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EVALUATION THE FATIGUE RESISTANCE AND COLOR STABILITY OF ACETAL RESIN AND BRE- FLEX (2nd EDITION) IN KENNEDY CLASS I REMOVABLE PARTIAL DENTURE. AN IN-VITRO STUDY

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ABSTRACT

Purpose: This study was aimed to compare and evaluate the fatigue resistance and the color stability of polyoxymethylene (Acetal) and Bre-Flex (2nd edition).

Materials and Method: Twenty partially edentulous models Kennedy class I were constructed with first premolars are last abutments. Models were divided into two equal groups Group A: Construction of RPD with Polyoxymethylene (Acetal) clasps and denture base, Group B: Construction of RPD with Polyamide (Bre-flex 2nd edition) clasps and denture base. The Retention and fatigue resistance of each clasp after cycling intervals (360 cycles, 720 cycles, 1440 cycles, and 2880 cycles) were measured by applying withdrawal force to it using a universal testing machine. The data of the retentive force magnitudes at different intervals were collected and tabulated. Also, the color change was evaluated after 4 weeks by measured a total 20 specimens for each group (size of the disc was set to 4 mm) in different immersion media cola (acidic pH), Licorice (alkaline pH), (neutral pH) Distilled Water using a portable Reflective spectrophotometer. The data were subjected to statistical analysis using 3-way-ANOVA test, Student's t and paired t-tests.

Results: Regarding the retention and fatigue resistance it was found that group B recorded statistically significant higher mean value than group A. Regarding the color change the total effect of the main group on color change (ΔE); it was found that group A recorded statistically significant higher change mean value than group B as revealed by two-way ANOVA test (**p=<0.0001<0.05).**

Conclusion: The removable partial dentures were constructed the denture bases and the clasps with the poly amid Bre-flex 2nd edition was exhibited superior color stability and fatigue resistance when compared with the removable partial dentures constructed their claps and denture bases from polyoxymethylene (Acetal).

KEYWORDS: Clasp; Acetal Resin; Bre-Flex 2nd edition; Fatigue Resistance, color stability.

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INTRODUCTION

Most of the removable partial denture wearers are complaining form the metal display .and they seeking for partial denture with metal-free clasps in order to improve esthetic appearance, Several types of non-metal clasp dentures are presented due to superior esthetics. Their flexibility and highly elastic nature, which minimize the stress on the abutment teeth. [1,2]

Furthermore, Sufficient retention and esthetics of removable partial dentures (RPDs) are considered the most important factors affecting their clinical success. So the achieving of optimal esthetics while maintaining retentive integrity, and preserving the health of the abutment is an important issue .also, the retentive clasp arms of the Removable partial denture must be capable of flexing and returning to original form and should resist the plastic deformation of the clasp in function. As the clasp fatigue is based on the repeated deflection of the clasp during insertion and removal of the RPD over the undercuts of the abutments. In addition, claps should not exert any excessively stress on the abutment teeth or be permanently distorted during service.[3-6]

The polyoxymethylene (Acetal) is a thermoplastic very strong material exhibit superior abrasion resistance and lower creep with higher surface luster than nylons making them suitable for maintaining vertical dimension during provisional restorative therapy. These materials are flexible, no deformation occurs for the Acetal resin clasps after 36 months of simulated and that less force is required for insertion and removal than Co-Cr clasps. [7-11]

The Bre -flex 2"d edition It was unbreakable, flexible and monomer free developed to improve the property of this polyamide as it offered better color stability, improved durability, increased flexibility find more comfort. It is supplied in variable shades such as crystal clear, pink 2,pink-veined and pink 4.It is a suitable prosthesis for a hypersensitive patient seeking esthetic appearance. Also, it is Ideal for patients who need temporary appliances during the healing period of implant-supported restorations; It may be used in combination with metal frameworks or precision attachments. Other applications also include splints and sports mouth guards. However, full dentures, crowns, and bridges, attachments are a contraindication for its use. **(Bredent 2009)**

Color stability of denture base acrylic resins is an important aspect, as it is associated with esthetic reproduction of oral mucosa. and also, Color stability of denture base resins is related to the eating habits as It has been reported that certain drinks such as coffee, tea, and alcohols, cause discoloration of acrylic resins. Discoloration of acrylic resins may be due to: Intrinsic factors or extrinsic factors, the degree of alteration and residual monomer can influence color stability considered as intrinsic factors while the effect of cleaning solutions, tobacco, a composition of saliva and denture hygiene habits considered as extrinsic factors. Another important source of color change is the porosity and water sorption. It is caused by overheating or pressure during processing or even from the residual monomer. [12,13]

The color stability and minimizing color change is a factor that should be considered in the selection of materials and techniques also, the material translucency should be maintained during processing and even after using the dentures under a different clinical conditions.[14,15]

Aim of the study : this study was aimed to compare and evaluate the fatigue resistance and the color stability of polyoxymethylene (Acetal) and Bre-Flex (2nd edition).

MATERIALS AND METHODS

An experimental models of maxillary edentulous case (Kennedy class I) was fabricated with last standing teeth the first premolars to be used as master model to simulate the oral cavity.

The master model was surveyed with the occlusal plane parallel to the base of the surveyor (Ney Surveyor, DENTSPLY, USA) in zero tilt position used, Analyze the proximal abutment tooth surfaces with the surveyor-analyzing rod was done and the proximal surfaces were in parallel relation to one another as that parallel proximal plane acts as guiding plane, the undercut was done by dimpling preparation on the buccal surface of the first premolars to create 0.02 inch .[1]

The distal guiding planes on the last abutments (first premolar) were prepared to include two-thirds of crown length (minimum 2mm in length) using(milling Tungsten carbide profile bur with relief, parallel, face straight F1162H23 Bredent Germany).

Conventional Occlusal rest seats were prepared on the premolars and cingulum rests were prepared on the lingual surface of the canines .

Drawing the design of the partial denture framework on the master cast .as the direct retainers were RPI clasp on the teeth no. 14, 24 and cingulum rests were on the teeth no. 13, 23 act as indirect retainers and major connector was Antroposterior palatal strap .

Blocking-out the undesirable undercuts. then, wax trimmer was used to trim the excess wax that may be inserted into those undercuts areas which are to be obliterated.

The modified master cast was duplicated as conventional manner[17] , 20 refractory casts were poured on the silicon mold then, The wax pattern of the major connector and the saddles were waxed and casted at first as usual with chrome –cobalt alloy the finished and polished after the casting procedure was done the refractory models were randomly divided into 2 groups 10 model in each group. **Fig. (1)**

Group A: were constructed the denture base and the clasps by polyoxymethylene (Acetal) as a control group.

Group B: were constructed the denture base and the clasps by polyamide (Bre-flex 2nd edition).

The clasps and rest seats were waxed from inlay wax. waxing up was made extended and large enough with minimal thickness of 1.5mm , setting up was done in group B (Bre-flex 2nd edition) then injection procedure was done . while in the group A Polyoxymethylene (Acetal) the denture base was injected at first then the teeth attached to the denture base by self-cure acrylic resin .

The model was seated inside the flask then, excess stone was removed from the sprue channel path way.[18]The flask was assembled and screws were tightened and the Stone was mixed and poured into the flask through the opening in the upper compartment. Then, After the stone had set, the screws were slightly loosened and the flask was

Fig. (1) wax pattern and casting of the Antroposterior palatal strap major connector

submerged into boiling water for 15 minutes. Then, the two halves of the flask were then disassembled. The wax elimination was done by hot water. The mold was inspected and any sharp edges of the investment were removed.

Adequate quantity of the material for both groups, group (A) : polyoxymethylene (Acetal) and group (B) : polyamide (Bre-flex 2nd eidition) was loaded into a disposable cartridge. The thermopress 400 machines (Bredent, Germany) was adjusted to the preset program for each material. Approximately both materials was injected at 220 C; this temperature was reached over approximately 15 minutes form pressing the start/heating key. [19]

After the injection process was finished all the screws assembling the flask were removed. Then , Any excess of the high-temperature grease material remaining in the injection channel was removed to avoid this residual form being injected into the mold cavity together with the material during the next injection process. finishing and Polishing were made with pumice powder and its brush than with the high luster polishing paste with the cotton polishing buff. **Fig.(2)**

Color change measurement

A total of 20 specimens for each group (size of the disc was set to 4 mm) were prepared and measured in different immersion media (cola (acidic pH), Licorice (alkaline pH), (neutral pH) Distilled Water) using a portable Reflective spectrophotometer (X-Rite, model RM200QC, Neu-Isenburg, Germany). The specimens were exactly aligned with the device. A black background was selected and measurements were made according to the CIE L*a*b* color space relative to the CIE standard illuminant D65. The color changes (ΔE) of the specimens were evaluated after 4 weeks of immersion, using the following formula:

$$\Delta E CIELAB = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})\ ½$$

Where: L* = lightness (0-100), a* = (change the color of the axis red/green) and b* = (color variation axis yellow/blue)

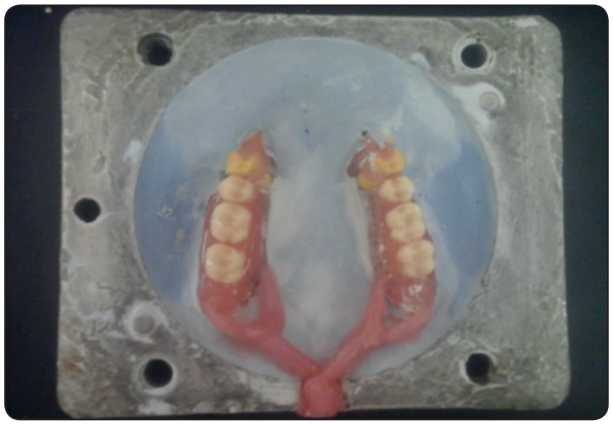

Fig. (2) Bre-flex denture base with teeth arrangement.

Fatigue resistance measurement

To perform the insertion-removal test, a programmable logic controlled equipment; the newly developed four stations multimodal ROBOTA chewing simulator integrated with thermo-cyclic protocol operated on servo-motor (Model ACH-09075DC-T, AD-TECH TECHNOLOGY CO., LTD., GERMANY). Each sample was then placed on the corresponding abutment and fixed to Jakobe's chuck of the upper part of the machine through inverted t-shaped auto-polymerizing acrylic resin (Caulk, Dentsply) centrally positioned horizontal bar between 2nd premolar and 1st molars to facilitate the aligning with the loading axis of machine and proper load distribution (Fig.3).

The machine allowed the placement of the clasp to its predetermined terminal position and its subsequent removal from the abutment, thus simulating the placement and removal of an RPD. The models with the PRDP were mounted in Teflon housing in the lower sample holder of the chewing simulator .

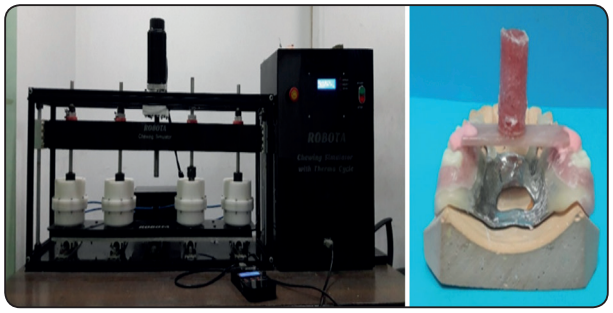

Fig. (3) ROBOTA chewing simulator

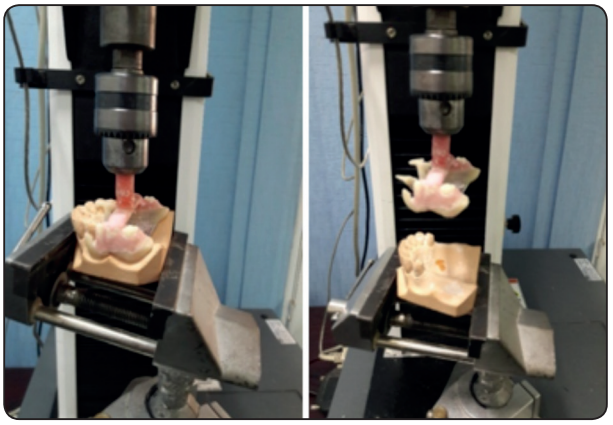

Fig. (4) insertion-removal test

The test conditions were maintained at room temperature (20±2 °C) and wet condition (distilled water). To analyze the data obtained during the simulation test, intervals every 360, 720, 1440 and 2880 cycles were established, representing the simulated insertion and removal of the PRDP over 3months, 6minths, 12months and 2 years, estimating that the patient would perform four removals and insertions of the PRDP per day.

These tests were performed using Bluehill® Lite from Instron Instruments. Each cast with its RPD was fixed to the lower fixed compartment of a materials testing machine (Model 3345; Instron Instruments Ltd., USA) with a load cell of 5 kN and data were recorded using computer software (Bluehill Lite; Instron Instruments). The sample was attached through centrally positioned horizontal inverted t-shaped auto-polymerizing acrylic resin bar between 2nd premolar and 1st molars to facilitate the aligning with the loading axis of the machine and proper load distribution. A tensile load with pull out mode of force was applied via materials testing machine at a crosshead speed of 5 mm/min. The load required to totally dislodge sample was recorded in Newton fig. (**4**)

RESULTS

Data were presented as mean, standard deviation (SD) for values. The results were analyzed using Graph Pad Instat (Graph Pad, Inc.) software for windows. A value of $P < 0.05$ was considered statistically significant. After homogeneity of variance and normal distribution of errors had been confirmed, one-way ANOVA followed by Tukey post-hoc tests were to detect significance between staining solutions with each main group. Student t-test was done for compared main groups. Two -way analysis of variance was performed to detect the effect of each variable (material group and staining solutions). Sample size (n=7) was large enough to detect large effect sizes for main effects and pair-wise comparisons, with the satisfactory level of power set at 80% and a 95% confidence .

Results of Color change (E)

Color change (E) results (Mean±***SD***) for both groups as function of staining solutions are summarized in table (1) .

With group (A): polyoxymethylene (Acetal) and With group (B) : polyamide (Bre-flex 2nd eidition) there were found that Cola (acidic pH) subgroup recorded the highest color change followed by Licorice (alkaline pH) subgroup while the lowest color change recorded with D. Walter (neutral pH)

sub group and this was statistically significant as revealed by one-way ANOVA test (p=<0.0001< 0.05). Pair-wise Tukey post-hoc showed non-significant (p>0.05) difference between D. Walter (neutral pH) and Cola (acidic pH) subgroups. table (1) .

Comparison between group A : polyoxy methylene (Acetal) and group (B) : polyamide (Bre-flex 2nd eidition)

With D. Walter it was found that group A recorded statistically non-significant higher change mean value than group B change mean value as revealed by t-test (p=0.6624 > 0.05). table (1)

With Cola (acidic pH)and Licorice (alkaline pH); it was found that group A was recorded statistically significant higher change mean value than group B change mean value as revealed by t-test (p=<0.0001< 0.05).

Total effect of main group on color change (E); regardless to staining solutions, totally it was found that group A recorded statistically significant higher change mean value than groupBas revealed by two-way ANOVA test (p=<0.0001<0.05).

Total effect of staining solutions on color change (E); irrespective of material groups, totally it was found that it was found that Cola (acidic pH) subgroup recorded the highestcolor change followed by Licorice (alkaline pH) subgroup while the lowest color change recorded with D. Walter (neutral pH) subgroup and this was statistically significant as revealed by one-way ANOVA test (p=<0.0001< 0.05).

Results for Retention and fatigue measurement

Retention results, mean and standard deviation (SD) measured in Newton of force (N) for both groups as function of evaluation time were presented in graph drawn in figure (6)

With group (A) it was found that baseline recorded the highest retention mean value followed by 3 months (360 cycles) and 6 months (720 cycles) respectively then12 months (1440 cycles) while the lowest retention mean value recorded after 24 months (2880 cycles).It was found that the retention decreased significantly with time as indicated by one-way ANOVA test (p=<0.0001<0.05). Pair-wise Tukey post-hoc showed non-significant (p>0.05) difference between 3 months (360 cycles) and 6 months (720 cycles).

With group (B) it was found that baseline recorded the highest retention mean value followed by 3 months (360 cycles) and 6 months (720 cycles) respectively then12 months (1440 cycles) while the lowest retention mean value recorded after 24 months (2880 cycles).It was found that the retention decreased significantly with time as indicated by one-way ANOVA test (p=<0.0001<0.05)

TABLE (1) Color change results (Mean±***SD***) for both groups as function of staining solutions from baseline

Variables		Main group		
		Group A	Group B	Statistics
		Mean±***SD***	Mean±***SD***	P value
Staining solutions	Cola (acidic pH)	1.923^{c}***0.46±***	1.723^{b}***0.94±***	0.6624 ns
	Licorice (alkaline pH)	3.55^{b}***0.08±***	1.057^{b}***0.17±***	<0.0001*
	D. Walter (neutral pH)	7.56^{a}***0.70±***	3.417^{a}***0.59±***	<0.0001*
Statistics	P value	<0.0001*	<0.0001*	

Different letters in same column indicating significant (p<0.05). ns; non-significant (p>0.05) *; significant (p<0.05)

Comparison between group A :polyoxy methylene (Acetal) and group (B) : polyamide (Bre-flex 2nd eidition)

At baseline , After 3 months (360 cycles), After 6 months (720 cycles);After 12 months (1440 cycles) and After 24 months (2880 cycles) there were found that group B recorded statistically significant higher mean value than group A mean value as revealed by t-test (p=<0.0001< 0.05).

Total effect of main group on retention

Regardless to evaluation time, totally it was found that group B recorded statistically significant higher mean value than group A as revealed by two-way ANOVA test (p=<0.0001<0.05).

Total effect of evaluation time on retention

Irrespective of material groups, totally it was found that it was found that retention decreased from baseline where it recorded the highest mean value to 24 months (2880 cycles) where it recorded the lowest mean value, and this was statistically significant as revealed by two-way ANOVA test (p=<0.0001< 0.05).fig. (5)

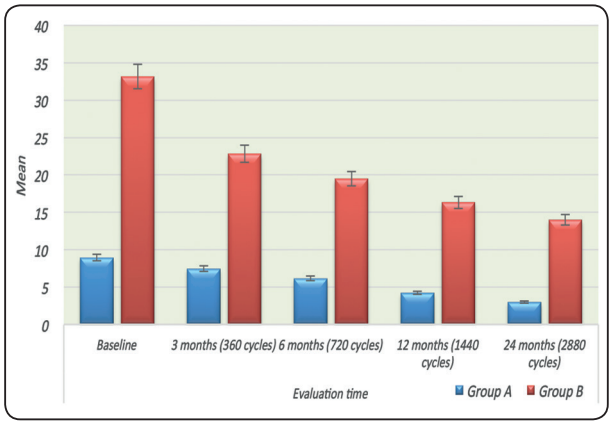

Fig. (2) Bre-flex denture base with teeth arrangement.

DISCUSSION

The material of choice for removable partial denture should have enough flexibility for clasp and rigidity for other components of the partial denture. also, The material should exhibit sufficient amount of esthetic in order to improve the patient comfort and satisfaction, such as thermoplastics resins are limited due to the lack of information provided by manufacturers or literature regarding their color stability and fatigue resistance behavior .[19-22]

Therefore, the present study was conducted to assess the influence of different staining beverages on the color stability of two newly introduced thermoplastic Acetal resin tooth-colored clasp materials by scanning spectrophotometer at different immersion periods.[23,24]

Retentive clasp arms must be capable of flexing and returning to their original form .also , must be minimize the stresses on the abutment as much as possible and prevent permanently distorted during service in addition to provide good aesthetic results [25-27]

In this in vitro study the two different materials were used Group A: polyoxymethylene (Acetal) and Group B: polyamide (Bre-flex 2nd edition) for construction RPD esthetic clasp and denture base.

Acetal resin has a high proportional limit with little viscous flow. This property enables them to cover a large area in clasp fabrication (7,8). Also, resin clasps may be resilient enough to engage undercuts for the retention of removable partial dentures but the low Flexural modulus requires coverage of greater cross-sectional area than metal alloys in order to gain useful retention.[20,21]

The results of this study regarding the retention and fatigue resistance indicate that group B clasps were constructed from polyamide (Bre-flex 2nd edition) are recorded statistically significant higher mean value of retention after 3, 6 and 12 months represented by 360 , 720 and 1440 cycles than group A:clasps were constructed from polyoxymethylene (Acetal). [29-31]The retentive force of the clasps polyamide (Bre-flex 2nd edition) did not decrease over the cycling periods. This would be attributed to the resilient nature of group B over group A.

Under the conditions of the present study polyoxymethylene (Acetal) clasps lost retentive force and recorded the lowest retentive mean values at 2880 cycles which represented 24 months of placement and removal and continued to lose retentive force during the remaining test period and that means the group B more resist for the fatigue and indicate the durability of the Bre-flex 2nd edition over the polyoxymethylene (Acetal) clasps . [32-35]

Color changes can be evaluated by instrumental techniques or even visually. Since instrumental measurements eliminate the subjective interpretation of visual color comparison, the spectrophotometer was used in this study. [28]

The reflective spectrophotometer consists of special software that stores the data and transforms it into a spread sheet for statistical analysis. This capability virtually eliminates the process of manually inserting the data into a spreadsheet, a process that has a great potential for errors. In this study, color measurements were performed in front of a black background based on the fact that the oral cavity represents a dark environment and to ensure that only the light reflected or scattered from the specimen is measured with no reflected light from the background

Walter (neutral ph) , licorice (alkaline ph) and cola(acidic ph) are commonly used and identified to be staining substances. Therefore, these solutions were used to evaluate the color stability for the different RPD materials. One of the drawbacks in the present investigation might be related to the methodology utilized for the staining procedures. Between the different immersion intervals, the specimens were not subjected to any cleaning procedures, which might not accurately reflect clinical conditions. But the solutions were subjected to refreshment every day in order to keep the solution free from contamination as much as possible.

In most of in vitro color stability studies, specimen's immersion period is about 4 weeks or more are typically used in order to achieve a cumulative staining effect and obtain distinct results.

Furthermore , The results of this study regarding the color stability the total effect of staining solutions on color stability (ΔE) for both groups it was found that the Cola (acidic pH) subgroup recorded the highest color change followed by Licorice (alkaline pH) subgroup while the lowest color change recorded with D. Walter (neutral pH) subgroup that due to the effect of carbonated water on the resin surface as it produce erosive effect followed by adsorption of the caramel pigment present in the cola.[13,14]

However , when compared the Total effect of main group on color change (ΔE); regardless to staining solutions, it was found that group A recorded statistically significant higher change mean value than group A, this could be explained by subjected the polyoxymethylene (Acetal) to water sorption with its hydrolytic effect that might alter the original color of the Acetal resin material. furthermore, the recent studies using polyamide resin (Bre-flex 2nd edition) with lowered water sorption rates reported that no differences in mean water sorption rate were observed in heat polymerized resin .also, recent polyamide type denture base materials were developed to reduce water sorption by controlling the amide group concentration and resist to hydrogen bonding thereby demonstrating water sorption rates similar to heat polymerized resin .[23,24,29]

In addition the Bre-flex 2nd edition is a monomer free denture base material used for fabrication of unbreakable flexible partial denture this fact may attribute to decrease the rate of the water resorption as the technical data of the bre flex 2nd eidition was reported that the water sorption 24 hours at 23c equal 1.1 %.**(Bredent 2009)**

RECOMMENDATIONS

Further studies are recommended to better understand the relationship between the physic-chemical properties and the mechanical properties of polyoxymethylene (Acetal) &Bre-flex 2nd edition and correlate with the clinical performance in relation to its expected life time.

REFERENCES

1. Abdel-Rahim Nahla Y, Abd El-Fattah Fadel E, El-Sheikh Mohamed M.Laboratory Comparative Study of Three Different Types of Clasp Materials." Tanta Dental Journal 13(1):p.41–49, 2016.
2. Takabayashi Y. Characteristics of denture thermoplastic resins for non-metal clasp dentures. Dent Mater J.29: 353–361, 2010.
3. P. N. Savitha, K. P. Lekha, Ramesh K. Nadiger .Fatigue resistance and flexural behavior of acetal resin and chrome cobalt removable partial denture clasp: An in vitro study. J Prosthet Dent 3 :71-76 ,2015.
4. Shah, Ronak, and M. Aras. Esthetics in Removable Partial Denture - A Review. Kathmandu University Medical Journal 11(44): p.344–48,2013.
5. Alwan SS, Ismail IJ. Retentive forces, tensile strength and deflection fatigue of Acetal thermoplastic clasp material in comparison with cobalt-chromium alloy. Journal of Baghdad college of dentistry. 26(1),2014.
6. Arda T, Arikan A. An invitro comparison of retentive force and deformation of acetal resin and cobalt-chromium clasps. J Prosthet Dent.94(3):267-74,2005.
7. Wu JC, Latta GH, Wicks RA, Swords RL. Invitro deformation of acetyl resin and metal alloy removable partial denture direct retainers. J Prosthet Dent. 90(6):586-90,2003.
8. Arikan A, Ozkan YK, Arda T, and Akalin B. Effect of 180 days of water storage on the transverse strength of acetal resin denture base material. J. Prosth. 19(1):p.47-51,2010.
9. Dhiman RK, and Chowdhury R. Midline fractures in single maxillary complete acrylic vs flexible dentures. Medical Journal Armed Forces Indiam, 65(2):p.141 -45, 2009.
10. Bortun C., Lakatos S., Sandu L., Negrutiue M., and Ardelean L. Metal-Free Removable Partial Dentures Made Of Thermoplastic Materials. TMJ. 56(1):p.80-87,2006.
11. Ewoldsen N, Kurtzman G, and Sundar V. Interim and Definitive Metal-Free Partial Dentures inside Dentistry .7(5):p1-6, 2011.
12. Imirzalioglu, P, Karacaer, O, Yilmaz, B, Ozmen I. Color Stability of denture acrylic resins and a soft lining material against tea, coffee, and nicotine. J Prosthodont .19: 118–124,2010.
13. Koksal T, Dikbas I. Color stability of different denture teeth materials against various staining agents. Dent Mater J .27:139-144, 2008.
14. Al Kheraif A-A A-A, Bin Qasim SS, Ramakrishnaiah R, Rehman I. Effect of different beverages on the color stability and degree of conversion of nano and microhybrid composites. Dent Mater J. 32: 326–33,2013.
15. Gupta G, Gupta T. Evaluation of the effect of various beverages and food material on the color stability of provisional materials – An in vitro study J Conserv Dent. 14: 287–292,2011.
16. Pun, Deo K., Michael P. Waliszewski, Kenneth J. Waliszewski, and DavidBerzins. "Survey of Partial Removable Dental Prosthesis (Partial RDP) Types in a Distinct Patient Population." Journal of Prosthetic Dentistry 106(1):p.48–56, 2011.
17. Marković, D., Puškar, T., Hadžistević, M., Potran, M., Blažić, L., &Hodolič, J. The Dimensional Stability of Elastomeric Dental Impression Materials.ContemporaryMaterials1(3).Retrieved(http://doisrpska.nub.rs/index.php/conterporarymaterials3-1/article/view/134) , 2012.
18. Ardelean L, Bortun C, Motoc M. Metal-free Removable Partial Dentures made of a Thermoplastic Acetal Resin and Two Polyamide Resins. Materiale Plastice..44(4).p.345-348,2007.
19. Singh JP, Dhiman RK, Bedi RP, and Girish SH. Flexible denture base material: A viable alternative to conventional acrylic denture base material. Contemp. Clin. Dent. 2(4):p.313-7, 2011.
20. Thomas SA, Nandini VV. Acetal resin -A quantum leap in aesthetic restorative dentistry. IJCDS.4: 56-59, 2011.
21. Lekha K, Savitha NP, Roseline M, Nadigar RK. Acetal resin as an aesthetic clasp material. J Interdiscip Dent. 2:11-14, 2011.
22. Tannamala PK., Pulagam M., Pottem SR., and Karnam S.

Flexible resins in the rehabilitation of maxillectomy patient. Indian J. Dent. Res. 23(1):p.97-100,2012.

23. Arıkan A, Ozkan YK, Arda T, Akalın B. Effect of 180 days of water storage on the transverse strength of acetal resin denture base material. J Prosthodont.19: 47–51, 2010
24. Mundim FM, Garcia LFR, Pires-De-Souza FCP. Effect of staining solutions and repolishing on color stability of direct composites. J Appl Oral Sci. 18: 249-254, 2010.
25. Tannous F, Steiner M,Shahin R ,Kern M. Retentive forces fatigue resistance of thermoplastic resin clasp . Dental material; 28:273-8, 2012.
26. Abd-Elrahman IA, Helal MA, Saqar HM, Abas M .Evaluation of Fatigue Resistance of Acetal Resin and Cobalt–Chromium Removable Partial Denture Clasps. An In-vitro Study:Part 1. J Dent Oral Care Med . 2(3): 304,2016.
27. Helal MA, Baraka OA, Sanad ME, Al-Khiary Y, Ludwig K, et al. Effect of clasp design on retention at different intervals using different abutment materials and in a simulated oral condition. J Prosthodont.23: 140-5,2014.
28. Helal MA, Baraka OA, Sanad ME, Ludwig K, Kern M . Effects of long-term simulated RPD clasp attachment/detachment on retention loss and wear for two clasp types and three abutment material surfaces. J Prosthodont.21: 370-7, 2012.
29. Taleb FAA, Eltorky IR, El-Sheikh MM, MoulaSA . Patient Satisfaction and Radiographyical Evaluation of Acetal Resin Retentive Clasp Arm versus Conventional Clasp on Abutment Teeth in Upper Unilateral Removable Partial Dentures. J .AmerSci 9: 425-31, 2013.
30. Tannous F, Steiner M, Shahin R, Kern M . Retentive forces and fatigue resistance of thermoplastic resin clasps. Dent Mater .28: 273-8,2012.
31. Ucar Y, Akova T, and Aysan I. Mechanical properties of polyamide versus different PMMA denture base materials. J. Prosth.21 (3):p.173-6, 2012.
32. Tandon R., Gupta S., and Agarwal SK. Denture base materials: From past to future. Indian Journal of Dental Sciences. 2(2):p.33-39,2010.
33. Thakral GK, Aeran H, Yadav B, and Thakral R. Flexible Partial Dentures A hope for the Challenged Mouth people's journal of scientific research. 5(2):p.55-59,2012.
34. Goiato MC, Panzarini SR, Tomiko C, and Luvizuto ER. Temporary flexible immediately removable partial denture: a case report. Dent. Today. 27(3):p.114, 16 , 2008.
35. Yazici AR, Çelik C, Dayanga B, Özgünaltay G. The effect of curing units and staining solutions on the color stability of resin composites. Oper Dent.32: 616-622,2007.