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Effects of Long-Term Simulated RPD Clasp Attachment/Detachment on Retention Loss and Wear for Two Clasp Types and Three Abutment Material Surfaces

Mohamed A. Helal, MDS, DDS,[1,2] Osama A. Baraka, MDS, DDS[2] Mohamed E. Sanad, MDS, DDS,[2] Klaus Ludwig, PhD,[3] & Matthias Kern, DMD, PhD[3]

[1]Department of Rehabilitation of the Mouth, Face, and Jaws, King Abdul Aziz University, Faculty of Dentistry, Jeddah, Saudi Arabia
[2]Department of Removable Prosthodontics, Faculty of Dentistry, Al-Azhar University, Cairo, Egypt
[3]Department of Prosthodontics, Propaedeutics and Dental Materials, Christian-Albrechts University, Schleswig Holstein, Germany

Keywords
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Correspondence
Mohamed A. Helal, King Abdel Aziz University – Faculty of Dentistry, Dept. of Rehabilitation of the Mouth, Face, and Jaws, Jeddah, Sulmania, 80200, Saudi Arabia.
E-mail: helalminime@yahoo.com, Mhelal71@gmail.com

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Abstract

Purpose: The purpose of this in vitro study was to measure the loss of retention and wear of two clasp types (E-circlet, back action) against three abutment materials (enamel, composite, CAD/CAM ceramic) after 16,000 simulated cycles of attachment-detachment.
Materials and Methods: Forty-eight models were constructed by placing either an upper first premolar or a metal die inside a metal rectangular block. Models were divided according to the abutment teeth into three groups. Group E consisted of 16 unrestored human premolars with sound enamel. Group R had 16 premolars recontoured buccally using composite resin. Group C had 16 metal dies (duplicated from a human premolar) covered by CAD/CAM all-ceramic crowns. On the models, E-circlet (E) and back-action (B) clasps were constructed to engage the model's teeth. Withdrawal and insertion cycling of clasps was carried out for 16,000 cycles by using a chewing simulator. The retention force of each clasp was measured after cycling. An acrylic replica was made for each abutment retention surface before and after cycling. Each replica was examined by SEM, and the wear areas were measured. The data were analyzed statistically using one-way ANOVA, two-way ANOVA, and Mann-Whitney tests.
Results: There was no significant retention loss after 16,000 cycles ($p \geq 0.05$) of both clasps (E, B) on the three abutment materials (E, R, C). The mean of wear areas in mm^2 were 1.83 ± 0.36, 0.85 ± 0.66, 2.37 ± 1.88, 1.7 ± 1.11, 0.6 ± 0.2, and 0.06 ± 0 for EE, BE, ER, BR, EC, and BC, respectively. There were significant differences among the wear areas of the abutment surface of the six subgroups ($p \leq 0.05$).
Conclusion: The composite resin contoured surfaces showed more wear than the enamel and ceramic surfaces. E-clasps caused more wear on the abutment materials than back-action clasps.

Sufficient retention of removable partial dentures (RPDs) is considered one of the most important factors affecting their clinical success. Many studies have investigated the effect of clasp design on retention force.[1-4] Retention of RPDs is accomplished by placing clasp parts into undercuts on abutment teeth. When a natural undercut cannot be located with a surveyor, it may be created artificially by crowns, a class V restoration, recontouring of enamel (dimpling or altering the height of contour), or recontouring with composite resin.[5-10]

The recontouring of enamel by using composite resin has provided a conservative means of modifying tooth contour to create undercuts for the retention of RPD clasps.[7] This technique provides minimal tooth destruction (a few microns during etching) as well as the advantages of ease of preparation, repair, and alteration.[12-15]

The conservative partial-coverage porcelain laminate offers an esthetically pleasing and minimally invasive alternative for creating an undercut for RPDs.[16-19] Some authors[20] used a cast gold crown to fit the RPD clasp, while others[21] fabricated a ceramic-metal crown to fit the RPD direct retainer.

The wear of the enamel or composite resin as related to the direct retainer is unlikely to cause a noticeable loss of

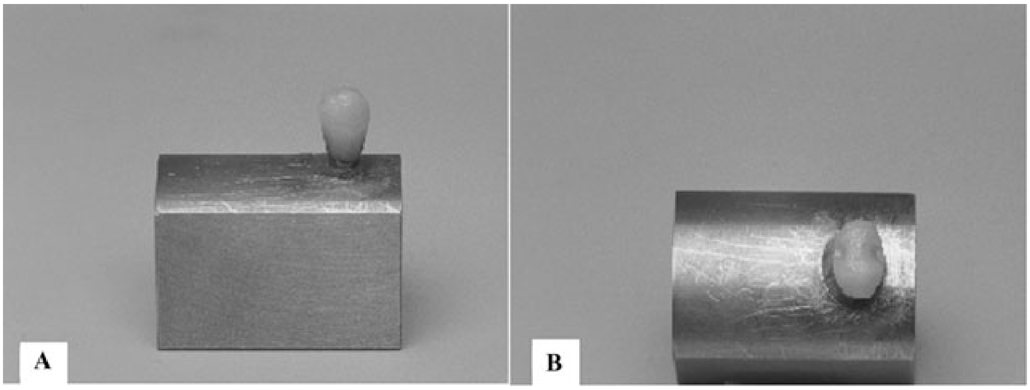

Figure 1 (A&B). Tooth fixed inside the laboratory metal model.

retention in the clinical situation.[22–24] Retention force is affected by wear.[25] In another study[26] retainers with round profiles caused less wear of restorative materials than those featuring flat contact surfaces. Little wear or no changes were recorded on the porcelain surface when it was subjected to functional movements of RPD retentive clasp arms.[27] The enamel surface can withstand the wearing effect of an RPD clasp more than composite resin can.[28,29]

Although retention force is affected by wear, it is not yet known how the wear differs among retention surfaces, and how the wear affects the retention of the clasp of RPDs. Therefore, the effect of wear on the retention of clasps and on the retention surface needs further research.

The purpose of this study was to measure the loss of retention and wear of two clasp types (E-circlet, back action) against three abutment materials (enamel, composite, CAD/CAM ceramic) after 16,000 simulated cycles of attachment-detachment.

Materials and methods

Simulation of RPD detachment was mimicked using the chewing simulator device to constantly attach and detach RPD clasps from abutments involving different materials that created undercuts for 16,000 cycles of use. Retention loads were measured before and after cycling. Wear was examined in the SEM using replicas of the abutment surfaces. Comparisons among combinations were statistically analyzed.

A pilot study had been carried out to determine the initial force of retention.[1,2,4] This pilot study was carried out with two types of clasp design (E-clasp, back-action clasp) on natural teeth having sound enamel surfaces to determine the initial retentive force to start this experiment. This experiment was conducted to simulate approximately an 11 year period. If an RPD would be removed four times each day[7] for 11 years, there would be about 16,000 insertions and removals; however, another study[22] was carried out over 25,000 cycles.

Forty-eight models were constructed to create an apparatus to hold the abutment within the chewing simulator. These models were constructed from rectangular metal blocks with a natural or modified tooth embedded in each model vertically to the cementoenamel junction (Fig 1). According to the model's teeth, they were divided into three groups. The first group (E) consisted of 16 extracted premolars with retentive areas on their buccal enamel surfaces. The second group (R) had 16 premolar teeth modified buccally by composite resin (Spectrum, Dentsply, Konstanz, Germany) to achieve sufficient undercut. The third group (C) had 16 metal dies covered by CAD/CAM (Sirona Dental System GmbH, Cerec Scan, Bensheim, Germany) ceramic crowns (Vita, Zahnfabrik, Bad Säckingen, Germany).

The laboratory models were duplicated into investment models (Optivest, Degussa Dental, GmbH & Co.KG, Hanau, Germany). On the investment models, cast cobalt-chromium alloy (BEGO Co., Bremen, Germany) frameworks with E-circlet and back action clasps were constructed. The frameworks were tried on the models and were considered to be suitable for testing when the occlusal rests fit well in their rest seats, the retainers were in contact with the abutments, and the positive part of the framework rested on the testing model (Figs 2–3). Each group of models was subdivided into two subgroups according to the framework design, subgroup E for E-clasps and subgroup B for back-action clasps (eight each).

Two saucer depressions were made at the suspected wear area of the abutment retention surface (as reference points).[7,24] A direct retainer holding device (DRHD) was constructed specifically for this study. The DRHD consisted of (1) a vertical aluminum column, (2) a horizontal aluminum arm, (3) a specimen holder constructed from acrylic to hold the model, and (4) a testing column holder (to hold the direct retainer) connected with the vertical column.

Each clasp and its model were mounted on a DRHD, and the whole was placed on a universal testing machine (Zwick/101, GmbH & Co., Ulm, Germany). Retention of each clasp was measured by applying withdrawal force to it by this machine.

Each subgroup of models (eight models) within the DRHDs were mounted inside a chewing simulator device (Firma Willytec, München, Germany), and withdrawal and insertion cycling of clasps were carried out for 16,000 cycles (Fig 4). Specimens were cycled in room temperature and 200 ml artificial saliva[4,7] (Table 1). The machine was run at 8 mm/s with 3 kg for loading. After cycling, the retention force of each clasp was measured, and the loss of retention was calculated.

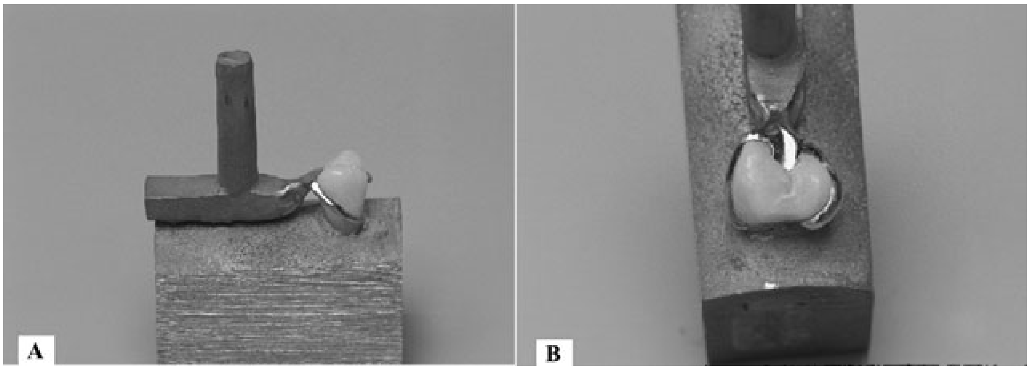

Figure 2 Framework of E-clasp, (A) lateral view and (B) frontal view.

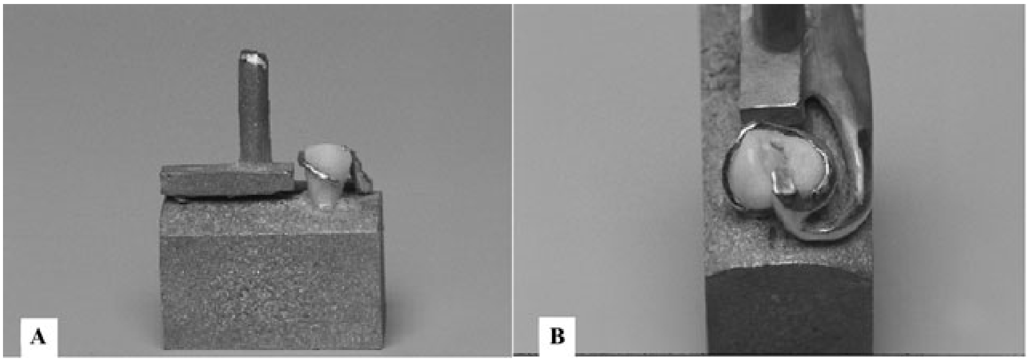

Figure 3 Framework of back-action clasp, (A) lateral view and (B) frontal view.

Acrylic replicas were made for each abutment retention surface before and after cycling. Silicon duplicating material was mechanically mixed and applied inside a duplicating ring. The crown of the abutment tooth was immersed into the duplicating material and left for 1 hour then removed. An epoxy resin (Stycast 1266, Emerson & Cuming, Westerlo, Belgium, Germany) was mixed according to the manufacturer's instructions and poured into the mold. The ring was placed in a vacuum machine (Degusint Vac, Degussa, Darmstadt, Germany) for 20 minutes to remove any air bubbles in resin. The epoxy resin was left to polymerize at room temperature for at least 24 hours.[30-32]

Figure 4 The specimens within DRHDs were mounted inside a chewing simulator device.

The replicas were attached to an aluminum SEM stub and sputtered coated with gold (Balzers Union, Balzers, Liechtenstein, Germany). The replicas were examined at the suspected wear areas using a scanning electron microscope (XL 30 CP, Philips, Eindhoven, Netherlands) at a magnification of 50× using 10 kV acceleration voltage.[7,16,17,19,28,31]

The wear areas of the abutment surfaces were measured. The SEM photograph was printed larger than normal (100× magnification) to clarify the wear area. Then transparent paper (scale in mm^2) was placed over the SEM photograph, and the wear areas were traced out. The reduction of retention force after 16,000 cycles of each subgroup and wear areas of retention surface of different subgroups were subjected to analysis using one-way ANOVA, two-way ANOVA, and Mann-Whitney tests.

Table 1 Composition of artificial saliva

Whole resting saliva	(mg/100 ml)	Supplied as
Na+	15	38.1 mg NaCl/100 ml
K+	80	88.2 mg KCl/100 ml
(PO3)4-	51(16.8 p)	5.4 ml 100 m MKPO4 PH7
Ca++	5.8	16 mg CaCl2/100 ml
Mucin	200	Procine-mucine 200 mg/100 ml

Table 2 Mean and standard deviation of the retention force (N) before and after cycling, and the loss of retntion and the percentages of retention loss for each subgroup

SG	(No.)	Before cycling	After cycling	Retention loss	Percentage of loss
EE	8	13.0 ± 4.0	3.4 ± 1.7	9.0 ± 4.0	69%
BE	8	11.0 ± 4.3	4.6 ± 2.0	6.3 ± 4.0	57%
ER	8	13.2 ± 4.7	4.2 ± 1.7	9.0 ± 3.8	68%
BR	8	11.4 ± 3.5	5.0 ± 1.3	6.0 ± 3.7	52%
EC	8	11.2 ± 2.2	3.9 ± 1.4	7.0 ± 2.2	62%
BC	8	10.7 ± 3.9	4.3 ± 4.0	6.3 ± 5.4	59%

EE: subgroup of E-clasp of the enamel group; BE: subgroup of back-action clasp of the enamel group; ER: subgroup of E-clasp of the composite resin group; BR: subgroup of back-action clasp of the composite resin group; EC: subgroup of E-clasp of the ceramic group; BC: subgroup of back-action clasp of the ceramic group

Results

Table 2 shows the mean and standard deviation of the retention force (N) before and after cycling, and the loss of retention and the percentages of retention loss of the E-circlet clasps and back-action clasps on different abutment materials (enamel, composite resin, and ceramic). Statistically, one-way ANOVA showed no significant differences among the means of retention loss of different subgroups after 16,000 cycles at a 95% confidence level ($p > 0.05$). Also, two-way ANOVA was used to study the effect of different clasp designs or using different abutment retention surface on the amount of retention loss after 16,000 cycles. None of these factors had a statistically significant effect on loss of retention after 16,000 cycles at a 95% confidence level ($p > 0.05$).

The ceramic specimens showed no or little wear by the action of the two clasps studied, while enamel and composites showed wear areas under the two clasps. Figures 5–10 show SEM photomicrographs for abutment retention surfaces after cycling; however, one-way ANOVA showed significant differences among the wear areas of the abutment surfaces of the six subgroups after cycling at 95% confidence level ($p \leq 0.05$) (Table 3). Two-way ANOVA was used to study the effect of different clasp designs or using different abutment materials on the amount of wear. Both of these factors had a statistically significant effect on amount of wear at a 95% confidence level ($p \leq 0.05$). A pairwise Mann-Whitney test showed significant differences between EE and BE, EE and EC, BE and BC, ER and EC, BR and BC, and EC and BC ($p \leq 0.05$); however, there were no significant differences between EE and ER, BE and BR, and ER and BR ($p > 0.05$) (Table 4).

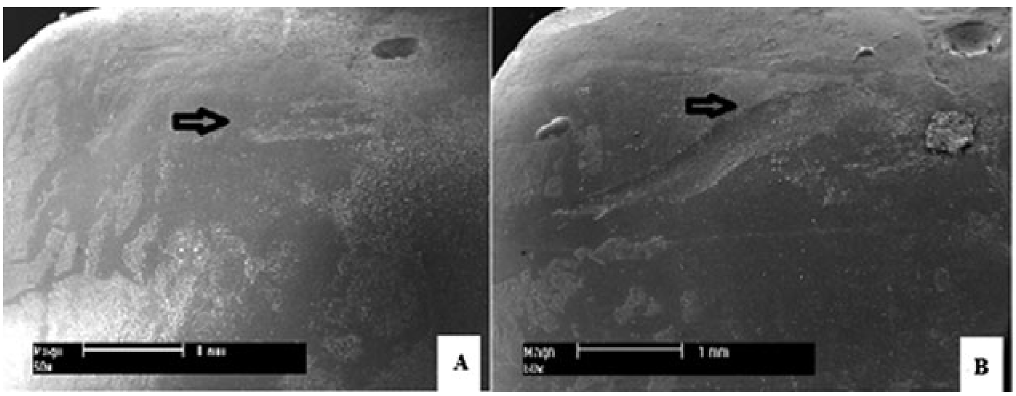

Figure 5 Effect of E-circlet clasp on the enamel surface, {before cycling (A), after cycling (B)}.

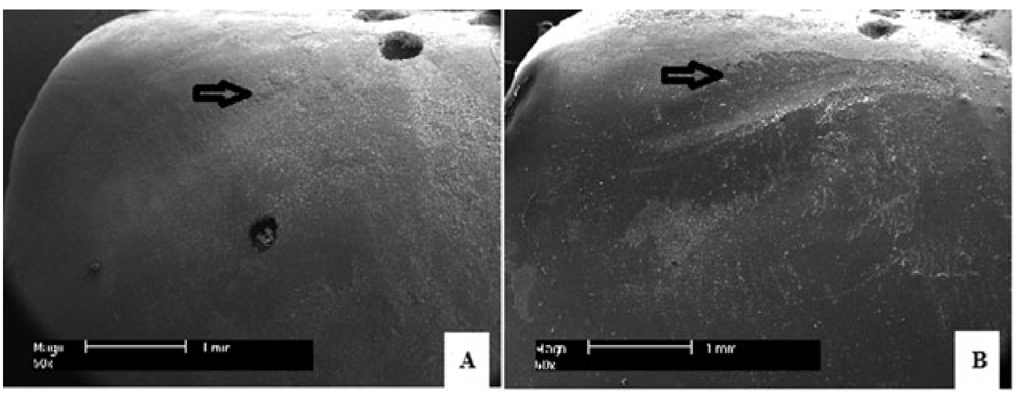

Figure 6 Effect of back-action clasp on the enamel surface, {before cycling (A), after cycling (B)}.

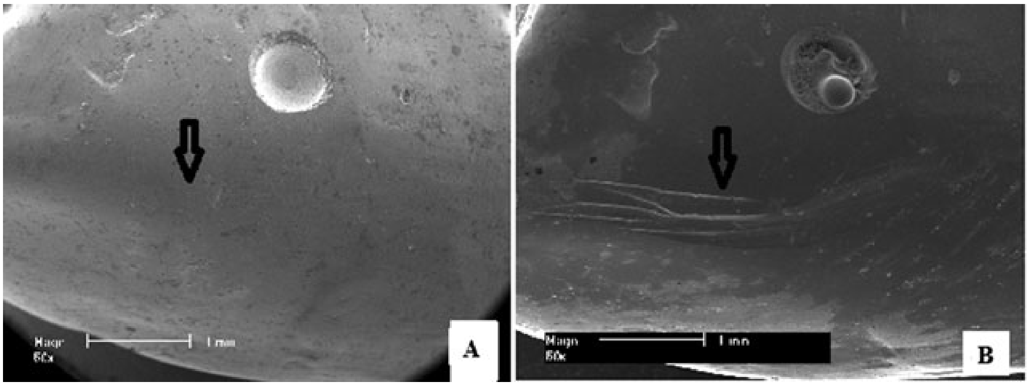

Figure 7 Effect of E-circlet clasp on the composite resin abutment material, {before cycling (A), after cycling (B)}.

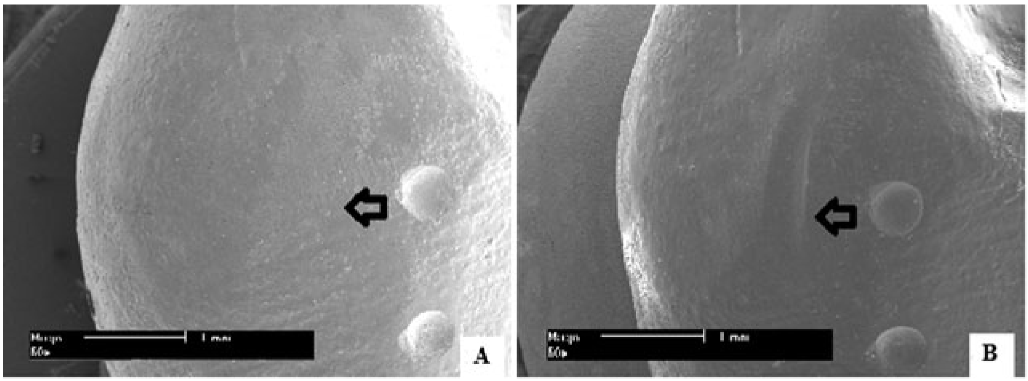

Figure 8 Effect of back-action clasp on the composite resin abutment material, {before cycling (A), after cycling (B)}.

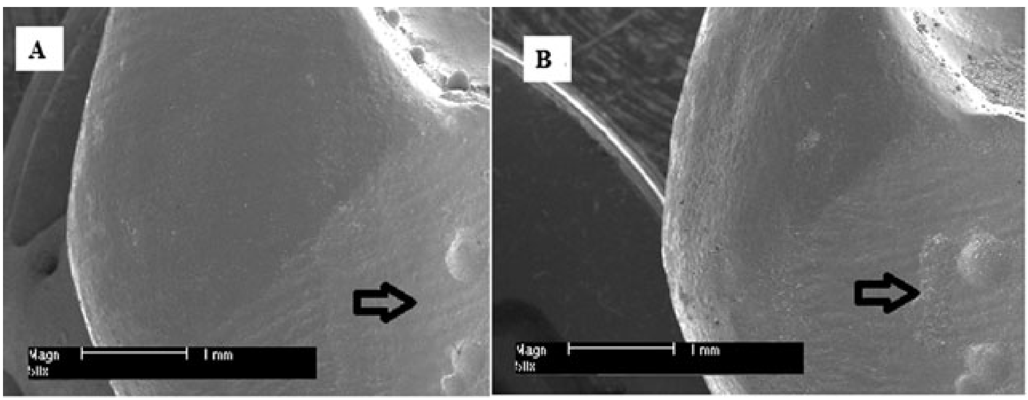

Figure 9 Effect of E-circlet clasp on the ceramic abutment material, {before cycling (A), after cycling (B)}.

Discussion

The results of retention force before cycling were in agreement with previous studies.[1,2,4] Firtell[1] found that the retention force of the E-clasp was about 13.7 N and 1.6 N for the back-action clasp. Bates[2] obtained similar results in a similar experiment; however, Soo and Leung[4] reported that the retention force of Aker's clasp was 17.5 N. The results of retention force before cycling were in agreement with previous studies.[1,2,4]

The loss of retention of each clasp was chosen for comparison because it gave the results in numbers, which are considered more accurate and easier for comparison between subgroups rather than the percentage of loss; however, although the percentage of loss gives misleading readings or results, it can still be used as an indicator of clinical acceptability. In this research $<25\%$ retention loss was considered as the target for clinical acceptability. The percentages of loss for all subgroups were not accepted clinically. This may due to the longevity of this

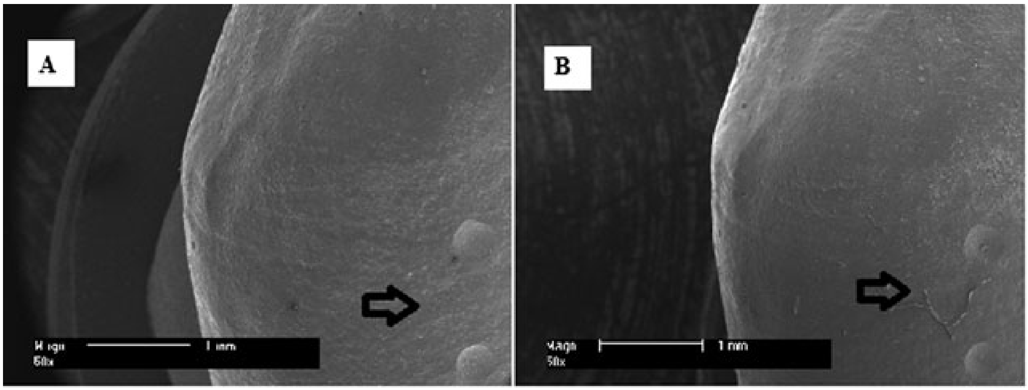

Figure 10 Effect of back action clasp on the ceramic abutment material, {before cycling (A), after cycling (B)}.

Table 3 Mean, standard deviation, and median of the wear areas of different subgroups after 16,000 cycles

Subgroup	No.	Mean ± SD	Median
EE	8	1.83 ± 0.36	1.80
BE	8	0.85 ± 0.66	0.76
ER	8	2.37 ± 1.88	2.0
BR	8	1.70 ± 1.11	1.3
EC	8	0.60 ± 0.20	0.6
BC	8	0.06 ± 0.0	0

Table 4 Pairwise comparisons of wear area between test subgroups after 16,000 cycles (Mann-Whitney test)

Groups compared	*p*
EE vs. ER	0.599
EE vs. EC	0.0009*
ER vs. EC	0.018*
BE vs. BR	0.172
BE vs. BC	0.005*
BR vs. BC	0.0005*
EE vs. BE	0.007*
ER vs. BR	0.372
EC vs. BC	0.0014*

*denotes significant difference

study. There were no significant differences in the retention loss of all subgroups at a 95% confidence level ($p > 0.05$); however, there were significant differences among the wear areas of the abutment surface of the six subgroups after cycling at the 95% confidence level ($p \leq 0.05$), which may reflect the effect of abutment retention surface on retention loss of an RPD clasp after 16,000 cycles.

The wear of enamel by back-action RPD clasp was considered as a reference for this study, according to Phillips and Leonard[22] who found little or no wear of the enamel by action of the direct retainer. In this research <2 mm^2 was considered an acceptable wear value.

Although wear was measured only two-dimensionally, it can be assumed that the measured 2D wear facets correlate strongly with 3D wear (volume), as the tooth curvature approximates the shape of a cup (dome). Under this consideration the calculation of the volume loss would be as follows:

$$V_{cup} \approx \frac{S^2}{3*C}$$

where V_{cup} is the volume of the cup removed by wear (cup over the measured area); S is the measured (worn) area; C is the circumference of the tooth at the equatorial cross-section (i.e., circumference of the embrace).

As the tooth shape approximates only the shape of a cup (dome), volume loss could not be calculated, but it is reasonable to assume that the measured 2D wear correlates strongly with the 3D wear on the curved tooth surface.

The results of this in vitro experiment indicated that the RPD clasps had a wearing effect on the enamel surface of the abutment teeth. Over an 11 year period of simulated insertion and removal cycles, the wear area was 1.83 mm^2 for EE and 0.85 mm^2 for BE. These results were at variance with Hebel et al[7] and Phillips and Leonard.[22] The difference in methodology, amount of undercut, clasp designs, the dislodgement force, number of cycles, and increased sophistication of equipment used to measure wear may be responsible for the differences in wear recorded by the different studies.

The composite resin contoured teeth showed significantly higher wear than the enamel by the action of E and back-action clasps and may not be clinically accepted. These findings were in agreement with Hebel et al,[7] Davenport et al,[24] and Tietge et al,[28] and at variance with Swift.[29]

No significant changes were found in the ceramic abutment retention surface by the action of E and back-action clasps. None of the specimens failed due to porcelain fracture, which indicates that a well-fabricated glazed porcelain surface can withstand the wear forces of RPD retentive clasp arms. These results are in agreement with those of Tietge et al[19] and Marso et al.[27]

There was a statistically significant difference in the wear of enamel and ceramic abutment retention surface by the action of E and back-action clasps ($p \leq 0.05$). This significant difference may be due to the E-clasp's rigidity, which is higher than that of the back-action clasp.

There were significant differences among the different retention surfaces by the action of the two clasps. Porcelain showed the least amount of wear, followed by enamel, and then by composite, which showed the largest amount of wear. This is probably due to the differences in wear resistance of these materials.

All specimens exhibited some retention at the end of this study (after 16,000 cycles), and there were no significant differences in the retention loss of all subgroups at a 95% confidence level ($p > 0.05$); however, no resin additions were lost during the course of the experiment, and none of the specimens failed due to composite fracture. Although direct retainers cause wear of composite resins, these materials have been recommended for creation of abutment tooth undercuts, suggesting that resin contouring of teeth is a viable technique for creating retention for RPD clasps. This finding was in agreement with Hebel et al,[7] Davenport et al,[11] and Pavarina et al.[15] This research suggests measuring the retention force of RPD clasps on different abutment materials at different intervals for future work.

Conclusions

Within the limitations of the current experimental simulation, the following could be concluded:

1. The difference in design between circlet E-clasps and back-action clasps had no significant effect on the loss of retention force after 16,000 cycles.
2. Using different abutment surfaces for clasp retention had no significant effect on the amount of retention loss after 16,000 cycles.
3. The composite resin contoured teeth showed more wear than the enamel and ceramic by the action of E and back-action clasps; however, E-clasps caused more wear on the abutment materials than back action clasps did.

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