Fatigue behaviour of Recasted Removable partial denture alloys
Abdul Aziz Al Kheraif, Murali Ramamoorthi

Abstract
Background: Clasps undergo fatigue fracture under repeated flexures caused by denture insertion, removal and mastication. Aims & Objectives: The aim of this study was to compare the fatigue behaviour of different generations and different proportions of as cast and recasted alloys used for removable partial denture. Material Methods: A total of 210 specimens were casted and divided into 21 groups each 10 specimens for four different alloy groups. The alloys studied were low gold alloy, medium gold alloy, and palladium alloy and cobalt chromium alloy group. Different proportions used were 100%, 50%, 75% new alloy and alloys were studied up to three generations. One way deflection fatigue test was used. The number of cycles required to fracture each specimen was recorded and subjected to statistical analysis [95% confidence level]. Results: Results revealed invariably decreased fatigue resistance for the alloy groups studied for the second and third generation. Also it is decreasing if the new alloy percentage used was less than 100%. Conclusion; Recasting apart from compromising the biocompatibility, fatigue resistance is also compromised.

Key Words: Deflection fatigue test; Noble alloys; Recasting

Introduction
Casting procedures require use of more metal than is needed to produce a restoration. Dental laboratories often reuse the casting surplus like sprue and metal remaining in the crucible former to produce castings when high cost alloys are used. Alloy reproducibility is an important factor to consider when choosing the alloy material due to its oxidation, component volatilization by the heat source. A recast alloy may not have the same reproducibility as a new alloy. Since physical properties of new and recasted alloys are not always the same. Tucillo et al compared the effects of different melting techniques on the physical properties of recasted noble alloys.(1) They concluded that the amount of noble metals [gold, platinum and palladium] and other major elements [silver, copper] in the alloy composition remained stable. Literature guidelines for recasting dental alloy vary from adding no new metal to some new metal to 50% new metal with previously melted buttons or sprues removed from castings.(2-4) Although several publications have characterized the material science aspects of recasted alloys, no mention has been made in the technical literature about the effect of recasting on fatigue behaviour of the alloy. Removable Partial denture frameworks are designed based on theoretical biomechanical requirements and fabricated using a sequence of technical steps, their behaviour over time is important. Fatigue behaviour and survival rates of the clasps have not been well described in the literature. Fatigue was first mentioned in the mid 1970’s. The loss of a material’s mechanical properties after repeated loading is an important consideration in metal selection for framework fabrication. This study was conducted to evaluate the fatigue behaviour of different combinations and generations of recasted noble alloys and base alloys.

Materials and Method
The basic test specimen used was the prefabricated clasp wax pattern of dimension 15mm length and 10mm outer diameter similar to the studies done by Vallitu and Kokkonen. The wax patterns were invested and casted using type IV noble alloys [yellow special, pontor MPF, ceradelta] and a cobalt chromium base metal alloy [metalloy cc] with a phosphate bonded investment. A total of ten specimens for each alloy group were casted. Groupings of the alloys studied for the fatigue behaviour were showed in the Table 1 and 2. Different generations and different proportions of new and recasted alloy were studied. Up to three generations were studied and three casting protocols were compared according to the proportion of as received and recast alloy. In the first group all metal was used for the first time [100% as received metal]. In the second group the sprue assembly was carefully removed, cleaned, weighed and combined with an appropriate amount of new metal with previously melted buttons or sprues removed from castings.(2-4) Although several publications have characterized the material science aspects of recasted alloys, no mention has been made in the technical literature about the effect of recasting on fatigue behaviour of the alloy. Removable Partial denture frameworks are designed based on theoretical biomechanical requirements and fabricated using a sequence of technical steps, their behaviour over time is important. Fatigue behaviour and survival rates of the clasps have not been well described in the literature. Fatigue was first mentioned in the mid 1970’s. The loss of a material’s mechanical properties after repeated loading is an important consideration in metal selection for framework fabrication. This study was conducted to evaluate the fatigue behaviour of different combinations and generations of recasted noble alloys and base alloys.
From the results it is revealed that the number of loading cycles required to fracture each specimen was recorded automatically. The test was carried out until fracture of the specimen. The number of loading cycles required to fracture each specimen was recorded automatically. No polishing procedures were performed to ensure uniformity. Only nodules were carefully removed under magnification.

**Table -1 Alloys studied**

<table>
<thead>
<tr>
<th>Alloys</th>
<th>Manufacturer</th>
<th>Composition</th>
<th>Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow special</td>
<td>Metallor, Switzerland</td>
<td>Au-41% Ag-44.9% Pd-1.7% Cu-11% Pt,Ru,Sn,Zn</td>
<td>Phosphate bonded investment</td>
</tr>
<tr>
<td>Pontor</td>
<td>Metallor, Switzerland</td>
<td>Au-72% Ag-13.7% Pt-3.6% Cu-9.8% Zn,Ir</td>
<td>Phosphate bonded investment</td>
</tr>
<tr>
<td>Ceradelta</td>
<td>Metallor, Switzerland</td>
<td>Pd-57.5% Ag-32% In-6% Sn-2% Ga-1.5% Zn-1%</td>
<td>Phosphate bonded investment</td>
</tr>
<tr>
<td>Metalloy CC</td>
<td>Metallor, Switzerland</td>
<td>Co-61.5% Cr-27.5% W-8.6% Si-1.3% Mn,N,Nb</td>
<td>Phosphate bonded investment</td>
</tr>
</tbody>
</table>

Recovered castings were cleaned with airborne particle abrasion using 80 micron aluminum oxide particles. The dimensions of the specimens were measured by a digital micrometer [with an accuracy of 0.001mm] supplemented with a profile projector [Model 6 c; Nikon corps, Tokyo, Japan]. Specimens with defects [macropores and metal protrusions] were rejected and repeated. Incomplete and deformed castings were also discarded. No polishing procedures were performed to ensure uniformity. Only nodules were carefully removed under magnification.

**Table-2 Physical properties of alloys studied**

<table>
<thead>
<tr>
<th>Alloys</th>
<th>Vicker hardness hvs</th>
<th>Modulus of elasticity Mpa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow special</td>
<td>160</td>
<td>80,000</td>
</tr>
<tr>
<td>Pontor MPF</td>
<td>220</td>
<td>1,00,000</td>
</tr>
<tr>
<td>Ceradelta</td>
<td>270</td>
<td>122,000</td>
</tr>
<tr>
<td>Metalloy CC</td>
<td>290</td>
<td>2,00,000</td>
</tr>
</tbody>
</table>

Fatigue test: A one way constant deflection fatigue test was used with the pneumatic testing machine used by the previous studies. (5) The specimens were deflected with a 0.6 mm one way constant amplitude force at intervals of 300 milli seconds. The maximum deflection force, time and number of loading cycles were registered. The loading frequency used in this test was 3.3 Hz; the loading waveform was square and R-5% [load ratio-ratio of minimum and maximum fatigue force]. The test was carried out until fracture of the specimen. The number of loading cycles required to fracture each specimen was recorded automatically. The specimens was less to the second generation than the first generation alloys for all the groups, third generation alloys require less cycles than the first and second generation alloys for all the alloys studied, and it is not affected by heat treatment also. The 100% new alloy used for casting requires more number of cycles to undergo fracture than the 50% as cast and 75% as cast new alloy used to obtain the castings. The mean values were compared and statistical analysis was done. There was no statistical difference between the groups at 95% confidence level.

**Discussion**

For decades gold has been used to fabricate cast dental prosthesis. In an attempt to reduce the expenses of these restorations gold alloys could be recast. Over time for economic reasons base metal alloys have become widely used as cast materials. Base metal alloys are prone to various types of corrosion depending on alloy composition and the oral environment. To further decrease the cost, previously used base metal alloys may be combined with new metal to produce restorations. Manufacturer product information on casting alloys typically states that scrap metals can be remelted to fabricate clinically acceptable castings providing that at least 50% new metal is used. The basis for this empiric guideline is that certain important secondary elements present in small percentages in the original alloy compositions may be lost during melting, through volatilization or oxidization. The best example is zinc which act as an oxygen scavenger during melting to minimize the oxygen of other elements in the alloy. Some studies concluded that amount of noble metals and other major elements in the alloy composition remained stable during remelting. This was concluded from the results of the present study also. However some studies proved the poor surface texture of the remelted castings, this is probably because of some alloy components like tin, and indium was volatilized due to their low melting point. (6)

Fatigue which is the process of progressive localized permanent structural change in a material subjected to cyclic loading is responsible for 90% of all service failures due to mechanical causes. Fatigue fracture develops from small cracks presented on the surface and propagates through the grains of the material. The causes of cyclic fatigue in the material are its inhomogeneity and anisotropy. Metallurgical concentrators, such as superficial defects and notches, poor surface polishing, inclusions and porosity are particularly dangerous and can lead to catastrophic failure and the reduced number of
cycles. These imperfections lead first to the development of micro cracks, which coalesce and ultimately to a microscopic crack and failure.

The testing method in this study used a deflection of 0.6 mm. obviously; the magnitude of deflection is greater than the retention undercut of the tooth used clinically. It has been suggested that for an RPD with wrought-wire clasps, an undercut of 0.25 mm provides adequate retention. Later, after testing wrought-metal wire clasps, Ikebe et al. reported undercuts greater than 0.5 mm are too large for base metal wires.(7) Because of relatively high modulus of elasticity, the cobalt-chromium alloy clasp should, according to the literature, be used in retentive undercuts of less than 0.5 mm.(6) It can be roughly estimated that the clasp of the RPD bends 10 times per day from insertion and removal of the RPD, which means that the clasp is affected by 3600 deflections per year.(7-10) Furthermore mastication affects bending of the clasps and should also be considered. If no wearing of the retentive undercuts of the tooth is seen, metal fatigue may fracture the yellow special alloy after 11 years, Ponto mpf alloys after 18.5 years, ceradehta after 20 years and metalloy cc after 12.4 years. This hypothesis, however, requires further verification. An important factor that affects the strength of an alloy is its grain structure. Biffar and Appel examined the grain size of cobalt-chromium alloy at different locations on the RPD and found that the grain count decreased continuously from the clasp tip towards the sprue.(11) The grain count in a clasp cross-section has been reported to be as low as two or three. On the other hand, in a cross-section of a gold alloy clasp there can be as many as 100 grains.(8) Further investigations should be conducted to determine the cytotoxicity, surface roughness of recasted alloy. Specimens were subjected only to vertical directed forces, clinically the forces are multidirectional. Hence the influence of these factors should be considered in future experiments before a more accurate evaluation can be made.

Conclusion

Within the limitations of the study the following points were concluded;
1. The fatigue resistance of recasted alloy is less compared to the fresh alloy.
2. The one way deflection fatigue test is a useful tool to study the fatigue behaviour of an alloy.
3. Noble alloys shows better fatigue resistance than base metal alloy.

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