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The Fatigue Behavior of Restorations Used Under the Rest of Removable Partial Denture

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Abstract

Statement of Problem: The question about resistance of resin composites under rest in removable partial denture (RPD) is still unanswered. It is important to find the strongest material that withstands the applied stresses when used under RPD components.
Objectives: To evaluate and compare the fatigue behavior of amalgam and composite restorations used under the rest of the removable partial denture.
Materials and Methods: Forty-five permanent human upper premolars were prepared with standard class II DO cavities and divided into 3 groups of specimens (n=15 for each group). Group I was filled with amalgam (Dispersalloy), group II and III were filled with resin composite (Flitek Z250 and Tetric ceram, respectively). The teeth were stored in distilled water for 14 days before testing. After thermocycling, the "staircase" approach was used to determine the flexural fatigue limits (FFL). The mean differences were evaluated using One-Way ANOVA and post hoc test.
Results: A strong significant differences of flexural fatigue strength have been found between amalgam and composite groups ($P<0.001$). There was no significant difference between two groups of resin composite ($P=0.1$).
Conclusions: To achieve more flexural fatigue strength in the rest seats, the use of resin composite in comparison with amalgam is recommended.

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Introduction

An occlusal rest in a removable partial denture (RPD) provides vertical support and allows occlusal forces to be transmitted through the long axis of the abutment tooth. When RPD is under stress, there are various contact points between the different types of rests and its supporting surface, namely, the rest seat in the tooth or restoration. Normal functional performance without deformation and fracture of the rest seat material is critical [1,2].

Intraoral deterioration of dental restorations has been described in terms of different factors such as fatigue or wear. In regard to mechanical properties such as elastic modulus, flexural strength and fracture toughness, substantial differences are observed between resin composite and amalgam. Mechanical properties of dental materials under masticatory load, considering their properties in relation to fatigue resistance, are the major factor in their selection as a rest seat [3]. Under cyclic loading the degradation of strength can be directly assessed by measuring the crack advance in relation to the range of stress intensity factor applied [4]. The fillings are mainly subjected to cycles of loading-unloading and corrosive water attack at a certain temperature (37^0C). Therefore, during mastication, failure may occur due to fatigue at stresses below their ultimate tensile strength [4].

Patients with removable partial dentures insert occlusal forces in the range of 65 to 235 N [5,6].

The use of resin-based composites for posterior teeth restoration has increased significantly in recent years. This increase is attributed to the demand for improved aesthetics and general concerns about the possible release of mercury from amalgam restorations. Clinical evaluations of class I and II composite restorations have shown that the incidence of their failure is close to dental amalgam. [7,8]. Restorations show regions of compressive loading surrounded by areas where the material is stressed in tension during mastication. This is especially true when a restoration is bonded to the tooth structure [4]. Composites are much weaker in tension than compression; therefore it is important to exclude fatigue-sensitive restorative materials from placement in stress-bearing areas since the question about their resistance under rest in RPD is still unanswered [9,10].

Previous studies have shown that the incidence of tooth fracture is the highest in the first permanent molars and premolars under rest when a filling is existed [11,12]. There are limited published reports showing the most resistance available restorative materials when are used as rest seat. The purpose of this in vitro study was therefore to determine and compare the flexural fatigue strength of resin composite materials and amalgam under fatigue conditions inserted by rest of RPD. The null hypothesis is that there are no differences between flexural fatigue strength of amalgam and composites under RPD's rest.

Materials and Methods

Forty-five freshly extracted permanent upper premolars, without caries, restorations or signs of fractures and with the same crown lengths were collected. All teeth were disinfected in 5.25% sodium hypochlorite for 8 hours and stored in 0.9% physiologic serum for 24 hours. All specimens were molded with the same distance from cemento-enamel junction in the acrylic resin.

The restoration size, location and cavosurface line angles of the cavities were chosen to conform the standard cavity design for amalgam and composite preparations. Both the amalgam and composites class II (Cl II) cavities were modeled with an isthmus width exceeding 1/3 of the inter-cuspal distance and a depth of 3.0 and width of 5.5 mm considering the incidence of failure associated with these dimensions. Finally, the preparations were finished with pear bur number 245 or 329.

There were three individual groups in this study (Table 1). Cl II DO cavities were prepared in all 45 extracted teeth and randomly divided into 3 groups of 15. The first group was filled with lathe-cut high copper non γ_2 amalgam, (Dispersalloy) Zn-free which was triturated using Wig-Bug amalgamator (Model 5AR, Crescent Dental Manufacturing Co., Chicago, IL, USA) according to the manufacturers' instructions. The load was repetitively applied by hand, producing a maximum condensation stress. The second and third groups were filled with resin composites; Flitek Z250 and Tetric® ceram respectively. To fill the second and third groups with composite, the teeth were etched with 37% phosphoric acid gel and the recommended dental adhesive for each composite material was applied to the walls and cured using halogen light curing unit (Elipar® Trilight, 3M, ESPE, Germany). The composites were inserted in incremental horizontal layering technique and irradiated from an occlusal, mesial and distal direction (800 w/cm^2). The illumination time on a single point was 20s for all the resin composites.

The procedures followed the manufacturers' recommendation and ISO 4049 standard. The restoration surfaces were finished and polished and ground with silicon carbide paper up to 1000 grit to avoid and remove the cracks at their edges.

Twenty-four hours after filling, 45 standard rest seats were prepared with a rounded triangular outline form with the floor of the rest resembling a saucer or spoon shape (2×2.5×1.5mm). All the teeth were stored for two weeks in distilled water at 37^{o}C. Teeth were subjected to 500 thermal cycles (ATICO House, 5309, Grain Market, Ambala-133001, Haryana, India) at temperatures between 5^{o}C and 55^{o}C. The thermal cycling consisted of a 30s soak in a water bath at each respective temperature, and a 30s transfer between temperature baths. In addition, the restorations were subjected to load cycling which followed the staircase approach as outlined by previous studies. The loading rate was 0.5 mm/min.

The 'staircase' approach method was used for fatigue evaluation. Initially 20 kgf loads were applied

Table 1: Materials used in this study

Material	Manufacturer	Type	Filler fraction (Wt%)	Composition
FiltekZ250	3M ESPE, St. Paul, MN,USA	Hybrid Composite	82.60	BIS-GMA, TEGDMA, Zirconia Silica
Tetric ceram	Vivadent, Schaan, Liechtenstein	Micro hybrid Composite Fine particle hybrid	78.6	BIS- GMA, TEGDMA, UDMA, Ba-Al-Flurosillicate/Barium glass
Dispersealloy	Johnson & Johnson Dental Product Co East Windsor, NJ, USA	Non γ_2, Zn-free	N/A	Ag, Sn, Cu

on the rest seat which is equivalent to mastication force. For every cycle the stress alternated between minimum and the maximum stress. Tests were conducted sequentially, with the maximum applied stress in each succeeding test being increased or decreased by a fixed increment, according to whether the previous test resulted in failure or not. The first specimen was tested at approximately 50% of the initial flexural strength value. The flexural fatigue limits (FFL) of the materials were determined for 10^5 cycles under equivalent test conditions at a frequency of 0.5 Hz.

the mean and standard deviation of fatigue limit for each group was determined. Data were analyzes using SPSS 16. The fatigue behavior of studied groups were analyzed by One-way ANOVA and its appropriate Tamhane's Post Hoc test for multiple comparisons. $P<0.05$ was considered as significant.

Results

The Filtek Z250 displayed the highest mean values (1.16×10^6) and amalgam the lowest (6×10^5). Mean flexural fatigue strength and standard deviation of all groups are presented in Table 2.

Table 2: Mean flexural fatigue strength and standard deviation of Amalgam and Composites.

Materials	N	Mean (Cycle)	±SD
Dispersalloy	15	6×10^5	1.59×10^5
FiltekZ250	15	1.16×10^6	2.72×10^5
Tetric ceram	15	9.57×10^5	2.18×10^5
Total	45	9.06×10^5	3.19×10^5

The results of One-way ANOVA and pair comparison (Table 3) revealed a significant difference between the materials ($P<0.001$). The Tamhane's post Hoc test indicated significantly higher mean flexural fatigue strength for composite groups in comparison with the amalgam group ($P<0.001$). The results also showed no significant differences between Filtek Z250 and Tetric-ceram.

Discussion

In this study, cyclic flexural fatigue of three different filling materials were investigated at the rest seat area for supporting removable partial denture. Cyclic flexural fatigue of the two resin composites and a conventional non γ_2 dental amalgam were investigated in this study by staircase approach following the method used by Ferracane et al [9]. The results showed a significant difference between two composites and dental amalgam ($P<0.05$), so the null hypothesis was rejected. Among the tested materials resin composites were more resistant to cyclic loading than amalgam.

The flexural fatigue limit refers to the resistance of the material to cyclic loading with a force well below the ultimate fracture strength of the material. The internal coherence of the material may change under cyclic loading below its fracture strength, as occurs during mastication, and may lead to failure due to fatigue. These properties predict the durability of the restorations under clinically simulated conditions [9].

Lutz et al. [13] have suggested that the use of amalgam substitutes for stress–bearing restorations in the permanent teeth cannot be recommended without caution. This is particularly true if a dynamic force such as RPD is applied. Normally, fracture in the amalgam occurs at the grain boundaries. Although the tested amalgam in this study was high-copper disperse alloy with high resistance to both marginal breakdown and fatigue crack propagation [14] it was more susceptible to fatigue than the composite materials.

According to Arola et al. [15] location and orientation of occlusal loading was the most important oral parameter to the restored molar with an amalgam restoration, and occlusal loads had little effect on the molar with a composite restoration. They reported that the molar with a composite restoration was less sensitive to mastication due to cusp reinforcement achieved by dentin and enamel bonding. Marginal bonding reduced stresses resulting from occlusal loads in molars with MOD amalgams. Moreover there was a trend for amalgam restoration to display a greater extend of crevice formation than the composite restorations [6].

The present study showed that the fractured cycle of Dispersealloy (6×10^5 cycles) was lower than the mean of the two resin composites' fracture cycles (Filtek Z250: 16×10^6 and Tetric ceram: 9.57×10^5). Htang et al. [16] described a correlation between filler content and fatigue resistance. They determined the maximum fatigue resistance at 75 %wt filler fraction. The two composite materials in the present study had

Table 3: Multiple comparison of fatigue behavior in studied groups

Groups		Mean Differenc	P value
Dispersalloy	FiltekZ250	-0.669*	<0.001
	Tetric Ceram	-0.477*	<0.001
FiltekZ250	Dispersalloy	-0.669*	<0.001
	Tetric Ceram	-0.192	0.108
Tetric Ceram	Dispersalloy	-0.477*	<0.001
	FiltekZ250	-0.192	0.108

different fillers content; Filtek Z250 had 82% wt and Tetric ceram had 78% wt. Adifferent filler content might exhibit a further insight on light polymerization kinetics. Lindberg et al. [17] have proven the hypothesis that higher filler contents are attributed to an increased scattering of light at the filler particles and thus followed by a changed monomer cross-linking and a decreased in-depth degree of conversion. This might be an important factor for the difference between Z250 and Tetric ceram.

The most common causes of tooth fracture have been identified as high impact forces produced by biting on a hard object or uncontrolled contact of opposing teeth. Similar phenomenon are also expected to affect posterior composite restoration, therefore, in this study, a repetitive impact load was laid to determine the effect of fatigue resistance of resin composite. A bonding system that bonds efficiently to tooth enamel and dentin, was applied because the adhesion of resin through the cavity was improved the fracture resistance of rest seat [18]. The monomer type and its exothermic reactivity as well as different initiator systems and additives might further result in material properties [19].

When resin based material is used as restorative, the interface of adhesive bonding to the enamel and dentin might play an important role in preventing micro-leakage and secondary caries [20]. Fracture was detected both at the composite tooth interface and within the composite itself [20]. Creep deformation and dynamic mechanical properties in dental restoratives were attributed to variations in filler configuration, such as filler size and fraction [19]. However in this study, Filtek Z250 and Tetric ceram had light activated polymerization, the same organic matrix (BIS-GMA, TEG DMA), and filler sizes (fine particles).

Lohbauer et al. [20] showed that materials with higher filler contents exhibited a tendency towards improved fatigue resistance. In the preset study, Filtek Z250 had higher filler content than Tetric ceram. In the current investigation, it was critical to replicate clinical function as closely as possible within the limitations of in vitro testing. Cyclic loading levels and frequency, rest seat size, and environmental conditions were all chosen to simulate oral conditions, in order to assess the effects of cyclic loading on composites and amalgam flexural fatigue strength. However this study employed traditional fatigue testing, which typically does not simulate occlusal loading. Therefore, due to higher stresses and loading frequencies that apply in oral environment, failure mechanisms may be different. Since In this study only the fatigue strengths of the materials were compared we cannot recommend the use of composites versus amalgam for the rest seats. Other properties such as wear resistance are important factors that need to be considered, so further in vivo and in vitro studies are recommended.

Conclusion

Based on the limitation of this study it was concluded that resin composite restoratives provide a higher flexural fatigue strengths compared to amalgam.

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