Eur. J. Prosthodont. Rest. Dent., Vol.15, No. 1, pp 13-18
Printed in Great Britain

The Abrasion of Dental Composite by Cobalt-Chromium Clasps

Mohamad M. Hamirudin* and Michael J. Barsby†

Abstract - *In cases where there are no suitable natural undercuts on the teeth which can be used to provide clasp retention for a partial denture artificial undercuts can be created by the application of a composite filling material. An in-vitro investigation was undertaken to assess the surface integrity of three different composite restorative materials following repeated cycles of movement of cobalt-chromium I-bar clasps over artificial undercuts created using the composite materials. A laser reflection confocal microscope was used to quantify surface changes in the composite specimens. Simulation of the equivalent of 5 years of clinical usage showed that a composite resin with the smallest particle size exhibited the least surface wear.*

KEY WORDS: Composite resins, clasps, partial denture retention

INTRODUCTION

Retention is that property of a denture which resists displacement of the denture away from the tissues. Retention of a partial removable denture depends on direct retention, indirect retention and guide planes. The most commonly employed type of direct retainer is a clasp. In cases where there are no suitable natural undercuts, the abutment teeth may be modified in shape by the placement of suitably contoured inlays or crowns. However, such restorations are a poor choice for a caries free tooth.

Various techniques have been described as a means of creating artificial undercuts on natural teeth. A technique of using a threaded pin had been described to create a slight projection on the buccal tooth surface, as the artificial undercut[1]. However, since this involves some removal of tooth tissue it is not a minimally invasive technique. Another simple method of creating a buccal undercut is to prepare a dimple with a diamond or carbide bur[2]. With this procedure, penetration into the dentine can occur which may cause dentinal hypersensitivity and because the surface may be difficult to clean there is an increased risk of caries.

Alternatives to these invasive methods are now available. Acid-etching of enamel has led to development of resin-bonded restorations[3]. Bonding of a metal veneer to acid etched enamel can be used but may compromise appearance. A simple technique is to create an undercut by the application of a composite filling material to the appropriate region of the tooth crown[4-6]. Partial coverage porcelain veneers are another alternative, but thin porcelain may be prone to fracture because of its brittleness and is impossible to repair[7].

The aim of this study was to assess and compare the surface integrity of three different composite restorative materials used to create artificial undercuts on natural teeth following repeated cycles of movement of cobalt-chromium I-bar clasps over the artificial undercut.

The objectives were:

1. To develop a method of quantifying surface changes in a composite material following repeated cycles of movement of a cobalt-chromium clasp over it.
2. To investigate the abrasion resistance and abrasivity of different composite resins when used to provide tooth undercuts for removable partial dentures.
3. To examine material loss from a cobalt-chromium I-bar following repeated cycles of movement over an artificial undercut created with composite resin.

MATERIALS AND METHODS

This was an in-vitro investigation. The composite materials used in this study, though all manufactured by the same company, were chosen because of differences in their composition in order to see whether this would affect their resistance to wear when used for making artificial undercuts. In order to have standardisation, a Cosmo® lower premolar acrylic tooth was used to make the mould of the composite specimens comparable in size and contour, and only composite shade of A3.5 was used in order to reduce variables.

The brands of composite resin tested were: Herculite HRV, Point4 and Prodigy which according to the manufacturer have mean sizes of filler particles 0.6µm, 0.4µm and 0.8µm respectively. Five replicas of premolar teeth were made from each brand of composite and mounted on an acrylic base (Figure 1). A dental surveyor was used to locate an undercut of 0.25 mm on each of the composite specimens which were subsequently marked. Three line markings close to the undercut area were made on each specimen to ensure reproducibility of placement of the clasp specimens at every cycle interval between runs of 1100 cycles.

Based on a paper presented at the British Society for the Study of Prosthetic Dentistry Annual Conference 2005 in Cardiff.

* BDS, MClinDent (Prosth.), Dip.DCSc, MFDS,RCS(Eng)
† BDS, BSc, PhD, FDS,RCS, Dip.Psych.

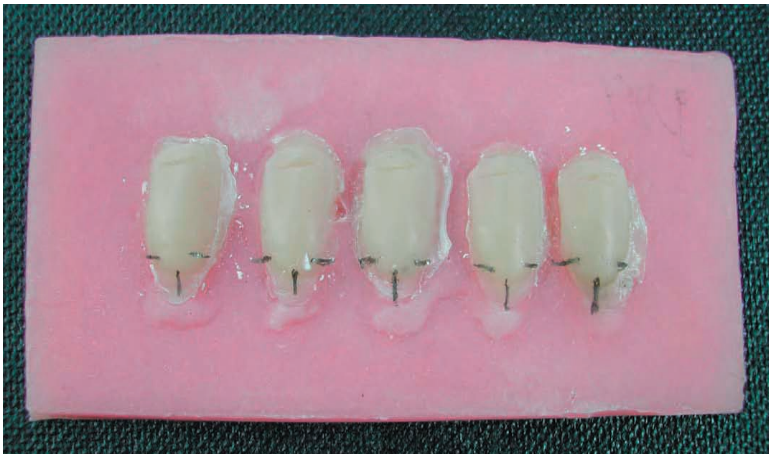

Figure 1. *Composite specimens.The specimens were marked to ensure reproducibility of placement of the clasp specimens.*

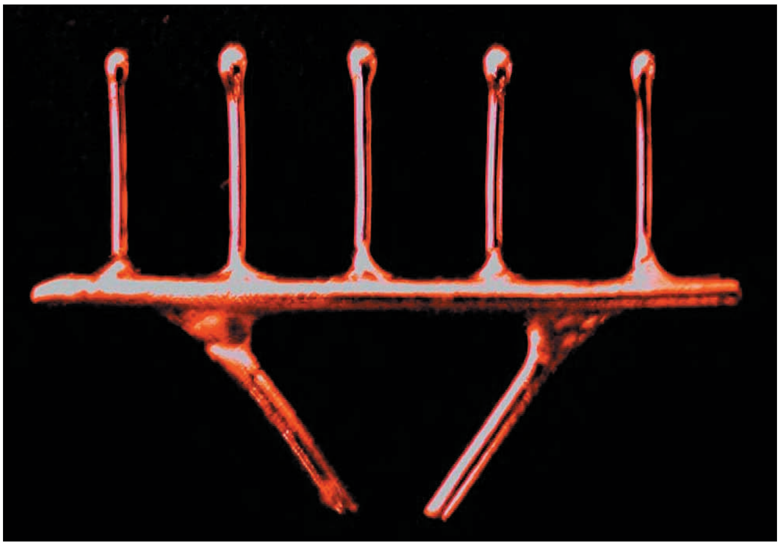

Figure 2. *Cast cobalt-chromium clasp specimens.*

Preformed wax patterns were used to form uniform wax patterns of the I-bars. The length of each clasp was 15mm. A working clasp length of 15 mm was selected because it has been suggested to be clinically relevant [9,10]. All clasps were joined together to form a triangular bar to facilitate retention in the test rig (Figure 2). Three cobalt-chromium alloy specimens each comprising five I-bar clasps were made. The clasp specimens were weighed before and after the test cycles at 1100 cycle intervals.

A servo hydraulic fatigue test machine (Mayes®) was used to move the composite specimens against the clasp specimens. Composite specimens were mounted to the lower test rig while the clasp specimens were mounted to the upper test rig and attached to the test machine. A 10 Newton load was calibrated to the clasp specimen by using a force applicator cell with a stopper. The load was oriented perpendicular to the long axis of the composite specimens when the clasps were being loaded to the undercut area. The tips of the clasp specimens were placed on the composite specimens where the undercut area was marked. Testing was carried out with the specimens immersed in circulating normal saline at 37°C (Figure 3). The test was run up to 5500 cycles at 1 Hertz. The figure of 5500 cycles was chosen and thought to be equivalent of 5 years of clinical usage based on the assumption that a patient might insert and remove a denture into and from his/her mouth three times a day. Micro movement of the denture during the function was not considered in this test.

A laser reflection confocal microscope (Lasertec®-ILM2W) was used according to the operating manual to quantify surface loss from the composite specimens that were loaded with a force of 10 Newtons by the clasps. The images produced were viewed at magnification of x 4 (Plan Apo 4/0.20 Nikon®) and x 10 (Plan Apo 10/ 0.45 Nikon®) lenses for the selected specimens. Images were analyzed using software for image segmentation and 3D data computation. Measurements were made along the groove made by each clasp below the bulge of the composite specimens by placing two points on either side of the groove and a third point at the bottom of the groove, to establish the height difference in microns. The measurements were made from point A to point B and point C to point B (Figure 4). The average of these two measurements presented the depth of the groove made by the clasps.

The raw data were entered into a Microsoft excel XP spreadsheet file and imported into the SPSS Data Entry Programme (version 10.0). The variables recorded were composite specimens number (n = 15), the I-bar clasp specimens number (n=15), composite wear rate after being abraded by I-bar clasps at 1100 cycles intervals for 5500 cycles and weight loss of I-bar clasp specimens similar to the cycles mentioned earlier. The data were analysed using SPSS statistical software (version 10.0). Descriptive statistics were used to describe the results.

RESULTS

Composite specimens

Composite wear was noticed at 1100 cycles with Point4®, Prodigy® and Herculite® specimens. The amount of wear was more pronounced with Prodigy® specimens followed by Point4® and Herculite® specimens. Point4® specimens showed more wear compared to Herculite® specimens at 1100 cycles. This was probably due to its surface roughness before testing, since more filler particles may be exposed and prone to dislodgement from the resin matrix during the test cycles.

At 2200 cycles the amount of composite wear for Point4® and Herculite® specimens were similar while Prodigy®

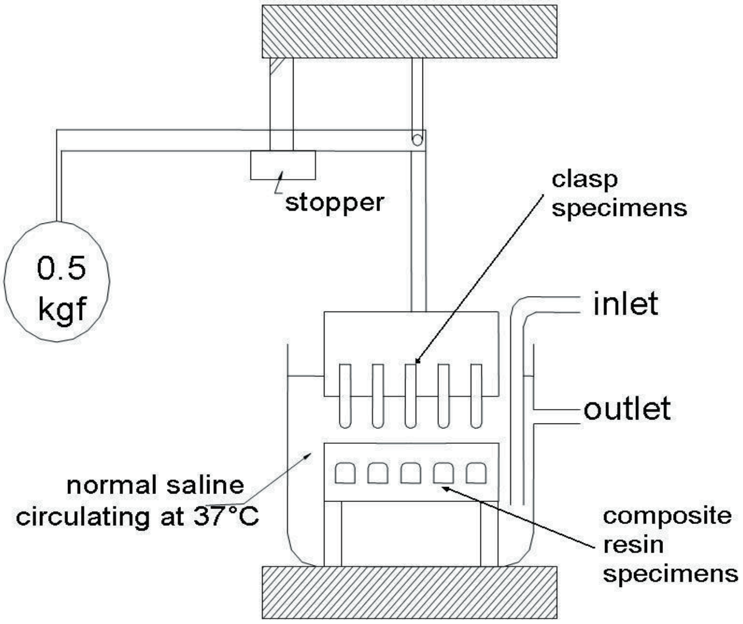

Figure 3. *Diagrammatic representation of the test compartment.*

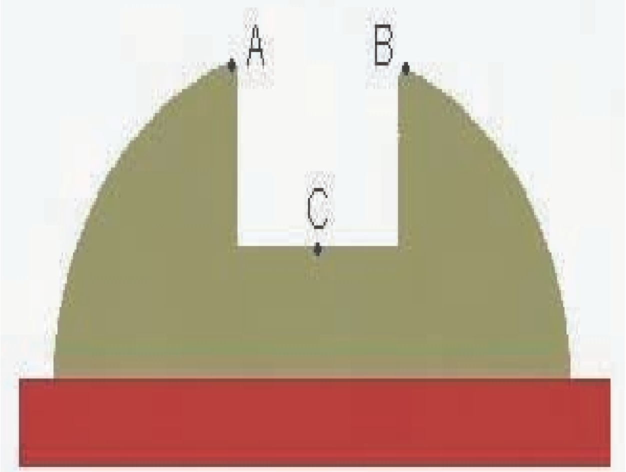

Figure 4. *Three point markings are made on the image to its surface tangent*

specimens still had the highest amount of composite wear. At this cycle Point4® specimens had been polished by the movements of the clasp specimens. Therefore less wear was seen.

The subsequent test cycles at 3300 cycles, 4400 cycles and 5500 cycles showed Point4® specimens had the lowest amount of wear followed by Herculite® and Prodigy® (Figure 5). At these stages the amount of wear appear to be associated with the size of the filler particles with the smaller the size of filler particles accompanied by the least amount of wear of composite specimens. Point4® specimens had 0.4 μm of filler particles this would give a smoother surface for the clasps to move on, whereas Prodigy® and Herculite® would provide rougher surfaces and therefore the amount of wear was higher with these specimens.

Clasp specimens

No statistical analysis was made of changes in the clasp specimens. However, the clasp specimens were weighed for comparison in weight reduction after each 1100 test cycles. No significant weight loss had occurred even after 5500 test cycles and ranged from 0.2 to 0.85 per cent. Weight reduction was very similar for the clasps used with Point4® and Prodigy® but was higher for clasp used with Herculite®.

Presentation of Laser Reflection Confocal Microscopy Images

Images from laser reflection confocal microscopy were colour coded to produce topographical map image. Each pseudo-colour band represents 3 μm. The pre-test image of a composite specimen is shown in Figure 6 in which the white colour band represents the top most area while the blue area represents the lowest area of the specimen. At 1100 cycle there were signs of abrasion on the composite specimen as seen in Figure 7. At the subsequent 5500 cycle the composite specimen was severely abraded by the clasp specimen especially below the top most area which also represents the 0.25mm undercut area (figure 8).

DISCUSSION

The aim of this study was to assess and compare the surface integrity of three different restorative composite materials used to create artificial undercuts on natural teeth following repeated cycles of movement of cobalt-chromium I-bar clasps over the composites. The experiment has attempted to simulate approximately 5 years clinical usage of insertion and removal of a removable partial denture.

The technique of creating artificial undercuts on teeth using composite resins has been available for nearly three decades[4]. It is therefore surprising that few studies have been undertaken to investigate either, wear of composite resins when used in this way, or, the effect of the composite on the clasp materials. The only comparable study found in the literature appears to be that carried out by Davenport et al.[8]. However, in the latter study, microscopy techniques were not used to quantify surface changes following repeated cycles of a cobalt-chromium I-bar clasp.

Testing was carried out in vitro, but the oral environment was simulated by using normal saline maintained at 37°C circulated in a water-bath. The normal saline was changed at every 1100 cycles for each composite specimen group so that filler particles accumulated during the test were removed from the recirculating normal saline and did not subsequently influence the rate of abrasion. The clasp and I-bar clasp specimens were both rigidly attached to the test rig component of the test machine and to prevent any unintentional movement during the test. A force of 10 Newtons (equivalent to 1 kg) was applied to the clasp specimens during movement over the bulge (0.25 mm undercut) of the composite specimens to comply with the 1 kg load to the clasp during function suggested by Bates[9]. However, it is not known how realistically the stresses

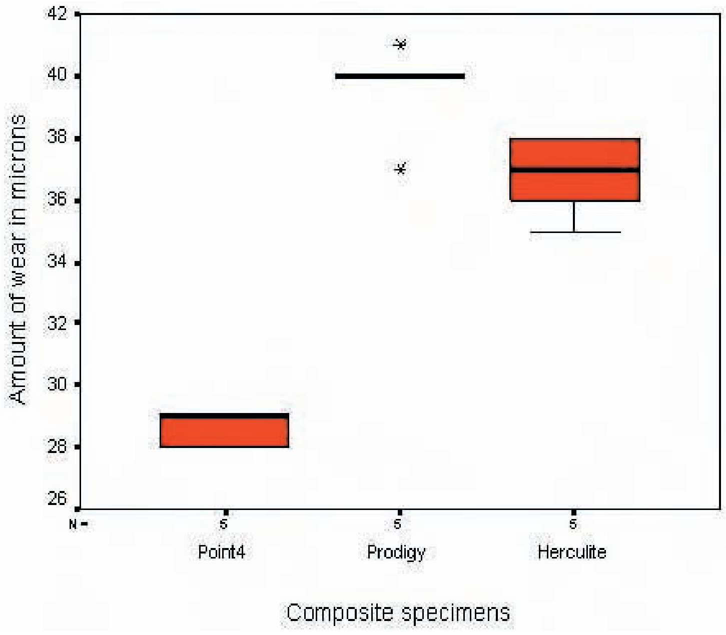

Figure 5. *Amount of restorative composite material wear at 5500 cycles (μm)*

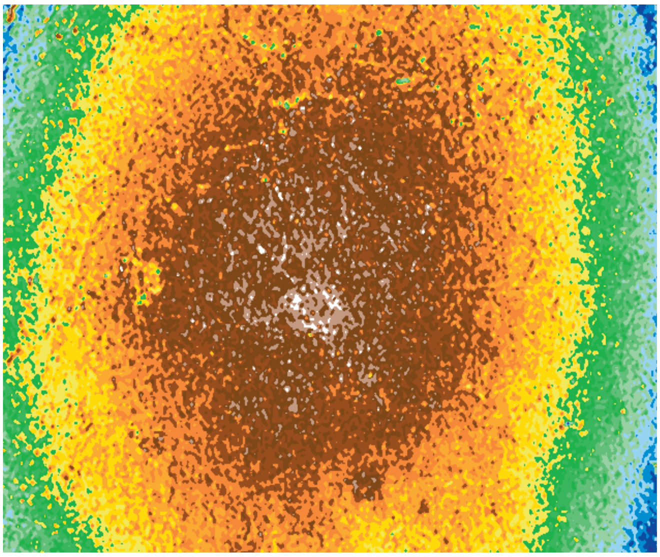

Figure 6. *Topographic map image of Prodigy specimen at 0 cycles acquired with x 10, Plan Apo 10/ 0.45 Nikon® lens at the 0.25 mm undercut area. Depth range was 43.1 µm. Each pseudo-colour band represents 3 µm. Field width is 946 µm.*

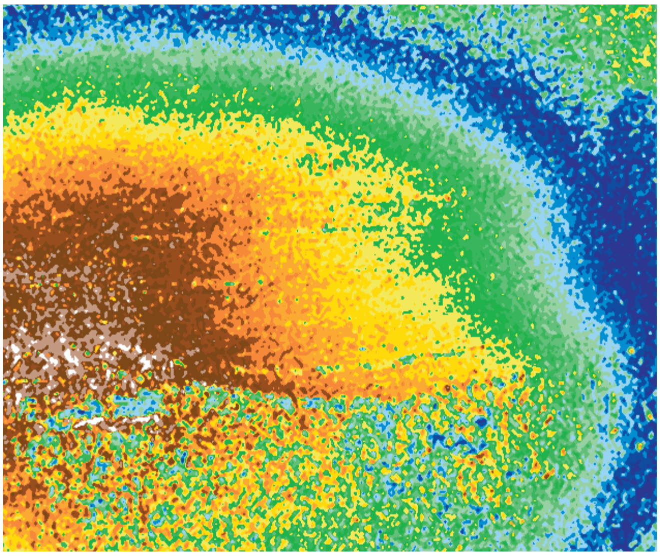

Figure 7. *Topographic map image of Prodigy specimen at 1100 cycles acquired with X 4, Plan Apo 10/ 0.45 Nikon® lens at the 0.25 mm undercut area. Depth range was 200 µm. Each pseudo-colour band represents 3 µm. Field width is 2285 µm.*

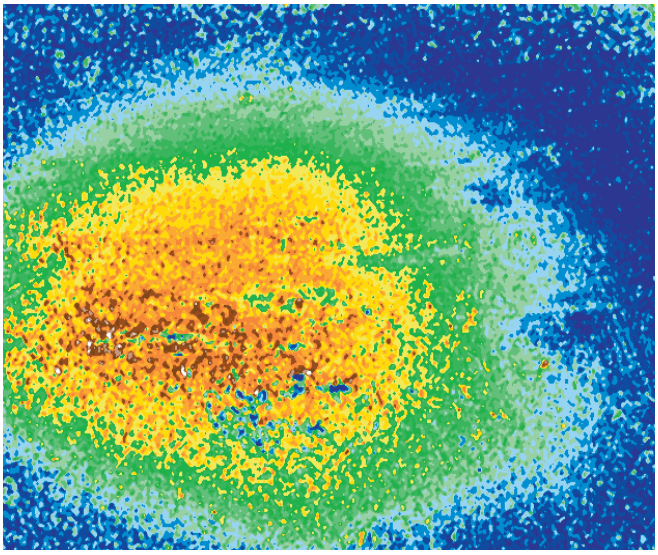

Figure 8. *Topographic map image of Prodigy specimen at 5500 cycles acquired with x 4, Plan Apo 10/ 0.45 Nikon® lens at the 0.25 mm undercut area. Depth range was 168 µm. Each pseudo-colour band represents 3 µm. Field width is 2285 µm.*

at the point of contact of the clasps with the composite specimens simulate actual clinical situations.

The study by Davenport et al.[8] investigated the mutual abrasion of composite resins and clasps but the clasp engagement at 0.25 mm was not mentioned in the study and the pattern of the wear groove made by the claps was not reported. In the present study undercuts were measured with a dental surveyor at 0.25 mm and the wear grooves made by the clasps on the composite specimens were analyzed with the laser reflection confocal microscope.

Previous authors suggest that the retention of clasps decreases with time as a denture is worn [11,12]. In this study because the clasps were repositioned against the composite specimens every 1100 cycles deterioration in retention would not necessarily be the case but might be expected in clinical usage due to reduction in the size of the artificial undercut or loss of clasp content. Repeating the test without interruption to 5500 cycles might show significant loss of clasp contact and therefore retention.

No conclusion can be made concerning material loss from the clasp specimens because no significant weight loss was identified during the test. However, a more accurate result might be obtained if the clasp specimens could be evaluated individually. The study by Davenport et al. [8] reached a similar conclusion on this point.

This study confirms that the creation of artificial undercuts with composite material could be an effective method of providing retentive undercuts for cobalt-chromium clasps if the composite material used is resistant to wear. It appears that the smaller the size of filler particles the greater the wear resistance. Combe and Burke[13] suggest that these very small particles may fill spaces between larger particles and allow higher filler loading. This in turn will improve the physical properties of the composite material. What is not known here is whether the manufacturer of the composites used in this study has achieved differences in particle size by the use of a different filler or by using different amounts of filler.

The cobalt-chromium alloy used for the partial denture framework may be as important as the composite material in terms of durability. In this study the fatigue resistance of the alloy used was shown to be high because none of the clasp specimens fractured due to fatigue failure after 5500 test cycles. Lassila and Valittu[14] stated that both water and artificial saliva reduce the fatigue strength of cobalt-chromium alloy. However, cobalt-chromium alloys possess superior fatigue resistance in comparison to any other dental alloy[15].

CONCLUSIONS

The laser reflection confocal microscope has been shown to be an effective tool in quantifying surface changes of composite resin materials following repeated cycles of movement of I-bar cobalt-chromium clasps over them.

1. The greatest composite abrasion occurred with Prodigy® followed by Herculite HRV® and Point4® after completion of extended in-vitro testing. Therefore, the creation of undercuts by addition of Point4® restorative composite material is likely to be clinically more durable than the other materials tested.
2. There was some evidence of material loss from the clasps although this is probably not significant.
3. It is not known how realistically in-vitro studies of abrasion simulate actual wear of materials in real life clinical practice.

MANUFACTURERS' DETAILS:

- KERR CORPORATION, Kerr USA, 1717 West Collins Orange, CA 92867
- DeguDent GmbH, Rodenbacher Chaussee 4, 63457 Hanau-Wolfgang / Germany

ADDRESS FOR CORRESPONDENCE:

Dr M J Barsby, Centre for Adult Oral Health, Barts and The London, Queen Mary's School of Medicine and Dentistry, Turner Street, London E1 2AD, UK.
E-mail: michaelbarsby595@yahoo.co.uk

REFERENCES

1. Kirkos A.A. Artificial undercuts for teeth which have unfavourable shapes for clasping. *J. Prosthet. Dent.*, 1969; **22**: 301-306.
2. Crowther D.S., Lauciello F.R. and Casey D.M. Fabricated retention for removable partial dentures. *Quintessence Int.*, 1982; **12**: 1263-1267.
3. Buonocore M.G. A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. *J. Dent. Res.*, 1955; **34**: 849-853.
4. Jenkins C.B.G., Berry D.C. Modification of tooth contour by acid-etch retained resins for prosthetic purposes. *Br. Dent. J.*, 1976; **141**: 89-90.
5. Piirto M., Eerikainen E. and Siirla H.S. Enamel bonding plastic materials in modifying the form of abutment teeth for the better functioning of partial prostheses. *J. Oral Rehab.*, 1977; **4**:1-8.
6. Quinn D.M. Artificial undercut for partial denture clasps-a technique using composite filling materials. *Br. Dent. J.*, 1981; **151**: 192-194.
7. Dixon D.L., Breeding L.C., Swift E.J, Jr. Use of a partial-coverage porcelain laminate to enhance clasp retention. *J. Prosthet. Dent.*, 1990; **63**: 55-58.
8. Davenport J.C., Hawandeh K., Harrington E. and Wilson J.H. Clasp retention and composites: an abrasion study. *J. Dent.*, 1990; **18**: 198-202.
9. Bates J.F. Retention of partial dentures. *Br. Dent. J.*, 1980; **149**: 171-174.
10. Morris H.F., Asgar K., Brudwik J.S. Stress relaxation testing. Part IV- clasp pattern dimensions and their influence on clasp behaviour. *J. Prosthet. Dent.*, 1983; **50**: 319-326.
11. Anderson J.N. and Bates J.F. The cobalt-chromium partial denture. *Br. Dent. J.*, 1959; **107**: 57-62.
12. Tomlin H.R. and Osborne J. Cobalt-chromium partial dentures. *Br. Dent. J.*, 1961; **110**: 307-310.
13. Combe E.C. and Burke F.J.T. Contemporary Resin-based composite materials for direct placement restorations: Packables, flowables and others. *Dent. Update*, 2000; **27**: 326-336.
14. Lippo VJ Lassila and Pekka. K Valittu. Effect of water and artificial saliva on the low cycle fatigue resistance of cobalt-chromium alloy. *J. Prosthet. Dent.*, 1998; **80**: 708-13.
15. Morris H.F and Kamal Asgar. Physical properties and microstructure of four new commercial partial denture alloys. *J. Prosthet. Dent.*, 1975; **33(1)**: 36-46.