. Dimensional change in complete dentures fabricated by injection molding and microwave processing. J Prosthet Dent 2003;89:37-44.
9. Habib SR, Al Otaibi AK, Al Anazi TA, Al Anazi SM. Comparison between five CAD/CAM systems for fit of zirconia copings. Quintessence Int 2018;49:437-444.
10. McLaughlin JB, Ramos V Jr., Dickinson DP. Comparison of fit of dentures fabricated by traditional techniques versus CAD/CAM technology. J Prosthodont 2019;28:428-35.
11. Brosky ME, Pesun IJ, Lowder PD, DeLong R, Hodges JS. Laser digitization of casts to determine the effect of tray selection and cast formation technique on accuracy. J Prosthet Dent 2002;87:204-9.
12. Goodacre BJ, Goodacre CJ, Baba NZ, Kattadiyil MT. Comparison of denture base adaptation between CAD-CAM and conventional fabrication techniques. J Prosthet Dent 2016;116:249-56.
13. McGarry TJ, Nimmo A, Skiba JF, Ahlstrom RH, Smith CR, Koumjian JH. Classification system for complete edentulism. J Prosthodont 1999;8:27-39.
14. Norvell NG, Korioth TV, Cagna DR, Versluis A. Comparison of digital surface displacements of maxillary dentures based on noninvasive anatomic landmarks. J Prosthet Dent 2018;120:123-31.
15. Skinner EW, Jones PM. Dimensional stability of self-curing denture base acrylic resin. J Am Dent Assoc 1955;51:426-31.
16. Ceruti P, Mobilio N, Bellia E, Borracchini A, Catapano S, Gassino G. Simplified edentulous treatment: A multicenter randomized controlled trial to evaluate the timing and clinical outcomes of the technique. J Prosthet Dent 2017;118:462-7.
17. John J, Ann Mani S, Palaniswamy K, Ramanathan A, Razak AA. Flexural properties of poly (methyl methacrylate) resin reinforced with oil palm empty fruit bunch fibers: A preliminary finding. J Prosthodont 2015;24:233-8.
18. Allen PF, McMillan AS. A longitudinal study of quality of life outcomes in older adults requesting implant prostheses and complete removable dentures. Clin Oral Implants Res 2003;14:173-9.
19. Jadhav SS, Mahajan N, Sethuraman R. Comparative evaluation of the amount of the residual monomer in conventional and deep-frozen heat cure polymethylmethacrylate acrylic resin: An *in vitro* study. J Indian Prosthodont Soc 2018;18:147-53.
20. Sakaguchi RL, Ferrancane J, Powers JM. Craig's Restorative Dental Materials. 14th ed. St Louis: Elsevier; 2012.
21. Lee CJ, Bok SB, Bae JY, Lee HH. Comparative adaptation accuracy of acrylic denture bases evaluated by two different methods. Dent Mater J 2010;29:411-7.
22. Basso MF, Giampaolo ET, Machado AL, Pavarina AC, Vergani CE. Evaluation of the occlusion vertical dimension of complete dentures after microwave disinfection. Gerodontology 2012;29:e815-21.
23. Campos MS, Cavalcanti BN, Cunha VP. Occlusal changes in complete dentures processed by pack-and-press and injection-pressing techniques. Eur J Prosthodont Restor Dent 2005;13:78-80.
24. Hsu CY, Yang TC, Wang TM, Lin LD. Effects of fabrication techniques on denture base adaptation: An *in vitro* study. J Prosthet Dent 2020;124:740-7.
25. Cole D, Bencharit S, Carrico CK, Arias A, Tüfekçi E. Evaluation of fit for 3D-printed retainers compared with thermoform retainers. Am J Orthod Dentofacial Orthop 2019;155:592-9.
26. Hwang HJ, Lee SJ, Park EJ, Yoon HI. Assessment of the trueness and tissue surface adaptation of CAD-CAM maxillary denture bases manufactured using digital light processing. J Prosthet Dent 2019;121:110-7.
27. Manjin Z, Mariko H, Yuka S, Kelimu ME, Rongguang L, Yuan G, *et al.* OSC10: Observation of the teeth position in cleft lip and palate patients using three-dimensional assessment. J Indian Prosthodont Soc. 2018;18 (Suppl 1):S11.
28. Dastane A, Vaidyanathan TK, Vaidyanathan J, Mehra R, Hesby R. Development and evaluation of a new 3-D digitization and computer graphic system to study the anatomic tissue and restoration surfaces. J Oral Rehab 1996;23:25-34.

29. Artopoulos A, Juszczyk AS, Rodriguez JM, Clark RK, Radford DR. Three-dimensional processing deformation of three denture base materials. J Prosthet Dent 2013;110:481-7.
30. Fenlon MR, Juszczyk AS, Rodriguez JM, Curtis RV. Dimensional stability of complete denture permanent acrylic resin denture bases; a comparison of dimensions before and after a second curing cycle. Eur J Prosthodont Restor Dent 2010;18:33-8.
31. Laot CM, Marand E, Schmittmann B, Zia R. Effects of cooling rate and physical aging on the gas transport properties in polycarbonate. Macromolecules 2003;36:8673-84.