Innovative Analysis of Flexible Partial Denture Clasp after Fatigue Cycling Test

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Abstract

The utilization of polyamides in the construction of removable prostheses offers many advantages.

Aim: To examine the microstructure of polyamides and to evaluate their effect on the surface properties of enamel and ceramic restoration, in addition to studying the clasp tissue interface before and after fatigue loading.

Materials and Methods: 10 testing models were fabricated using polyamide resin with sound extracted lower first premolar teeth tested as the natural abutments for tooth 44, while porcelain fused to metal surveyed crowns were constructed for abutment tooth 34. Rapid repeated fatigue cycles (15,000) were carried out on these simulated models to simulate three years of clinical use.

Results: EDX-RA testing revealed the presence of zirconium particles within the polyamide surface. Flexible RPD underwent repeated rapid fatigue cycles without fracture.

Conclusion: Polyamide may be a suitable alternative to heat cured polymethylmethacrylate PMMA resins in the construction of flexible partial denture.

Keywords: Fatigue Cycling; Polyamides; Flexible Partial Denture; EDX-RA; Heat Cured Acrylic Resin

Introduction

In light of the advances in materials and their applications in Prosthodontics and Periodontics, fixed partial dentures are nowadays the restoration of choice for the replacement of missing teeth. However, in cases representing with bilateral distal extension saddles, the removable partial denture (RPD) becomes the only treatment modality possible [1,2]. Despite the wide use of implant supported fixed partial dentures especially when aesthetic demand is high, many patients are not suitable candidates for such treatment and the RPD is the indicated treatment option to replace missing teeth. Many factors affect treatment choices such as patient’s general and psychological health, anatomic consideration and factors as well as financial reasons, as treatment with RPD has been linked to demographics including income, educational attainment and socio-economic status [3,4].

One of the most important factors affecting the clinical performance of the RPD is its retention, which in some cases can hinder aesthetics due to display of the clasp assemblies [5]. Modern day technology enabled the employment of Polyamides in the fabrication of RPD. Conventionally, RPD are retained using the clasps as extra-coronal elements, or by incorporating the more expensive and technically demanding intra-coronal precision attachments. Although the clasp assembly provides acceptable retention to the RPD, aesthetics are sometimes compromised and often mechanical failure occurs as a result of fracture of the retentive component [6,7]. The alternative thermoplastic materials have a characteristically low modulus of elasticity (2 - 4 GPa) which provides superior flexibility compared to the conventional Cobalt Chromium (Co-Cr) alloys allowing their application as resin direct retainer and permits cervical placement of the
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Retentive arm to engage the deeper undercuts on abutment teeth which improves aesthetics. Additionally, these clasps exhibit minimum deformation of the clasp and decrease stress on the abutment [3].

There are numerous limitations to a conventional Co-Cr RPD as it acquires retention and bracing by extending the denture base into the gingival undercut area of the abutment tooth and through modifying the contours of the abutment tooth or teeth to create these undercuts when needed by dimpling, direct adhesive restorations and/or the fabrication of indirect inlays or crowns [8-10]. Such procedures are complex, require additional treatment chair time and increase the overall cost of the RPD. Furthermore, accurate surveying of the diagnostic cast as well as abutment teeth is needed for the preparation of guide planes and occlusal rest in a conventional RPD [11-13]. The establishment of a suitable path of insertion of RPD may sometimes be hindered by the presence of soft and hard tissue undercut and allergic reactions to the residual monomer component of the heat cured PMMA resin as well as fracture of denture base are some of the most critical short comings of these prostheses [14]. In some cases, abutments are restored with ceramic crowns to prolong the service life of an existing RPD [15].

The recent development in thermoplastic processing Polyamide resins has led to their application in the fabrication of RPD [16,17]. Today there are dozens of thermoplastic resins available for the fabrication of preformed clasps, metal free RPDs, temporary crowns, occlusal splints and orthodontic appliances [8,18]. Thermoplastic resin offer countless advantages and offer prolonged service lifetime [19].

The higher flexibility of polyamide enables the utilization of deeper undercuts on the abutment tooth with improved denture retention with minimal or no abutment modification required.

There is limited information available though on the structure of polyamides or their effect on the surface topography of the abutment enamel and restoration, The Aim of the current investigation was to analyze the microstructure of resins and Polyamides as well as to evaluate the effect of flexible RPD polyamide on the surface properties including topography of enamel and ceramic restoration as well as the clasp tissue interface before and after load cycling. The Scanning electron microscope (SEM) aided in studying surface topography while Energy Dispersive X-Ray Analyzer (EDX-RA) was employed to analyze the microstructure of the polymer and provide both quantitative and qualitative analysis.

Material and Method

Testing Models

The current study was conducted using a testing model simulating a lower Kennedy Class I RPD (bilateral free end saddle) constructed using heat cured PMMA resin (Acrostone; Acrostone Dental factory, England) and equipped with two extracted natural sound lower first premolar teeth as abutments (34 and 44). Abutments were embedded within the model socket using auto polymerizing cold cured acrylic resin (Acrostone; Acrostone Dental factory, England). All natural abutment teeth (34) were prepared to receive surveyed porcelain fused to metal crown while abutment teeth (44) were prepared with a mesio-buccal undercut measuring 0.75 mm, a mesial rest and a distal guiding plane. Similarly, ten flexible polyamide resin testing models were fabricated (Breflex, Bredent-From GmbH and Co. KG, Germany) to simulate the lower Kennedy Class I RPD distal extension removable partial dentures.

Surveyed crowns on abutments

All extracted natural sound lower first premolar abutment teeth 34 were prepared to simulate an abutment with a surveyed porcelain fused to metal crown. Each prepared abutment tooth was duplicated using additional silicone rubber material (Rapid. Coltène - Whaledent AG, Feldwiesenstrasse 20, 9450 Altstätten, Switzerland) to produce a working cast made of hard stone (Dentstone KD plaster, Saint-Gobain, USA). The surveyed crown was waxed up and surveyed to provide a mesio-buccal undercut measuring 0.75mm, a mesial rest and a distal guiding plane. These were then cast for the fabrication of the porcelain (VITAVM®13H. Rauter GmbH and Co. KG, Bremen.

Germany) fused to metal (Wiron®99, BEGO Bremer. Herbst GmbH and Co. KG, Bremen, Germany) surveyed crown. The completed crowns were cemented on the abutments with zinc phosphate cement (Hoffmann quick setting. 14193 Berlin, Germany).

**Waxing up the RPD**

The working cast was surveyed (Ney Surveyor Complete Kit. Dentsply Neytech. USA) at zero tilt to determine the height of contour, guide planes as well as to measure the mesio-buccal undercut assuring it was 0.75 mm. The RPD was waxed up (Dental wax. Lordell trading. New southwales. Australia) on the refractory cast and included the extension of the saddles, lingual plate major connector and the clasps assembly including the occlusal rests. Once completed and sprued, the wax pattern of the RPD was invested in a stone mould for injection moulding following wax elimination according to manufacturer’s instructions (Breflex, Bredent-From Gmbh and Co. KG, Germany) at an injection pressure of 720 - 750 KPa, at 220°C for 15 min. The flask was allowed to bench cool prior to finishing and polishing using silicone point.

The experimental model with the flexible RPD was subjected to the following tests:

**Fatigue Test**

The RPD was screwed onto a metallic ring (Figure 1a and b), the assembly was then mounted onto the mechanical fatigue testing machine (Vibration Type Fatigue Taster-Metrimpex-Hungarian trading Co. Budapest, Hungary) (Figure 2a and b). Fatigue testing was performed in dry air conditions with 15,000 fatigue cycles where each cycle consisted of placing and removing the RPD on and off the abutment teeth to simulate 10 years of clinical service with an estimation of RPD insertion and removal 3 times a day. Testing was at a load of 50N and the fatigue test was terminated upon fracture or deformation of the clasp.

![Figure 1 (a and b): RPD attached to the plate with screws.](image)

![Figure 2 (a and b): RPD and plate assembly mounted onto the fatigue cycles machine.](image)

**Scanning Electron Microscope (SEM)**

SEM investigation (JSM-6360la, JEOL, Tokyo, Japan) at 200 and 500 x magnifications of the surface to study the surface topography prior to and after insertion - removal test. This was to evaluate the effect of flexible RPD on the surface topography of the enamel (44), porcelain (34) and the clasp tissue interface of the retentive arm of the clasp assembly. Specimens were sputter-coated with gold to enhance the electron scattering from the specimens surface.

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Energy Dispersive X-Ray Analysis (EDX-RA)

The SEM was equipped with an Energy Dispersive X-Ray analyzer (EDX-RA, JEOL, Tokyo, Japan) that uses an X-Ray photoelectron beam (XPS) for qualitative and quantitative determination of the microstructure of analyzed surfaces. EDX-RA analysis of the microstructure of the polymer was carried out on all testing models as well as the retentive clasp arm, the enamel surface of the natural tooth and the porcelain crown surface.

Results

SEM examination of the interface of the flexible clasp arm prior to fatigue testing showed smooth surface of the polymer with a scattering of few inorganic particles (Figure 3a and b). Qualitative EDX-RA analysis of these particles revealed the presence of zirconium 20.6% (Figure 4).

Figure 3 (a and b): SEM of the inner surface of the retentive clasp arm before fatigue testing (magnification X200 and X500).

Figure 4: XPS spectrum of the inner surface of the retentive clasp arm before fatigue testing showing the element percent.
SEM imaging of both enamel surface of the abutment tooth and the tissue interface of the flexible clasp arm after load cycling showed abraded surfaces (Figure 5a and b). The results of EDX-RA analysis revealed zirconium particles (4.8%) (Figure 6).

**Figure 5 (a and b):** SEM of a: the enamel surface of the abutment and b: the inner surface of the clasp arm following fatigue testing (magnification X200 and X500).

SEM imaging of the ceramic crown and the interface of the flexible retentive arm of the clasp after testing showed less abraded surface with fewer scattered inorganic particles (Figure 7a and b). The results of quantitative analysis of EDX-RA revealed a zirconium particles about 85.7% (Figure 8).

**Figure 6:** XPS spectrum of the inner side of flexible clasp arm at the clasp tissue interface after testing.

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Figure 7 (a and b): SEM imaging of a: the ceramic crown and b: the inner surface of the clasp arm following fatigue testing (magnification X200 and X500).

Figure 8: XPS spectrum of the inner surface of flexible clasp arm contacting ceramic crown abutment after testing.
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Discussion

RPD is traditionally used to replace missing teeth and in some clinical situation, the restoration of the abutment with a surveyed crown is required to provide appropriate height of contour, restoration to abutment and to increase the longevity of the existing RPD.

The current study utilized the mandibular first premolar teeth as an abutment as these teeth represents an aesthetic demand when used as retainers for the PRD. These are usually equipped with civically approaching clasps as the occlusally approaching clasps of cast Co-Cr alloy was reported to produce excessive stresses on the premolar abutment [20]. Mandibular first premolar (34) was prepared to receive a surveyed crown replicating the clinical situation when a need to correct the height of contour is present.

Bre-flex polyamide material was selected because for the construction of the flexible denture due to its high strength and flexible nature which make it an idea option as a stress breaker to provide superior function and favourable stress distribution. Such flexibility eliminates the fulcrum effect of the distal extension (free end saddle) across the arch and allows equal distribution of forces along the edentulous ridge [12].

Fatigue was tested as it represents 90% of all RPD failure. This was tested by rapid cycling at a constant stress until failure occurs. No clasp or RPD fracture was noted in the present study which may be attributed to the flexibility of the material whereby no or minimal stress was created in the clasp assembly during simulated insertion and removal of the RPD [21-23].

SEM offers many advantages including higher resolution and magnification leading to better imaging [24,25].

The current investigation utilized an SEM with an attached EDX-RA which provides rapid qualitative and quantitative analysis of elemental composition. XPS analysis can form maps or line profiles to disclose the elemental distribution in a examined surface [26-28].

SEM imaging of the interface of the flexible retentive clasp arm prior to testing revealed a smooth surface with few scattered inorganic particles of zirconium as established by EDX-RA analysis. This may be attributed to the construction method of polyamides using the injection moulding technique which results in the mechanical qualities known and favoured for polyamides including high strength and hardness as well as resistance to solubility in acidic media [29].

SEM of the surface of abutments (both enamel and ceramic) presented slight abrasion which could be due to the presence of zirconium in the polymer. It may also be due to fatigue behaviour [15]. Zirconia is a ceramic material with high resistance to crack propagation and fracture which was reported to resist fracture of under fatigue loading similar to the current finding [30].

Conclusion

Within the experimental limitations of this study, Flexible RPD constructed using polyamides were found to exhibit high strength as no fracture occurred following 15,000 cycles suggesting that this is a clinically suitable polymer for the construction of flexible RPDs. The flexible RPD model displayed superior flexibility with lower stress transmitted to the clasp arm as indicated by absence of fracture and/or deformation. Furthermore, the flexible RPD resulted in less abrasion on ceramic surveyed crown of the abutment. The EDX-RA analysis of the flexible clasp arm following fatigue testing disclosed the presence of zirconium particles in the polymer. The reinforcement of polymer with zirconia may have resulted in the improvement in the fracture resistance of the flexible clasp arm.

Clinical Implication

Further investigation including in-vivo studies should be undertaken to assess the effect of temperature and pH.

Bibliography


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