An investigation of the effectiveness of indirect retainers

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Dentists have long advocated the use of indirect retainers for distal-extension removable partial dentures. The function of the indirect retainer is to prevent the distal-extension base from moving away from its seat because of cheek and tongue forces, sticky foods, or gravity on a maxillary prosthesis.

The effectiveness of the indirect retainer depends upon its distance from the fulcrum line, the effectiveness of the direct retainer, and the quality of support of the indirect retainer. The effectiveness of the indirect retainer is believed to increase the further it is located from the fulcrum line because the mechanical advantage increases proportionately. The direct retainer must be effective if the indirect retainer is to function when the denture rotates; otherwise the partial denture will be dislodged. An indirect retainer's effectiveness is reported to decrease when it is placed on an inclined plane because the tooth moves and the retainer slips.

Recent studies have indicated that mesially placed rests are less likely to generate harmful stresses to abutment teeth than distally placed rests when distal-extension removable partial dentures move tissueward. However, placing the rest on the mesial part of the occlusal surface rather than on the distal part moves the fulcrum line anteriorly and so shortens the distance from the fulcrum line to the indirect retainer. In this way the usefulness of an indirect retainer may be diminished.

Another investigation has shown that some clasps are more retentive than others in an experimental situation. Greater direct retention may therefore promote the function of the indirect retainer.

However, the effectiveness of an indirect retainer in preventing a denture base from moving away from its seat has not been determined under controlled conditions. It is not known how this movement is affected when the fulcrum line is moved anteriorly or when different direct retainers are used.

The purpose of this investigation was to measure the effectiveness of an indirect
METHOD

A model of a partially edentulous lower dental arch was used (Fig. 1). Testing a removable partial denture intraorally is possible but difficult because of the number of tests needed and the complexity of the apparatus. Little or no error is involved when using a model since most of the retention of the partial denture is supplied by the framework components rather than a border seal and the direction, duration, and amount of displacing forces may be chosen by the investigator in both cases.

The model was of a dental arch that had no molars and required a bilateral distal-extension removable partial denture. Gold crowns were constructed for the premolars and canines on each side to control contours because the quality of retention provided by a plastic abutment tooth may not be the same as that provided by the frequently used cast-gold abutment crown. The crowns were permanently cemented to the abutment teeth.

Rest seats were placed on the mesial and distal parts of the occlusal surfaces of the first and second premolars and on the lingual surfaces of the canines (Fig. 2). These sites are commonly selected for indirect retainer rests. Parallel guiding planes were created on the distal surfaces of the second premolar crowns, and all crowns had parallel lingual surfaces. Undercuts of 0.020 inch were created at the mesiobuccal and distobuccal aspects of the second premolars.

A chrome-cobalt framework was fabricated with L-bar clasps, distal guiding planes, and lingual reciprocal clasp arms on the second premolars; an incisal rest and its minor connector on the left central incisor; and a lingual bar major connector (Fig. 3). The occlusal part of the lingual bar and the framework distal to the second premolars contained nailheads surrounded by parallel walls. These parts permitted repeated attachment and removal of the occlusal rests.

Separate castings were made of each of the rests; these castings were secured to the framework with autopolymerizing acrylic resin that attached to the nailheads. The combination of rests was changed by burning away the acrylic resin and fitting on the next casting. The surrounding walls assured that the rests were re-placed
Fig. 3. (A) The nailheads on the occlusal surface of the framework were used to retain castings of the rests with autopolymerizing acrylic resin. (B) A distal guiding plane and an L-bar clasp were used on the second premolars.

Fig. 4. (A) A separate casting was made to fit each rest seat. (B) The castings were attached rigidly with autopolymerizing acrylic resin that surrounded the nailheads on the framework.

exactly each time (Fig. 4). The rest on the incisor was used to orient the framework when the other rests were changed. The central incisor was removed during testing so that it did not act as an indirect retainer. The lingual bar was also greatly reduced on the tissue side to avoid contact with the model upon rotation of the framework resulting from displacement of the denture. The rest locations on the right and left sides were kept identical.

The following combinations of rests were tested: (1) distal-rest second premolar/canine rest; (2) distal-rest second premolar/mesial-rest first premolar; (3) distal-rest second premolar/no indirect retainer; (4) mesial-rest second premolar/no indirect retainer; (5) mesial-rest second premolar/mesial-rest first premolar; and (6) mesial-rest second premolar/canine rest.

Autopolymerizing acrylic resin bases were attached to the framework. There were no undercuts in the basal seat. A rod connecting the distal portions of the bases had small loops soldered to it through which displacing forces were applied (Fig. 4, B). An Instron Universal testing instrument* was used to pull the removable par-

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*Instron Corp., Canton, Mass.
Fig. 5. The model placed near the center of the Instron instrument. Load and displacement were recorded on the strip chart on the left side of the machine.

tial denture from the model. The model was rigidly attached to the moving crosshead, and the framework was connected to a load cell in the upper section of the machine (Fig. 5). The load cell used strain gauges to detect tensile loads; load and displacement were measured simultaneously on a strip chart recorder on the Instron tester. Chart speed was synchronized with crosshead movement so that 10 mm. of chart movement equalled 1 mm. of crosshead movement. Thus denture displacement could be determined by measuring the distance the chart had moved and then dividing by 10. Ten replications were made of each test arrangement.

Dislodging forces may not always be uniformly distributed to the bases of bilateral distal-extension removable partial dentures. It is possible that components of indirect retention are influenced by the location of the force. This possibility was tested by applying the dislodging force at three points: to the base on the right and left sides and to the center of the bar connecting the bases (Fig. 6). This latter location represented bilateral displacement. The model could be positioned in the measuring instrument so that the displacing force was always directed vertically regardless of where it was applied.

The usefulness of an indirect retainer also may vary according to the anteroposterior direction of the dislodging force. To test for this the angle of the platform to which the model was bolted could be changed relative to the measuring unit (Fig. 7). Thus dislodging force was first applied perpendicular to the occlusal plane, and the tests were then repeated with the forces directed more anteriorly.

The model was removed from its platform several times to change clasp and rest
Fig. 6. Dislodging forces were applied unilaterally and bilaterally. A plaster index was used to reposition the model for subsequent tests.

Fig. 7. An anterior displacing force was obtained by tilting the model 30 degrees relative to the direction of crosshead movement.

The model also had to be moved to the left and to the right as well as anteriorly and posteriorly on the platform so that the various tests kept the dislodging force vertical to the load cell. A plaster index of each of these locations was used to reposition the model for subsequent tests.

The amount of indirect retention may vary according to the type of direct retainer in use. Therefore a wrought-wire clasp was substituted for the bar clasp on both second premolars. Before testing could proceed, however, it was necessary to determine if the two types of clasp were equally retentive. Unequal amounts of retention could bias the results since indirect retention is thought to depend to some extent on the effectiveness of the direct retainers. Although some clasps provide greater direct retention than others under standard conditions, any clasp may be made more or less retentive by changing its length or diameter, the degree of undercut engaged, or the material of which the clasp is made. Greater indirect retention might be achieved with a certain type of clasp but this should not be concluded simply because one clasp type happened to have been made more retentive. The essential point is whether a mesial or a distal undercut is more effective for indirect retention.

The amount of force required to dislodge the denture occlusally was measured first with the bar clasp arrangement in place. The force was applied equally to the anterior and posterior parts of the removable partial denture by the use of a second casting (Fig. 8). This second casting was attached to the load cell and thus distributed force to three widely separated points on the partial denture. No tipping of the denture was observed as it was removed.

The bar clasps were then bent out of contact with the abutment teeth. Eighteen-gauge wrought-wire clasps that had been soldered to chrome-cobalt plates were attached to the framework with autopolymerizing acrylic resin (Fig. 9). This method is comparable to the recommended procedure regarding location of the solder joint arrangement.
Fig. 8. A special casting permitted removal of the partial denture without tipping. The load measurements obtained in this manner were used to evaluate clasp retention.

Fig. 9. (A) The length of the wrought-wire clasps and the location of the solder joint were comparable to clinical examples. (B) The wrought wire and its plate have been attached to the partial denture. The bar clasp has been bent out of contact with the tooth.

and length of a clasp arm that is surrounded by resin. The tests were then repeated. The depths of the wrought-wire clasps into the undercuts were slightly adjusted until retentive values similar to those recorded with bar clasps were obtained. All combinations of rest locations and model positions were then retested.

The guiding planes on the distal surfaces of the second premolars may greatly affect indirect retention. Many removable partial dentures are constructed without good guiding planes on the abutment teeth either through oversight or lack of ap-
precipitation by the dentist. To demonstrate the influence of guiding planes on removable partial denture retention, we ground the part of the framework that contacted the guiding planes on the distal surfaces of the second premolars out of contact with the teeth except at the marginal ridges (Fig. 10).

The tests were repeated, first using the wrought-wire clasp and then the bar clasp. All combinations of rest locations and unilateral, bilateral, anterior, and posterior force applications were included. After the wire clasps were removed the bar clasps were readapted to the abutment teeth. The special casting was used to dislodge the denture occlusally, and the bar clasps were adjusted until retentive values were equivalent to the original measurements.

RESULTS

Three groups of data were obtained: (1) the amount of denture base movement when a 400 Gm. force was applied, (2) the amount of denture base movement at the point of maximum force, and (3) the maximum force during denture base displacement.

The five variables of (1) clasp type, (2) indirect retainer location, (3) rest seat position on the principal abutments, (4) unilateral vs. bilateral force application, and (5) vertical vs. anterior force direction were subjected to an analysis of variance. The analysis showed statistically significant differences among all factors. However, there was much more variability associated with some factors than with others.

Displacement at 400 Gm.

With guiding planes. The amount of movement that occurs upon application of a standard load is an excellent value for comparison of the effects of the several components. Because very few of the retentive values were below 400 Gm., that level was chosen.

The analysis of variance showed that the wrought-wire clasp allowed more displacement at the standard load than the bar clasp allowed. The clasp type had much more of an effect on denture base movement than any other factor.

A force directed anteriorly at 60 degrees to the occlusal plane caused no more
displacement than one applied perpendicular to this plane. There was no statistically significant difference in denture base movements with a mesial rest on the terminal abutment tooth or with a distal rest on that tooth.

Neither the presence nor the absence of an indirect retainer had an appreciable effect on the movement produced by a standard load. The displacing force also produced similar results whether it was applied unilaterally or bilaterally.

**Without guiding planes.** More denture base movement occurred when a wrought-wire clasp was used than when a bar clasp was used. Regardless of the type of clasp used denture displacement increased 50 per cent when the distal guiding planes were removed.

The lack of guiding planes caused a small increase in denture base movement when distal occlusal rests were on the terminal abutment teeth. However, the lack of guiding planes when mesial occlusal rests were on abutment teeth resulted in nearly twice as much denture base lifting.

No significant difference in denture base movement was observed when tests with an indirect retainer on the canine were compared with those without an indirect retainer. Much more displacement was noted when an indirect retainer was placed on the first premolar in the absence of proximal surface guiding planes.

Twelve per cent of the tests in which guiding planes had been removed produced retention values of less than 400 Gm. Comparisons at the proof level of 400 Gm. were made by extrapolating these few values rather than lowering the proof value to include the least retentive value measured. To have done so would have necessitated making most other measurements when the denture base had lifted only a few hundredths of a millimeter, and accuracy would have been compromised. Most of the extrapolations were for the framework that combined bar clasps with mesial occlusal rests on the second premolars.

**Displacement at maximum force**

Indirect retainers do not function in their usual manner when maximum force is applied because the denture becomes completely dislodged. Their ability to prevent denture base lifting cannot be determined accurately from the following results. However, comparison of maximum forces and displacement illustrates the effect of the components upon direct retention.

**With guiding planes.** Differences in the amount of denture base movement were due almost entirely to the type of clasp in use. The wrought-wire clasp allowed more base displacement to occur before the maximum force of removal was reached.

The indirect retainer location and the rest seat position on the terminal abutment teeth had much less effect. A distal rest allowed more movement than a mesial rest when a wire clasp was used, while movement was the same with either rest when a bar clasp was used. When a wire clasp was used an indirect retainer on the canine was more effective than a mesial rest on the first premolar, but no significant difference was noted with a bar clasp. The absence of an indirect retainer gave unpredictable results.

Very little difference in denture base movement was noted when the displacing force was applied unilaterally, bilaterally, perpendicular to the occlusal plane, or at an angle to the occlusal plane.
MAXIMUM DISPLACEMENT FORCE
WITH GUIDING PLANES

Fig. 11. More force was required to displace the removable partial denture with bar clasps when indirect retainers were absent. Greater force was needed for displacement when wrought-wire clasps were used, but the presence or absence of an indirect retainer had little effect.

Without guiding planes. Nearly all differences in the amount of denture base movement after the removal of guiding planes were attributed to the type of clasp. Much more denture base movement was noted at the point of maximum force when a wrought-wire clasp was used than when a bar clasp was used. There were no statistically significant differences in denture base displacement at the time of maximum force that could be ascribed to the presence or absence of guiding planes.

Maximum force

With guiding planes. The type of clasp had more influence than any other factor on the amount of force needed to dislodge the denture. The denture with the wrought-wire clasp required more force for removal from the model.

The position of the rest on the principal abutments had less of an influence on retention. Higher dialodging forces were required with the distal rest than with the mesial rest.

The location of the indirect retainer had even less of an effect on the dislodging force. Retention when using an indirect retainer on the mesial portion of the first premolar was not statistically different from retention when using an indirect retainer on the canine. When an indirect retainer was not used a greater force was required to displace the removable partial denture than when one was used.

Less force was required to dislodge the denture when the force was directed anteriorly at an angle of 60 degrees to the occlusal plane rather than perpendicularly. Force direction, though, appeared to be much less important than clasp type and rest location.
Fig. 12. More force was needed to displace the removable partial denture with wrought-wire clasps than with bar clasps. Less force was required to displace dentures with mesial rests than with distal rests. The absence of proximal guiding planes had little effect on retentive values except when a mesial rest was combined with a bar clasp.

The site of force application was of the least importance. Slightly more force was needed to dislodge the removable partial denture when the force was applied unilaterally instead of bilaterally.

There was much interaction between the factors. For example, much greater forces necessary for dislodgment were recorded when a bar clasp was used without an indirect retainer, whereas the presence or absence of an indirect retainer had little effect on the values obtained with a wrought-wire clasp (Fig. 11). When compared to a mesial rest a distal rest on the principal abutment tooth increased the retentive forces of both clasp types, but this was true to a greater extent with a wrought-wire clasp than with a bar clasp.

There was interaction between the location of the principal rest and the indirect retainer. Less force was required to remove the partial denture when a mesial rest rather than a distal rest on the second premolar was combined with an indirect retainer, whereas principal rest location had little effect on these values when no indirect retainer was present. Also, more force was required to displace the denture perpendicular to the occlusal plane than at 60 degrees when a distal rest was used on the principal abutments, but the direction of displacement made little difference in required force when a mesial rest was used.

Without guiding planes. The type of clasp was still the dominant factor in determining the amount of force needed to remove the denture when guiding planes were not used. The wrought-wire clasp was more retentive, and removal of the
guiding planes had no statistically significant effect on the amount of force needed. There was a significant decrease in the maximum force needed when a bar clasp was used without distal guiding planes.

Mesial occlusal rests on the terminal abutment teeth reduced the amount of force needed to dislodge the denture when compared to the force required when using distal rests. There were no statistically significant differences in necessary forces due to the presence or absence of guiding planes except when a mesial rest was combined with a bar clasp. In that instance, there was a great reduction in retentive force when the distal guiding plane was removed (Fig. 12).

The removal of guiding planes had little effect on the indirect retainers with one exception: Much less force was needed for dislodgment when an indirect retainer on the mesial part of the occlusal surface of the first premolar was combined with a bar clasp on the terminal abutment tooth and guiding plane contact was absent.

When guiding planes were absent very little difference in effect was seen when forces were applied unilaterally or bilaterally or directed vertically or anteriorly.

DISCUSSION

The usefulness of an indirect retainer in preventing occlusal displacement of a denture base appears to be very limited. This conclusion is supported by other research that has shown that little movement of the tooth supporting the indirect retainer is seen when a distal-extension denture base is lifted from the ridge. Frechette has demonstrated that removal of the indirect retainers from a removable partial denture results in the application of more pressure to the direct abutment teeth. The indirect retainer probably is more effective in distributing forces to teeth other than the direct abutments than in preventing denture base lifting.

In several instances more force was required to dislodge the denture base when the indirect retainer was missing. It can be assumed that this additional force was applied to the direct abutment teeth because they were the only ones still contacted by the framework. Increased force on an abutment tooth is not desirable especially when there is no concomitant benefit such as reduced denture base movement.

Differences in denture base movement due to the anterior distance of the indirect retainer from the fulcrum line were small. Similar results were noted when the indirect retainer was placed on the first premolar or the canine. Thus the choice of indirect retainer location should be made mostly on the basis of abutment tooth support, a crown form favoring adequate rest seat preparation, and the patient's esthetic desires.

Guiding planes on the distal surfaces of the terminal abutment teeth have an important role in preventing the lifting of a distal-extension denture base. Parallel guiding planes are more important than the distance of an indirect retainer from the fulcrum line. The dental laboratory technician must not use excessive block-out wax on the tooth surfaces of the master cast that have guiding planes and also must not overfinish the casting. One effect of these errors will be increased movement of the removable partial denture. The dentist can help control the quality of the framework by evaluating the blocked-out master cast and framework wax-up on the refractory cast prior to casting.
Several reports in the dental literature advocate the use of mesial rests on terminal abutment teeth to minimize harmful stresses on these teeth.\textsuperscript{8-10} Mesial rest placement decreases the distance from the fulcrum line to the indirect retainer, but this does not seem to increase denture base dislodgment. In fact, less denture base movement, depending on clasp type, was recorded several times when a mesial rest was used. However, guiding plane contacts are essential to resist lifting forces when using mesial rests. The decreased retention of the clasp used with mesial rests may favor preservation of the periodontal health of the abutment tooth.

Neither the bar clasp nor the wrought-wire clasp was obviously superior. The bar clasp permitted less movement of the denture base at 400 Gm. of force, but only two thirds as much total force was needed to dislodge the denture. The clasps were equally retentive when the force was applied simultaneously to all parts of the denture base and framework, but this condition probably does not often occur intraorally. Choosing between the two clasp types depends upon such clinical factors as undercut location and soft-tissue limitations.

A clasp design combining a mesial rest, proximal guiding plane, and facial bar clasp is often chosen for distal-extension partial dentures because of its stress-relieving capacity during gingival displacement. This investigation revealed the importance of parallel proximal guiding planes in resisting denture base movement in an occlusal direction. Retention with this clasp design is greatly reduced when the guiding plane on the proximal surface is not properly contacted.

CONCLUSIONS

On the basis of the results of this study the following conclusions may be stated:

1. The type of clasp used has the greatest influence on the amount of denture base displacement.
2. Indirect retainers have little effect upon retention of the distal-extension partial denture base.
3. Guiding planes on the proximal surfaces of terminal abutment teeth are important in preventing denture base lifting.
4. Use of a mesial instead of a distal rest on the terminal abutment tooth does not decrease indirect retention.
5. A distal-extension partial denture base is dislodged equally by a force directed anteriorly and a force perpendicular to the occlusal plane.
6. Under unilateral or bilateral forces there is no difference in movement away from the ridge of a distal-extension partial denture base.

SUMMARY

A mandibular bilateral distal-extension base removable partial denture was lifted from a model under standardized conditions. The amount of denture base displacement under various loads and the forces of removal were measured electronically. The framework was constructed to allow repeated changes in the type of clasp, location of indirect retainer, and position of the rest seat on the terminal abutment tooth.

The usefulness of an indirect retainer in preventing occlusal displacement of the denture base appears to be limited. The type of clasp had the greatest influence on the amount of denture base movement. Proximal surface guiding planes were also
found to be important in preventing lifting of the denture base. Use of mesial instead of distal rests on the terminal abutment teeth did not decrease indirect retention.

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References

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