Linear dimensional changes and surface hardness of acetal resin in different periods of artificial saliva immersion in comparison with heat cure acrylic.

Sura S. Khalid [(1)] Widad A. AL-Nakkash [(1)]

Background and Objectives: Acetal resins have a sufficiently high impact strength and resistance to organic solvents, the aim of this study was to evaluate the linear dimensional changes and surface hardness of acetal resin and compare it with heat cure denture base resin in different periods of artificial saliva immersion.

Methods: Forty specimens were divided into two main groups according to the type of material used (heat cure resin and acetal resin). For each test 10 specimens were used**.** In this study two tests were performed. 10 maxillary denture bases for linear dimensional change by using digital microscope (Dino-lite Digital microscope) to measure the linear distance between reference points on the denture base. Measurements were per formed in four interval times first after processing, second after storage in the artificial saliva for 24 hours, third after storage in saliva for 15 days, and fourth after storage in saliva for 30 days. Also 10 specimens for Rockwell surface hardness test were prepared in this study**.**

Results: For the linear dimensional change test, after processing T-test revealed a highly significant difference between acrylic and acetal groups in the AB line, a significant difference between the studied groups in the CD line, and a non-significant difference between the studied groups in BC, DA lines. While after immersion in saliva for 24 hrs., 15 days, 30 days: T- test revealed no significant difference between acrylic and acetal groups.

The acetal group exhibited higher surface hardness mean value (92.90); while the acrylic group exhibited a lower mean value (74.53)

Conclusion: Acetal resin can be used with limitation as an alternative to acrylic denture base in removable partial and complete dentures. Concerning linear dimensional change after processing: Nonsignificant difference between acrylic and acetal in BC, DA lines, statistically highly significant difference in AB line and significant difference in CD line. The immersion in saliva for three periods- 24hrs, 15 days, 30 days has no significant diffeence on linear dimensional change on both acrylic and acetal denture bases. Acetal group exhibited higher surface hardness than acrylic group.

Keywords:

linear dimensional changes, acetal, and Rockwell hardness**,** thermoplastic materials.

[(1)]Department of Prosthodontics, collage of Dentistry, Baghdad university, Baghdad, Iraq.

Correspondent Name: - Sura S. Khalid

Email: Dr.surasaleem@yahoo.com

Introduction

Removable partial dentures made without dimensional changes are more pleasing. The extents of dimensional changes are influenced by the polymerization systems and the type and quantity of the denture materials.[1]

Dimensional changes caused by water uptake are influenced by the storage period and may compensate for the polymerization shrinkage to a certain extent.[2]

Patients often cite lack of retention and poor esthetics as a reason for not wearing their partial dentures. Metal display on anterior teeth was often unacceptable.[3] Aesthetically pleasing removable partial denture (RPD) is a partial denture that blends in with the natural dentition and the one that does not show any indications of being a removable partial denture. Removable partial dentures made without a metal substructure are more aesthetically pleasing.

The possibility of injecting the resin into the mold has opened a new perspective on full denture and R.P.D. technology [4].

Research in polymer science has provided us with an alternative material called "Acetal resin". Also known as Polyoxymethylene (POM), acetal resin is formed by the polymerization of formaldehyde and is a thermoplastic techno polymer with a monomer-free crystalline structure [5].

The homopolymer, Polyoxymethylene (POM) is a chain of alternating methyl groups linked by an oxygen molecule. This material has been shown to have good biocompatibility and this has fostered its use in total hip replacement and as artificial valve occluders [6] It has also been used to form stress-absorbing component in a dental implant system (IMZ) [7].

Acetal resins are fast emerging as a successful denture base material, as tooth- colored clasps and in various other dental applications, proving to be the "Gen- X material in aesthetic restorative dentistry[8]".

Acetal resin is a very strong material, it resists wear and fracturing, and it is quite flexible. These characteristics make it an ideal material for pre-formed clasps for partial dentures, single pressed unilateral partial dentures, partial denture frameworks, provisional bridges, occlusal splints, and even implant abutments. Acetal resins resist occlusal wear and are well suited for maintaining vertical dimension during provisional restorative therapy [9,10].

Acetal does not have the natural translucency and vitality of thermoplastic acrylic and polycarbonate, and these materials might offer better results for short term temporary restorations[11].

Acetal RPDs are conFigured like metal framework RPDs, except that they are bulkier. Acetal resins are pressed at temperatures higher than nylon, which leads to less creep and superior dimensional stability. In vitro study has indicated that acetal occlusal rests can adequately support distal-extension RPDs for up to 3 years [12].

OBJECTIVES: It has been pointed out that there are five ways in which dimensional changes can take place in denture resin. These include water sorption, gain or loss of water, thermal changes, release of internal strain, chemical changes during processing and continued curing after being placed in service, and in complete denture polymerization[13,14.]

The objective of this study is to measure the linear dimensional change of acetal resin and compare it with heat cure acrylic as conventional material used in most removable dentures also to measure the linear dimensional change of these materials in three periods of immersion in artificial saliva. The other test was Rockwell hardness test to measure surface hardness of both materials

METHODS

A total No. of 40 specimens were divided into two main groups according to the type of material used (heat cure resin and acetal resin). Each main group was subdivided into two subdivisions according to the type of test used, for each test 10 specimens were used. 20 maxillary denture bases, 20 specimens for surface hardness, were prepared in this study.

Preparation of specimens for surface hardness test:

Plastic patterns were used to prepare acrylic specimens, these patterns were constructed by cutting plastic plate of certain thickness (2.5 mm) length (10mm) width (6.5mm) according to the American dental association[15] by using a highly accurate laser cutting machine for surface hardness.

Denture bases preparation for measuring the linear dimensional change

20 maxillary edentulous casts were prepared from an edentulous silicon mold. Dental stone type IV was mixed according to manufacture instructions.

Record base preparation:

20 samples for denture base were prepared using a biostar machine (Scheu – dental, Germany). The biostar (thermoplastic sheet) ;2mm thickness, clear, hard (imprelon, Scheu-Dental, Germany).

Reference point for linear measurements:

With aid of a record base made of biostar sheet, the reference points were marked on the cast. Four holes were made on record base on the position of the canine and 2nd molar on the right side and the same on the left side. The screws were fitted in the prepared holes. The size of screw was medium

number 5 for all holes and all casts.

Preparation of heat cured acrylic denture base:

Mould preparation:

The lower portion of the metal flask was filled with mixture of type IV dental stone (Zhermack, Germany) mixed according to manufacturer's instructions, and the cast and record base were inserted.

When the metal flask was opened after the complete set of the stone, the record base was removed from the mould carefully; the two portions of the metal flask were coated with a separating medium (vertex thermoflow) to be ready for packing with acrylic dough.

Preparation of acrylic resin dough

The proportion of mixing for acrylic resin was (3:1 /vol.) (P/L); according to manufacture instructions,

Packing of acrylic resin

Packing was started when the acrylic reached to dough stage, the resin was removed from the jar and rolled, then packed into mold previously coated with a separating medium, the two portions of the flask were closed together with a polyethylene sheet between them and placed under the hydraulic press under the pressure of 100 Bar for 5 min. A Second trail closure was performed without a polyethylene sheet and the flask was left under the press for 5 minutes before clamping then transferred to the water bath.

Curing

Curing was carried out by placing the flasks in a clamp and immersed in a digital water bath at 70°C for 90 min then the temperature was raised to100°C for 30 min according to manufacturer instructions.

Investing and injecting of acetal denture base:

A dental stone mix was poured into the lower half of the flask, then the cast and record base were inserted into the stone mix. After the stone was set, it was coated with a separating medium and allowed to dry, then wax sprues(Vertex Thermosens) were prepared to the required length - major sprues and minor sprues were attached to selected areas of the record base. The upper portion of the metal flask was positioned on top of the lower portion and filled with stone, after setting wax elimination was done by immersion of metal flask in hot water for 69 degrees for 10 minutes according to manufacturer instruction.

After cooling the flask is allowed for inserting into Vertex Thermoject 22, thus starting the injection of acetal resin material as shown in Figures1,2

Measurement of denture base linear dimensional change:

A digital microscope (Dino-lite Digital microscope) was used to measure the linear distance between reference points on the denture base. Measurements were performed in four interval times first after processing, second after storage in the artificial saliva for 24 hours, third after storage in saliva for 15 days, and fourth after storage in saliva for 30 days.

The linear dimensional change was performed by measuring the distance between the reference points as follows AB, BC, CD, DA. Line AB represents the distance from left canine to right canine.

Line BC represents the distance from the right canine to right 2nd molar. While line CD represents a distance from the right 2nd molar to the left 2nd molar. The last line is DA represents a distance from the left 2nd molar to the left canine. By using a digital microscope at a magnification of 18X, all four reference points were clear. Measurements were performed at five periods: first before processing, second after processing, third after storage in artificial saliva in24 hours, fourth after storage in saliva for 15 days, and fifth after storage in saliva for 30 days.

Preparation of Artificial saliva:

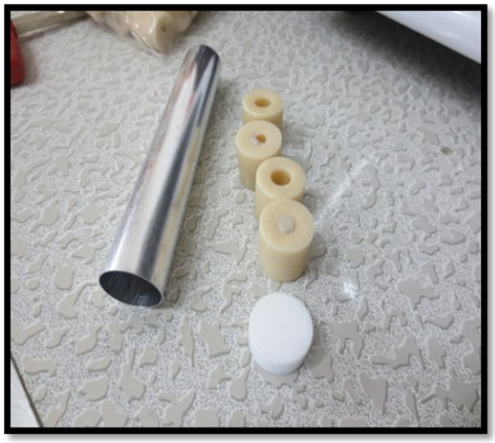


Figure 1: Large vertex cartridge, acetal dics, and replica

Figure 2: Vertex™ ThermoJect 22 Injecting Machine

To prepare 1 liter of artificial saliva, different materials each of them at specific concentrations were dissolved in (985.5) ml de–ionized water.

These materials are:

1. Sodium carboxymethyl cellulose…10g
2. Sodium chlride……1g
3. Sodium fluoride ……...0.0002g
4. Calicum chloride……0.05g
5. Potassium thiocyanate……0.01g
6. Sorbitol……...1g
7. Potassium chloride……1g
8. Magnisium chloride……...0.05g
9. Potassium phosphate……...0.04g

Then Sodium carboxymethyl cellulose was dissolved in 100 ml boiling water and after cooling, each other material was dissolved in de-ionized water and added to sodium carboxymethyl cellulose solution, the PH of prepared saliva was equal to seven[16].

The pH of saliva was changed within 48h. It was decided that the artificial saliva solution should be changed every 24 h.

Storage in Artificial saliva:

All the specimens were stored in artificial saliva inside the incubator at 37C˚ for 16 hours and for 8 hours inside the distilled water at room temperature to simulate the daily usage of the denture by the patient. This cycle was repeated for each specimen for 30 days for measurement of linear dimensional change.

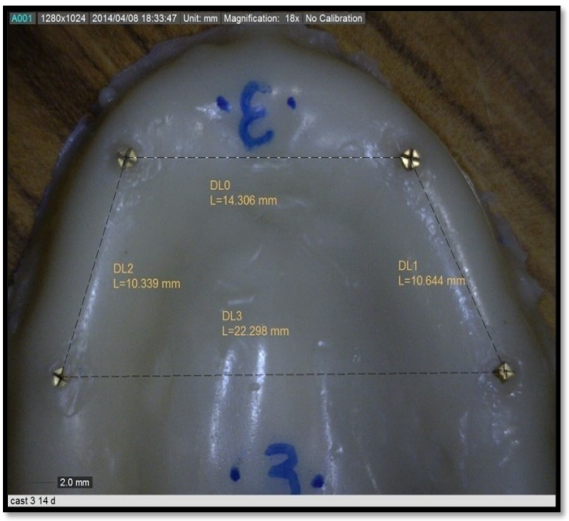


Figure 3: Measurement of linear dimensional changes using digital microscope on acetal denture base under magnification 18X.

Surface hardness test:

Surface hardness was determined by using a digital general hardness tester. Rockwell hardness testing is performed by first forcing a steel ball indenter into the surface of a material using a specified minor load. The load is then increased to a specified major load and then decreased back to the original minor load. Five readings were calculated for on each specimen, then the mean of five readings was registered.

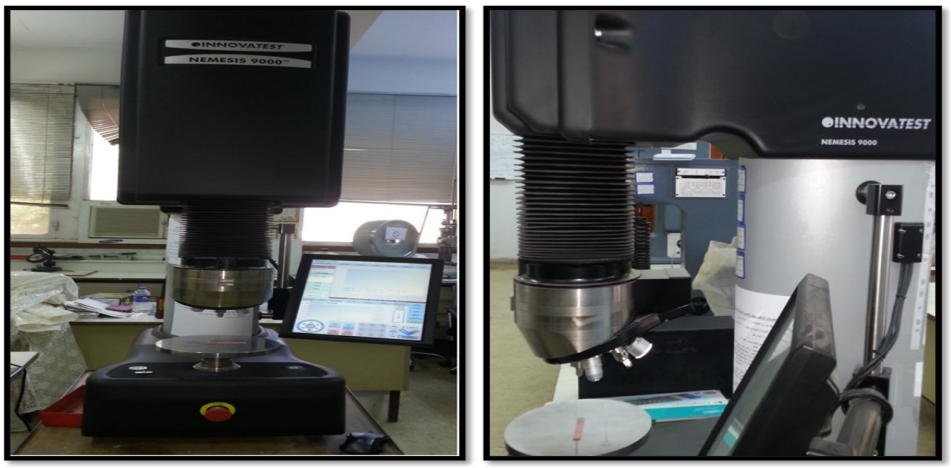


Figure 4: Digital general hardness tester (INNOVATEST. Company NEMESIS) Model no 9001, 2012

RESULTS

The data collected of the specimens were translated to computerized statistical analysis system by using (SPSS) statistical package for social sciences version 16.

A. Descriptive statistics: Mean, standard deviation (SD), standard error (SE),minimum (Min)

maximum (Max), statistical tables and graphical presentation by (bar-chart).

B. Inferential statistics

ANOVA (one way analysis of variance test) for assessing difference between more than two groups.

For more comparison between each group and the control, Dunnett t-test applied to see significances of all groups with control group. For the linear dimensional change test, after processing T-test revealed a highly significant difference between acrylic and acetal groups in the AB line, a significant difference between the studied groups in the CD line, and a non-significant difference between the studied groups in BC, DA lines. While after immersion in saliva for 24 hrs., 15 days, 30 days: T- test revealed no significant difference between acrylic and acetal groups as shown in Figure (5). The acetal group exhibited higher surface hardness mean value (92.90); while the acrylic group exhibited a lower mean value (74.53) as shown in Figure (6).

Table 1: Comparison the difference in each line between two periods-before and after processing _for acrylic and acetal groups.

Lines	Times	Descriptive statistics					Groups' difference		
		N	Acrylic		Acetal				
			Mean	S.D.	Mean	S.D.	Mean difference	t-test	p-value
AB	Before - Immediate	10	0.10	0.04	0.04	0.05	0.063	3.043	0.007 (HS)
BC	Before - Immediate	10	0.07	0.03	0.05	0.02	0.021	1.807	0.087 (NS)
CD	Before - Immediate	10	0.15	0.06	0.09	0.04	0.061	2.600	0.018 (S)
DA	Before - Immediate	10	0.06	0.03	0.05	0.04	0.011	0.742	0.467 (NS)

Table 2: Comparison the difference in each line between two periods –immediate and after 24hrs immersion in saliva _for acrylic and acetal groups (mm).

Lines	Times	Descriptive statistics					Groups' difference		
		N	Acrylic		Acetal				
			Mean	S.D.	Mean	S.D.	Mean difference	t-test	p-value
AB	Immediate - 24 hr	10	-0.04	0.06	-0.01	0.05	-0.032	-1.254	0.226 (NS)
BC	Immediate - 24 hr	10	-0.04	0.03	-0.02	0.03	-0.019	-1.449	0.165 (NS)
CD	Immediate - 24 hr	10	-0.04	0.10	-0.04	0.05	0.001	0.029	0.977 (NS)
DA	Immediate - 24 hr	10	-0.03	0.04	-0.02	0.03	-0.014	-0.959	0.350 (NS)

Table (3) Comparison the difference in each line between two periods –24hrs immersion in saliva and 15 days _for acrylic and acetal groups

Lines	Times	Descriptive statistics					Groups' difference		
		N	Acrylic		Acetal				
			Mean	S.D.	Mean	S.D.	Mean difference	t-test	p-value
AB	24 hr - 15 days	10	0.05	0.09	0.08	0.06	-0.033	-0.991	0.335 (NS)
BC	24 hr - 15 days	10	0.04	0.04	0.06	0.05	-0.016	-0.760	0.457 (NS)
CD	24 hr - 15 days	10	0.06	0.10	0.12	0.09	-0.062	-1.468	0.159 (NS)
DA	24 hr - 15 days	10	0.05	0.05	0.06	0.03	-0.011	-0.558	0.584 (NS)

Table (4) Comparison the difference in each line between two periods –15days and 30 days immersion in saliva _for acrylic and acetal groups.

Lines	Times	Descriptive statistics					Groups' difference		
		N	Acrylic		Acetal				
			Mean	S.D.	Mean	S.D.	Mean difference	t-test	p-value
A-B	**15 days- 30 days**	**10**	**-0.06**	**0.03**	**-0.06**	**0.03**	**0.002**	**0.104**	**0.918 (NS)**
BC	**15 days- 30 days**	**10**	**-0.02**	**0.05**	**-0.05**	**0.02**	**0.027**	**1.565**	**0.135 (NS)**
CD	**15 days- 30 days**	**10**	**-0.10**	**0.04**	**-0.09**	**0.02**	**-0.002**	**-0.177**	**0.862 (NS)**
DA	**15 days- 30 days**	**10**	**-0.05**	**0.03**	**-0.04**	**0.02**	**-0.011**	**-0.897**	**0.382 (NS)**

Figure (5) Comparison the linear dimensional changes between the acrylic and acetal groups in each time and line.

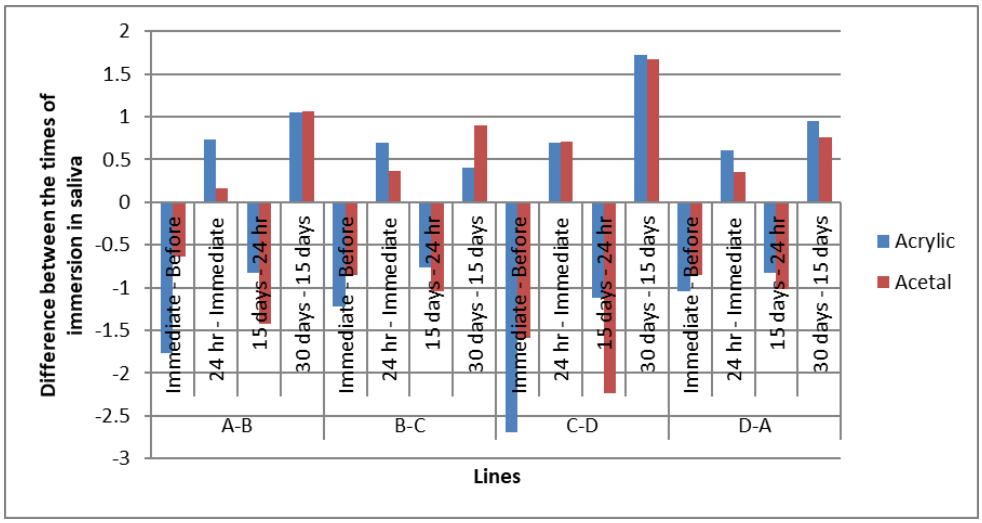
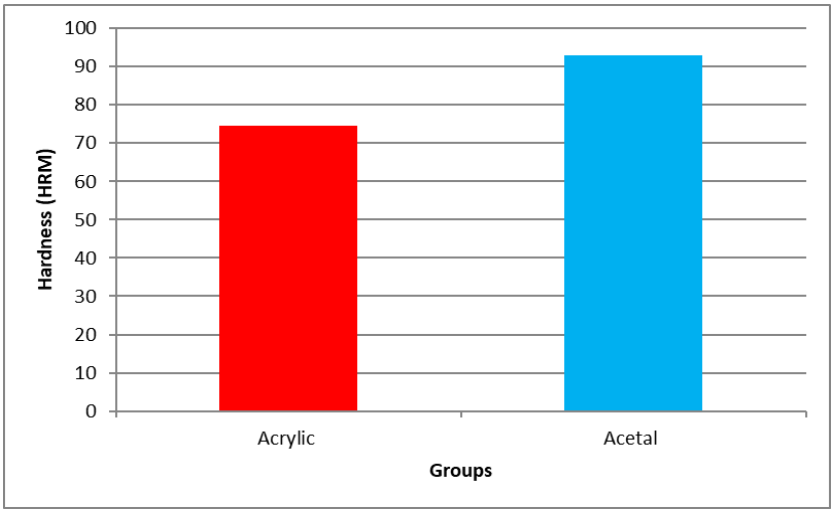


Figure (6) Bar chart of surface hardness test between studied groups



Discussion

The effect of the material on linear dimensional change:

The results revealed that heat cure acrylic denture bases had undergone higher shrinkage than acetal after processing.

These results could be due to of polymerization contraction, thermal contraction, or even internal stress release and this is in agreement with Woefel 17.The effect of saliva on linear dimensional change:

A. After immersion in saliva for 24hrs:

Expansion of acrylic greater than that for acetal resin could be explained as the amount of crystallinity present in a polymer which affects its properties. The acetal polymers exhibit high crystallinity 18, but Polymethyl methacrylate is a non-crystalline structure possessing high internal energy. Thus, molecular diffusion can occur in the resin, where less activation energy is required 19.

B. After immersion in saliva for 15 days:

Both acrylic and acetal materials had undergone shrinkage after immersion in saliva for 15 days. The cause of shrinkage in acrylic could be related to loss of free monomer in liquid or could be due to continuous polymerization this is in agreement with many other studies 17,20,21.

While for acetal linear dimensional shrinkage could be related to post-molding shrinkage, here the shrinkage can result from the high crystallinity which develops on cooling.

So, immersion in saliva for 15 days may not cause expansion. Where only the effect of polymerization shrinkage was evident this could be due to the fact that water absorption of acetal requires a longer time; since acetal highly crystalline has atoms with a very regular arrangement in space, and absorb less water than do non-crystalline materials 22.

C. After immersion in saliva for 30 days:

Both acrylic and acetal materials had undergone expansion after immersion in saliva for 30 days. poly (methyl methacrylate) exhibits a tendency to absorb water by a process of imbibition. Its non-crystalline structure. Thus, molecular diffusion can occur in the resin, because less activation energy is required. Furthermore, the polar carboxyl group, even though it esterifies, can form a hydrogen bridge to a limited extent with water 19. In Acetal resin, Due to the fact that C_O bond is balanced and much less polar than the carbonyl group present in nylon. The acetal resins are known to have relatively low water absorption. The small amount of moisture absorbed could cause swelling and dimensional changes 23.

Surface hardness test:

The acetal resin group exhibited higher surface hardness than acrylic resin. Acetals are highly crystalline, typically 75% crystalline,

and the chains pack closer together because of the shorter C_O bond 24.

CONCLUSION

Results revealed that heat cure acrylic dentures had undergone higher shrinkage than acetal. Expansion of acrylic greater than that for acetal resin could be explained as the amount of crystallinity present in a polymer affecting its properties. Both acrylic and acetal materials had undergone shrinkage after immersion in saliva for 15 days and had undergone expansion after immersion in saliva for
30 days.
Acetal resin exhibited higher surface hardness.

Conflict of interest

The author reported no conflict of interests.

References

1.Keenan, P. L., Radford, D. R. and Clark, R. K.: "Dimensional Change in Complete Dentures Fabricated by Injection Molding and Microwave Processing" J Pros Dent. 2003; 89, 37-44.

2. Miessi AC, Goiato MC, dos Santos DM, Dekon SF, Okida RC.: "Influence of storage period and effect of different brands of acrylic resin on the dimensional accuracy of the maxillary denture base." Braz Dental J. 2008; 19:204–208.

3. Sykes LM, Dullabh HD, Chandler HD, Bunn B: Flexibility of techno polymer clasps compared with cobalt-chromium and titanium clasps. SADJ 2002; 57: 166-71.

4. Bortun C, Lakatos S, Sandu L, Negrutiu M, Ardelean L: Metal free removable partial dentures made of thermoplastic materials. TMJ 2006; 56:80-7.

5. Hristovl, Yankov S: Thermoplastic materials in the dental practice: a review. Int J Sci Res 2017;6:1074–1076.

6. Fitton J S, Davies EH, Homlett JA et al. The physical properties of a polyacetal denture resin. Clin Mater 1995; 17:125-129.

7. Kirsch A, Ackerman KL. The IMZ osseointegrated implant system. Dent Clin. North. Am., 1989; 33:733-91.

8.Thomas S, A and Nandini V.V "Acetal Resin -A Quantum Leap in Aesthetic Restorative Dentistry" Int. Journal of Clinical Dental Science2011;2 (4):56-59

9.Phoenix R.D., Mansueto M.A., Ackerman N.A., Jones R.E: "Evaluation of mechanical and thermal properties of commonly used denture base resin." J Prosthodont 2004; 13:17-27.

10.Ozkan, Y.; Arikan, A.; Akalin, B. & Arda T: A study to assess the colour stability of acetal resins subjected to thermocycling, European Journal of Prosthodontics and Restorative Dentistry 2005, Vol. 13, No. 1, pp. 10-14, (March 2005), ISSN 0965-7452.

11.Negrutiu M., Senescu C., Romanu M., Pop D. and Laktos S:"Thermoplastic resin for flexible framework removable partial dentures." Temisora Med J. 2005;55:295-299.

12.Ewoldsen N. "What are the clinical disadvantages and limitations associated with metal-free partial dentures". J Can Dent Assoc. 2007; 73: 45-46.

13.Takamata T, Setcos JC, Phillips RW, Boone ME:"Adaptation of acrylic resin denture as influenced by the activation mode of polymerization". J Am Dent Assoc 1989; 119:271-276.

14.Chen JC, Lacefield WR, Castleberry DJ:" Effect of denture thickness and curing cycle on the dimensional stability of acrylic resin denture bases". Dent Mater 1988; 4:20-24.

15. American Dental Association Specification no.12 for denture base polymer guide to dental materials and devices, 7PthP edition, Chicago Illinois (1999).

16. Björklund M, Ouwehand A ,Forssten S:.Improved artificial saliva for studying cariogenic effect of carbohydrates. Curr Microbiol 2011; 63(1):46-9.

17. Woefel JB. Processing complete dentures. DentClin North Am 1977,21:329-338.

18. Brydson: plastics materials, 7th edition ,1999,pp537. ,.543).

19. Anusavice K.J.: P"PPhilips science of dental materials. Philadelphia: :WB Saunders; 2003 p.709

20. Baemmert R.J., Lang B.R. and Barco M.T. (1990): "Effect of denture teeth on the dimensional accuracy of acrylic resin denture bases." Int.J. Prosthodont;3: 528-537.

21. Philips RW. "Skinner's science of dental materials".9th ed. Philadelphia: WB saunders, 1991:177 -213.

22. O'Brien, W.J." Dental Materials and Their Selection." 3rd Edition. Quintessence Publishing, 2002:74-88,143.

23.Harper, Charles A." Modern Plastics Handbook" 1st ed. New York: McGraw-Hill. 2000: 15-18,1113

24.Gilbert, M. "Brydson's plastics materials".6th edition. Elsevier,2016:449-532.