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Comparative evaluation of fatigue resistance of acetal resin and peek aesthetic clasp materials with the conventional cobalt chromium clasp- an in-vitro study.

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Abstract

Introduction: While selecting a clasp material, importance should not only be given to the aesthetic property but also to the physical and mechanical properties. A clasp material with adequate fatigue resistance is required for the clinical success of removable partial dentures.

Objectives: This study evaluated and compared the fatigue resistance of Acetal resin and Polyether ether ketone clasp material with the conventional cobalt chromium clasp engaging two different undercuts over two years of simulated clinical use.

Methodology: Forty-eight maxillary/mandibular premolars and molars were divided into two groups based on the undercuts. Group 1 consisted of twenty-four mandibular/ maxillary premolars with an undercut of 0.25mm and Group 2 consisted of twenty-four mandibular/ maxillary molars with an undercut of 0.50mm. The main groups were further sub-divided based on the clasp materials into Cobalt-Chromium, Acetal resin and Polyether ether ketone groups. Fatigue resistance of the clasps were evaluated by measuring the distance between the retentive and reciprocal arm tip before and after simulation by Universal Testing

Machine The distance was measured using the digital caliper.

Results: The statistical analysis done using ANOVA revealed that the fatigue resistance was higher for the Polyether ether ketone clasps engaging the 0.25mm However, the fatigue resistance was higher for Acetal resin clasps engaging the 0.50mm undercut.

Conclusion: Within the limitations of this study, it was concluded that for teeth with shallow undercuts of 0.25mm both Polyether ether ketone and Acetal resin clasps can be considered as aesthetic alternatives to Cobalt-Chromium clasps. However, for teeth with deep undercuts of up to 0.50mm, Acetal resin clasps can be the choice of aesthetic clasp material.

Keyword: Acetal resin, Fatigue resistance, Cobalt-Chromium, Poly ether ether ketone, Undercuts

Introduction

Cast partial denture (CPD) presents as an excellent treatment option for patients who cannot be rehabilitated with either a fixed partial denture or an osseointegrated prosthesis because of periodontal reasons, inadequate bone quantity and quality and also in certain cases because of the patient's financial status [1].

For the long-term success of the cast partial denture, retention plays a critical role. Cast partial dentures are retained in the oral cavity with the help of clasp assembly, a component of the CPD which engages the undercuts present on the abutment teeth.

The clasp is often made of same material as that of the cast partial denture frame work and these materials include gold and gold alloys, Cobalt-Chromium alloys (Co-Cr) and Titanium alloys [2]. The main disadvantage of these materials is the unaesthetic display of the metal which is one of the main reason for patient's dislike towards the cast partial denture.

Various methods were used to overcome this disadvantage including, covering clasps with tooth-colored resin, use of lingually positioned clasps, engaging mesial rather than distal undercuts and precision attachments [3]. Precision attachments can be used to deliver aesthetically satisfying removable partial dentures. But these attachments also have disadvantages such as complexity of design, wear of the attachments over a period of time that might require repair or replacement, increased demand on oral hygiene performance and also the increased expenses [4]. Therefore, the increase in the demand for aesthetics has led to the development of new clasp materials that overcome the aforementioned disadvantages.

These materials include thermoplastics like Acetal resin and Polyether ether ketone.

Acetal demonstrates good wear and fracture resistance, high flexibility, high fatigue endurance and high creep resistance. It is also hydrophobic, which means that material does not absorb saliva or water. Because of little or no porosity, staining and accumulation of the plaque is also reduced. Acetal is free from monomer residues because of which it is considered as an RPD framework material for patients with allergic reactions to Co-Cr alloy [5,6].

Polyether ether ketone (PEEK), a high impact thermoplastic polymer material has been introduced into dentistry over the last decade. PEEK approximates the modulus of elasticity of dentin and cortical bone as a result less stresses are transferred to the abutment. Despite of low modulus of elasticity and low hardness, wear resistance of PEEK is comparable to that of the metal alloys. PEEK exhibits the highest flexural strength and creep resistance among other thermoplastic alternatives. The tensile strength of PEEK is similar to that of enamel and dentin which makes it suitable for the

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cast partial denture framework fabrication [7,8]. It also exhibits superior aesthetic property. Because of the aforementioned properties, PEEK can be used as an alternative clasp material for the cast partial denture.

While selecting a material for the clasp, importance should be given not only to the aesthetic property but also to the physical and mechanical properties. For the long-term usage of a cast partial denture, the clasp design should be such that it produces less stress on the abutment. The factors mainly affecting the clasp design are clasp material, clasp form and the depth of the undercut. Furthermore, these factors are associated with stress distribution, which affects fatigue and permanent deformation of the clasp material [4]

Metals and alloys are known to undergo deformation and fatigue when exposed to repeated stress. Fatigue is defined as the fracture of a material by repeated cyclic or applied loads below the yield limit [2]. In case of a clasp, fatigue is caused by the repeated deflection of the clasp during insertion and removal of the cast partial denture over the undercuts of the teeth as well as by the masticatory load. For the clinical success of removable partial dentures, a clasp material should demonstrate adequate fatigue resistance. Helal et al compared the clasp deformation and fatigue resistance of acetal and Co-Cr clasp and concluded that the Co-Cr clasps had a significant clasp deformation more than that of acetal resin clasp [10]. Alvarez *et al* compared the retentive force of PEEK and Co-Cr clasps by insertion and removal test and concluded that the retentive forces of PEEK were within clinically acceptable range [11].

But there are no studies comparing the fatigue resistance of Acetal resin, PEEK and the Co-Cr clasps and effects of the different depth of undercuts on the fatigue resistance of these clasps.

Therefore, the aim of this study is to evaluate and compare the fatigue resistance of Acetal resin and PEEK clasp materials with the conventional cobalt chromium clasp engaging two different undercuts, simulating two years of clinical use. The null hypothesis being tested is that there is no change in the fatigue resistance of the Acetal resin clasp, PEEK clasp and conventional cobalt chromium clasp material engaging the abutments with 2 different depth of undercuts.

Materials and Methodology

The sample size was estimated using the G Power software v. 3.1.9.2. Considering the effect size to be measured (f) at 58%, power of the study at 80% and the margin of the error at 5%, the total sample size needed was 48. Each group consisted of 8 samples. [8 samples x 6 sub-groups = 48 samples].

Sample preparation

Forty-eight non-carious and intact human extracted maxillary/mandibular premolars having an undercut of 0.25mm and maxillary/mandibular molars having an undercut of 0.50mm were collected. The teeth were preserved in 10% formalin solution. The teeth were mounted individually in a rectangular mould of dimension 4.00cm×2.00cm×2.00cm using pink and green auto-polymerizing acrylic resin (DPI) for two different undercuts of 0.25mm and 0.50mm respectively. Each mounted tooth specimen was placed on the surveying table and surveyed using the carbon marker on a Will's surveyor (Figure 1). Occlusal rest seat having the dimensions of one-third the mesio-distal width and one-half the Bucco-lingual width of the tooth was prepared on the mounted tooth using #4 round diamond bur (Figure 2).

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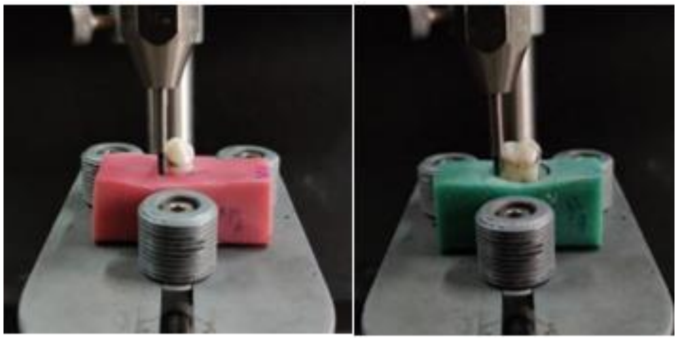

Figure 1: Surveying of the tooth on Will's surveyor

Figure 2: Rest seat preparation

Grouping of the samples

After the occlusal rest seat preparation, the mounted teeth were divided into two groups based on the undercuts present on the teeth as Group 1 and Group 2

Group 1

Twenty-four maxillary/mandibular premolars having an undercut of 0.25mm (Figure 3) which were further divided into 3 subgroups based on the material used for the clasp fabrication as follows:

Subgroup1A: Eight maxillary/mandibular premolars with Cobalt-chromium Aker's clasp each with a cross-sectional dimension of 1.5×3mm (Figure 4).

Subgroup1B: Eight maxillary/mandibular premolars with Acetal resin Aker's clasp each with a cross-sectional dimension of 1.5×3mm (Figure 5).

Subgroup1C: Eight maxillary/mandibular premolars with PEEK Aker's clasp each with a cross-sectional dimension of 1.5×3mm (Figure 6).

Figure 3: Group 1 samples (24 premolars)

Figure 4: Premolars with Cobalt-chromium clasps.

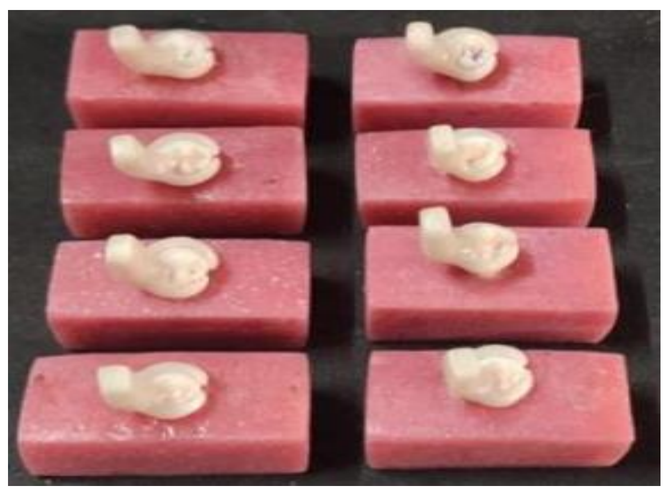

Figure 5: Premolars with Acetal resin clasps

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Figure 6: Premolars with PEEK clasps

Group 2

Twenty-four maxillary/mandibular molars having an undercut of 0.50mm (Figure 7) which were further divided into 3 subgroups based on the material used for the clasp fabrication as follows:

Subgroup 2A- Eight maxillary/mandibular molars with Cobalt chromium Aker's clasp each with a cross-sectional dimension of 1.5×3mm (Figure 8).

Sub group 2B- Eight maxillary/mandibular molars with Acetal resin Aker's clasp each with a cross-sectional dimension of 1.5×3mm (Figure 9).

Sub group 2C- Eight maxillary/mandibular molars with PEEK Aker's clasp each with a cross-sectional dimension of 1.5×3mm (Figure 10).

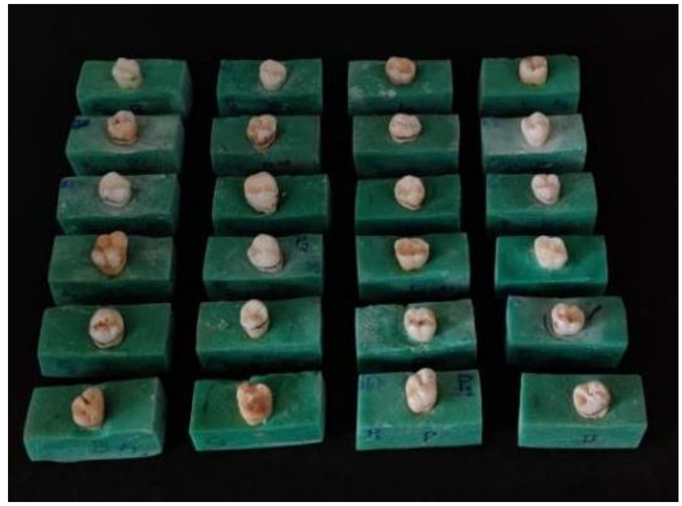

Figure 7: Group 2 samples (24 molars)

Figure 8: Molars with Cobalt-chromium clasps

Figure 9: Molars with Acetal resin clasps

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Figure 10: Molars with PEEK clasps

Clasp fabrication

Fabrication of Cobalt- Chromium Aker's clasps

The teeth receiving Cobalt Chromium clasps were scanned using Shining 3D DS-EX, a laboratory scanner. A CAD file was then generated for the eight maxillary/mandibular premolar and molar samples separately. The file was converted into an STL file for designing purpose (Figure 11). The designing was done in such a way that each clasp had a cross sectional dimension of 1.5mm×3.0mm (cross sectional width and length) and a vertical projection of length 10mm and width and thickness of 3.00mm extending from the body of the clasp. The vertical projection was made so that it would help in mounting of the specimens on a Universal Testing Machine for fatigue testing of the clasps. The STL file was sent to the DMLS machine for the direct metal laser sintering of the clasps. The samples were then finished and polished.

Fabrication of Acetal resin Aker's clasps

Similar procedure was followed for the fabrication of the Acetal resin clasps. After the designing, the STL file was sent to the 3D printing machine so that a pattern of the clasp could be fabricated using printed resin. The resin patterns were then invested and burnt out to create a clasp mold. These molds were mounted on Sab ilex® injection system (2AD 400) for the fabrication of the Acetal resin clasps by the injection moulding technique.

Fabrication of PEEK Aker's clasps

Similar procedure was followed for the fabrication of the PEEK clasps. After the designing, The file was converted into an STL file and sent to the Ceram ill motion 2 milling machine for the milling of the PEEK clasps.

Figure 11: STL file of the clasp design

Testing of the clasps for the fatigue resistance

The distance between the retentive arm tip and the reciprocal arm tip of the clasps in each group were measured using digital caliper prior to mounting onto a universal testing machine (Figure 12a). The clasps were checked for the fatigue resistance by subjecting them to a repeated cycling for 2920 cycles (to simulate two years of clinical use) using universal testing machine (Figure 13a & 13b). The load was applied at a cross head speed of 10 mm per minute to the clasp until it was dislodged from the extracted tooth. The distance between the retentive arm tip and the reciprocal arm tip of the clasps were measured again using digital caliper after cyclic loading (Figure 12b). The values obtained before and after cyclic loading were tabulated. The difference

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between the before and after values revealed the amount of deformation of the clasps after cyclic loading.

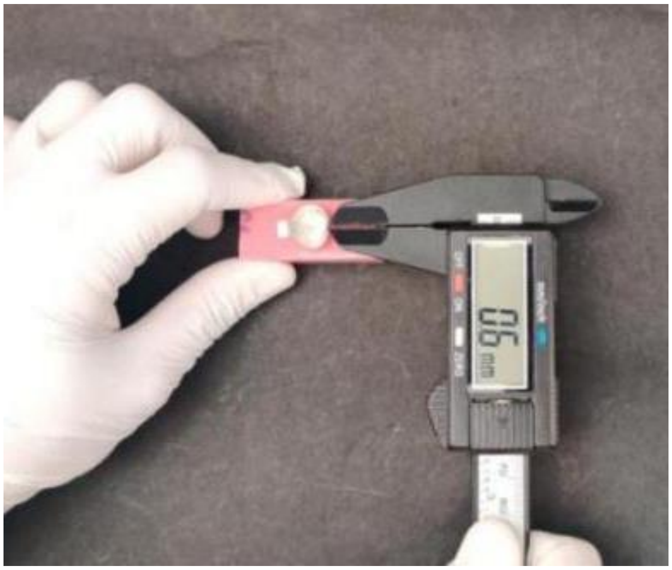


Figure 12a: Distance between retentive and reciprocal arm tip after cyclic loading.

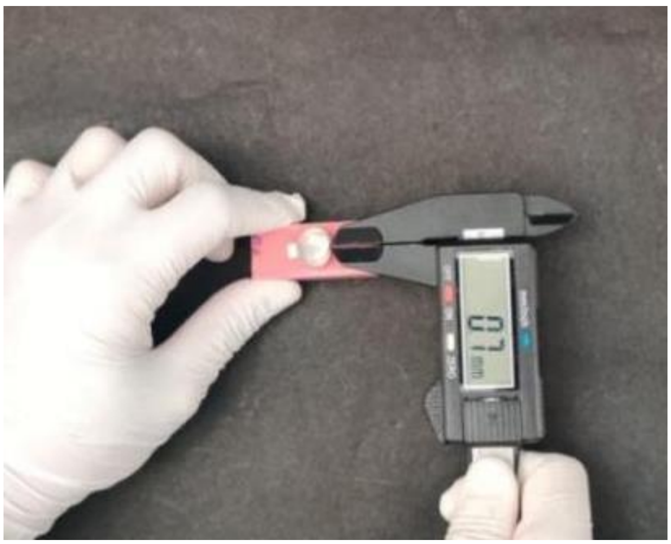


Figure 12b: Distance between retentive and reciprocal arm tip prior to cyclic loading

Figure 13: Cyclic loading of premolar by UTM

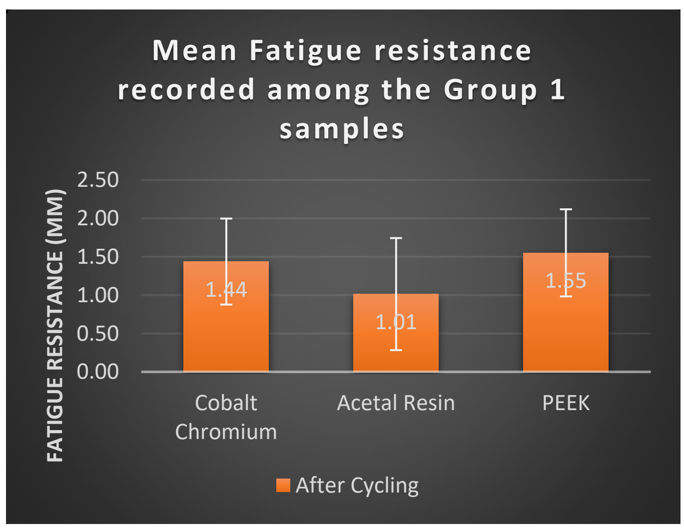
Figure 13a. Cyclic loading of premolar clasps by UTM

Figure 13b. Cyclic loading of molar clasps by UTM

Results

The values obtained were subjected to statistical analysis using the One-way ANOVA test. If there was a significant difference between the groups, multiple comparisons (post-hoc test) using Bonferroni test was carried out.

After cyclic loading of the clasps engaging an undercut of 0.25mm, higher mean fatigue resistance was recorded in the PEEK clasps, followed by the Cobalt Chromium clasps and the Acetal Resin clasps, respectively (Graph 1). The difference in mean fatigue resistance among the three clasps was not statistically significant.(P>0.05).



Graph 1: Graph of mean fatigue resistance of clasps on premolar group

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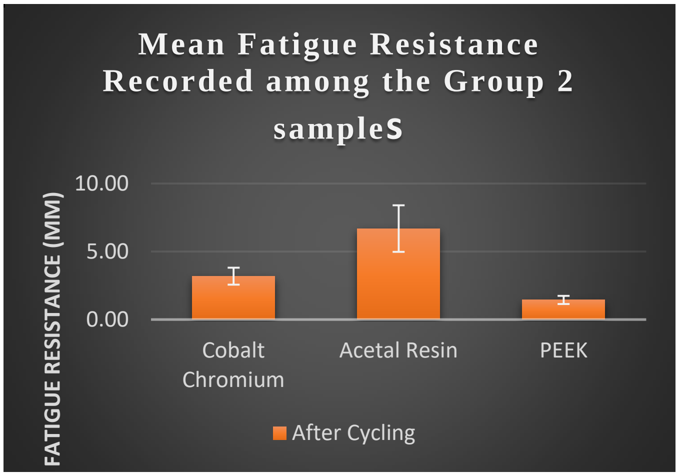
After cyclic loading of the clasps engaging an undercut



Graph 2: Graph of mean fatigue resistance of clasps on molar group

The pair-wise Bonferroni's test revealed that, after cyclic loading of the clasps engaging an undercut of 0.50mm, a statistically significant difference in mean fatigue resistance was observed between Cobalt Chromium & Acetal Resin ($P<0.001$), Cobalt Chromium & PEEK ($P<0.05$) as well as between Acetal Resin and PEEK ($P<0.001$)

Discussion

The present study evaluated the two thermoplastic materials, Acetal resin and PEEK for its fatigue resistance property and compared it with the conventional cobalt chromium alloy, the gold standard. In this study, several procedures were incorporated to secure the aim of the study and to aid in the standardization of the methodology. Many studies have used artificial metal abutments for the study. However, the use of metal abutments induces greater friction between the abutment surface and the clasp. Thus, natural teeth are considered as the best options to simulate the clinical condition. Thereby, premolar and molar teeth indicated for extraction for orthodontic and periodontal reasons were used for the study.

For the Cobalt-Chromium alloy clasps, the most commonly used undercut is the 0.25mm. To produce more aesthetic results, the clasps sometimes have to be placed closer to the gingival margins where the undercuts tend to be deeper. Thus, to simulate this clinical condition, teeth with both 0.25mm and 0.50mm undercuts were chosen for the study [12]. As the length of the claps increases, the flexibility increases and in turn there is less deformation of the material. The length of the clasps depends on the mesiodistal dimension/ width of the abutments. Therefore, to simulate this condition, clasps were fabricated on both premolar and molar teeth.

According to Tan nous et al., Turner et al., and Helal et al., if thermoplastic materials are to be used as the clasp material in removable partial dentures, the clasp thickness should be greater than 1mm in cross section in order to have the stiffness and retentive ability similar to that of cobalt-chromium clasps [12,13,14]. Thus, the clasps with a cross sectional dimension of 1.5mm× 3mm were fabricated for the present study.

The wax patterns of the clasps were digitized so as to obtain clasps of accurate dimension of 1.5×3mm engaging the desired undercuts of 0.25mm on the premolars and 0.50mm on the molars. By using the digital method of fabrication of the wax patterns, the human errors which can occur with the conventional method of fabricating the wax patterns were avoided.

Fatigue of the clasp is caused by the repeated deflection of the clasp over the height of contour of the abutments during insertion and removal of the cast partial denture. To simulate this clinical situation, the clasps have been subjected to cyclic loading by using Universal Testing Machine. Considering that the prosthesis will be inserted and removed from the mouth on an average of four times per day, 2920 cycles was chosen to simulate two years of clinical use.

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After simulation of the clasp on premolars having an undercut of 0.25mm (Group 1), higher mean fatigue resistance was recorded in PEEK clasp (Group 1C) followed by Cobalt Chromium clasp (Group 1A) and Acetal Resin clasp (Group 1B) respectively. Therefore, comparatively less deformation was noted in PEEK clasp group among the Group 1 samples. However, the difference in mean fatigue resistance among the three clasps were not statistically significant (P>0.05). This result was in accordance with the study conducted by Saja et al., which concluded that PEEK can be a promising clasp material in the fabrication of removable partial dentures as it showed lesser deformation and a retentive force comparable with that of Co-Cr clasps.

After simulation of the clasp on the molars having an undercut of 0.50mm (Group 2), higher mean fatigue resistance was recorded in Acetal Resin clasps (Group 2B) followed by Cobalt Chromium clasp (Group 2A) and PEEK clasps (Group 2C) respectively. Therefore, comparatively less deformation was noted in Acetal resin clasp group among the Group 2 samples. The difference in mean fatigue resistance among the three clasps was found to be statistically significant (P<0.001). The results of the present study were in contrast with the studies conducted by Lopes et al and Wu et al. in which a greater deformation was noted in the acetal resin clasps compared to cobalt chromium clasps engaging both 0.25mm and 0.50mm. However, the results of the present study was in accordance with the study conducted by Meenakshi et al., Savitha et al., and Helal et al., which stated that the acetal resin exhibits greater flexibility and are resistant to deformation when used as clasps on abutments having deeper undercuts [14, 15,16].

A probable reason for the lesser deformation of the acetal resin clasp on the molar teeth having an undercut of 0.50mm could be attributed to the property of modulus of elasticity and to the length of the clasp. For a deeper undercut of 0.50mm, the clasp has to be deflected to a greater depth without any deformation. For the Cobalt Chromium clasps, even though the clasp length is longer, its difficult for the clasp to deflect to a greater depth without deformation due to its rigidity. Since Acetal resin has a lower modulus of elasticity compared to that of cobalt-chromium, it resulted in lesser deformation of the clasp. In addition to this, as the length of the clasp increases, the flexibility increases which in turn results in lesser deformation of the clasps. Hence, Acetal resin clasp fabricated on molar teeth showed lesser deformation when compared to the Acetal resin clasp fabricated on premolar teeth.

However, among premolar group, PEEK showed lesser deformation than Acetal resin and cobalt chromium clasps. PEEK has similar modulus of elasticity compared to that of Acetal resin and a lower modulus of elasticity compared to that of cobalt-chromium alloy. As the depth of the undercut was shallower, that is 0.25mm for the premolars, the deflection of the clasp was lesser. Thus, the difference in the mean fatigue among Acetal resin, PEEK and Cobalt Chromium clasps was not statistically significant.

Therefore, from the results of the present study it can be noted that the thermoplastic materials like Acetal resin can be used as claps materials in the fabrication of the removable partial denture with abutments having deeper undercut upto 0.50mm as lesser deformation was noted compared to that of cobalt chromium claps and PEEK clasps. However, for shallower undercuts of 0.25mm, even though PEEK clasps showed maximum mean fatigue resistance, both PEEK and Acetal resin clasps can be considered as alternatives to Cobalt Chromium clasps as the difference in the mean fatigue resistance was not statistically significant.

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However, the present study has used digital caliper to measure the distance between the retentive and reciprocal arm tips before and after subjecting to cyclic simulation. A more accurate device such as tool marker microscope can be used to increase the accuracy of the study. The present study has evaluated only the fatigue resistance of the thermoplastic materials. Other properties such as retentive force, surface roughness, optical properties, effect of saliva on the fatigue resistance as well as the retentive force has to be evaluated in order to consider thermoplastic materials as an alternative material to the conventional cobalt chromium clasps.

Conclusion

Within the limitations of the study, it can be concluded that

1. For the abutments with undercuts of upto 0.25mm, Acetal resin and PEEK aesthetic clasp materials can be considered as alternatives to the conventional cobalt-chromium alloy.
2. For the abutments with undercuts of upto 0.50mm, Acetal resin aesthetic clasp material can be considered as an alternative to the conventional cobalt-chromium alloy.

However, further clinical studies are required to demonstrate the long-term success of these aesthetic clasp materials.

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