ACP
AMERICAN COLLEGE OF PROSTHODONTISTS®

# A Comparison of Retention Characteristics in Prefabricated and Custom-Cast Dental Attachments

Chin-Chuan Fu, DDS, MS & Yung-Tsung Hsu, DDS, MS

Department of Prosthodontics, University of Alabama at Birmingham, School of Dentistry, Birmingham, AL

**Keywords**
ERA; overdenture; matrix; patrix; retention.

**Correspondence**
Chin-Chuan Fu, UAB School of Dentistry–Prosthodontics and Biomaterials, SDB 617, 1530, 3rd Ave S, Birmingham, AL 35294. E-mail: ccfu@uab.edu

*This study was partly supported by the American College of Prosthodontists P&G Research Award in Complete Denture Prosthodontics (2005–2006).*

Accepted May 13, 2008

doi: 10.1111/j.1532-849X.2009.00459.x

## Abstract

**Purpose:** The aim of this in vitro study was to investigate the retention characteristics of attachments fabricated by machine milling or by custom casting. In addition, the retention of reduced dimension attachments was also evaluated.
**Materials and Methods:** Three types of ERA matrices, one prefabricated and two cast, were used. Ten specimens were made for each type, and white nylon patrices were transferred to denture bases. Tests were performed at a crosshead speed of 0.2 in/min with an Instron machine. The dislodging force at baseline, 100, 200, 300, 400, 500, and subsequently after every 500 pulls up to 2500 pulls were measured. ANOVA and Student's *t*-test were used to analyze the measurements.
**Results:** All three groups showed no difference at the baseline, but the cast groups showed greater variation within group. The prefabricated group showed higher retention after 200 pulls. Decreased-dimension attachments have no significant difference when compared to the cast regular dimension group after 400 pulls.
**Conclusion:** The prefabricated attachments had superior retention than the cast groups over time. Reduced dimension did not reduce the retention when compared to the cast group.

Mandibular overdentures supported by two implants have been recommended as the standard of care.[1] Attachments used to connect the denture and implants are fabricated either by machine milling on alloy or are custom cast from plastic patterns. Machine-milled attachments are commonly used on the individual implant, while custom-cast attachments in the bar design are popular. Both designs have shown satisfactory results in terms of implant success and patient satisfaction.[2,3] The advantages of the individual attachment include simplicity and lower cost; however, the paths of insertion for two attachments must be closely parallel to achieve the best result. The alternative option is to connect two implants with a bar and have the attachments cast or cemented onto it. A bar is useful, especially when implants are not parallel to each other. This method ensures that the path of insertion of two attachments will be parallel regardless of the angulation of the implants. The main concern with this design is the accuracy of the attachment when it is cast from the plastic pattern.[4] When an attachment is made using the casting procedure, several factors will affect the accuracy of attachment, including the laboratory procedures used and metal alloy selection. Inappropriate laboratory manufacturing may lead to porosities and shrink holes in the cast dental work which may adversely affect the accuracy of the product. This can result in higher plaque accumulation, corrosion, and lack of mechanical stability.[5] Moreover, the choice of casting alloys may also affect the accuracy of the attachments. The choice of casting alloy is governed by a number of factors, including cost, biocompatibility, mechanical properties, and the ease of casting.[6] Many studies have compared the mechanical properties and accuracy of various dental alloys after the casting process.[7–9] The ADA classification system categorizes dental casting alloys as four distinct types: I, II, III, and IV. Type IV alloys have the properties of low elongation and very high stress values and, as a result, are used for cast dowels and cores, long-span bridges, and partial denture construction, particularly clasp arms. Manufacturers also recommend the use of type IV alloys for custom-cast attachments; however, no controlled studies have tested this recommendation.

Another factor in attachment selection relates to the space available to accommodate the matrix and patrix. For implant overdentures with individual attachment design, 5 to 6 mm of vertical space is needed to accommodate implant attachment mechanisms.[10,11] When interarch space is limited, two options are available. First, if the volume of alveolar bone is adequate, an alveoplasty can be performed to reduce bone height and allow an inferior position of the implants in the bone, which essentially increases the interarch space. A second option is to use a shorter vertical height and/or a narrower dimension attachment. Although many manufacturers decrease the dimension of attachments to meet this goal, this modification may compromise attachment retention.

Extracoronal resilient attachments (ERAs; Sterngold, Attleboro, MA) have been widely used in dentistry.[12,13] Several studies have compared ERAs with other retentive anchor systems for implant overdentures.[14,15] Gamborena et al[16] studied the retention of different ERAs and the effect of multiple retentive pull cycles on retention. Results demonstrated that, although four different retentive elements are supplied by the manufacturers, these can be divided into only two groups with important differences: (1) the white matrix and (2) the orange, blue, and gray matrices. They also found that after the initial 500 cycles, the loss of retention for white, orange, blue, and gray matrices were 60%, 60%, 56%, and 54%, respectively; however, after 1500 cycles there were no differences in retentive values for any of the four groups. Epstein et al[17] compared the retentive properties of ERA white and ERA gray matrices connecting the prefabricated overdenture attachment systems with other attachments, both initially and over time using a 2000-pull design configuration. They found a substantial difference in the force required at pull 1, but at pull 2000, there were no statistical differences between any of the attachments studied. Other studies comparing retention with a large variety of overdenture anchor systems have varied in their methods and results, but comparisons of the characteristics of retention between prefabricated and custom-cast attachments and the retention of the reduced dimension attachments have not been adequately investigated.

This in vitro study, therefore, was designed to compare the retention characteristics of attachments with the same design fabricated by machine milling or by custom casting. In addition, the retention of reduced dimension attachments was evaluated. To simplify the study design, ERAs were used, since they have the same morphological design as the custom-cast and prefabricated matrices.

## Materials and methods

### Placement of implant analogs

An edentulous mandibular stone model (XNH-SE-91 A, Columbia Dentoform Corp., Long Island City, NY) was used to simulate the clinical situation. A record base was made, and denture teeth (Bioform H/330, Dentsply Trubyte, York, PA) were set according to a clinical and laboratory guide for complete dentures (Clinical and Laboratory Guide for Complete Dentures; Department of Restorative Dentistry, The University of Alabama School of Dentistry). Using an acrylic bur (251E-060, Brasseler USA, Savannah, GA), two recesses (7 mm in diameter, 11 mm in length) were prepared in the stone cast corresponding to the lingual side between lateral incisor and cuspid on each side. An autopolymerizing acrylic resin (Repair resin, Dentsply Trubyte) was used to secure an impression coping (Replace Select Impression Coping RP, Nobel Biocare, Goteborg, Sweden) on the analyzing rod of a surveyor (Ney surveyor, Dentsply Ceramco, York, PA). An implant analog (Replace Select Abutment Replica RP, Nobel Biocare) was attached to the impression coping and inserted into the prepared recess. The space between the analog and stone cast was filled with autopolymerizing acrylic resin (Repair resin). After polymerization of the acrylic resin, the impression copings were attached to the analogs, and an impression was made on the model with silicone material (REDU-IT, American Dental Supply Inc., Easton, PA). The impression copings were connected with implant analogs. A thin layer of petroleum jelly (Vaseline, Chesebrough-Ponds USA Co., Greenwich, CT) was applied to the alveolar ridge area of the mold and poly(vinyl siloxane) (PVS) impression material (Aquasil LV, Dentsply Caulk, Milford, DE) was injected into the mold. Several irregularities were created on the PVS material to facilitate mechanical retention of the stone base. The impression was poured with type IV stone (Silky Rock, Whip Mix Corp., Louisville, KY) (Fig 1).

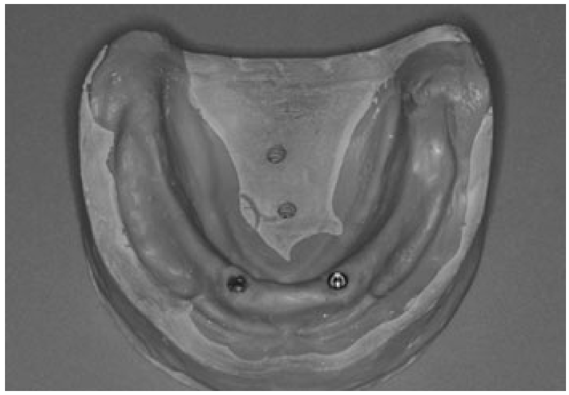

**Figure 1** Resilient material on the model.

### Preparation of the bar

The plastic copings (Temporary abutment non-engaging plastic, Nobel Biocare) were placed on the analogs, and screws were tightened onto the analogs. Autopolymerizing acrylic resin (DuraLay, Reliance Dental, Worth, IL) was used to build a $5 \times 5$ mm$^2$ square bar connecting the plastic abutments with the distal areas extended 10 mm from the distal surfaces of the plastic abutments on both sides. A 2-mm diameter hole was made on the distal extension surface. The surface was flat and at the same level as the top of the plastic abutments. The bar was cast with Co–Cr alloy.

### Preparation of the attachments

Three types of ERA matrices were used in this study. They included two cast groups: ERA Overdenture Female (ERA-cast) and Micro ERA Overdenture Female (ERA-micro), and one prefabricated group: 0° ERA-direct Overdenture Female (ERA-direct, large post 1.7 mm diameter, 9 mm length). No Micro ERA Direct Female was available at the time this study was conducted. For the custom-cast groups, a 14-gauge (1.7 mm) sprue was connected under the plastic pattern, and the plastic pattern cast with type IV gold alloy (Sterngold 100), according to the manufacturer's recommendations. Only those

**Figure 2** Matrices cemented on the bar.

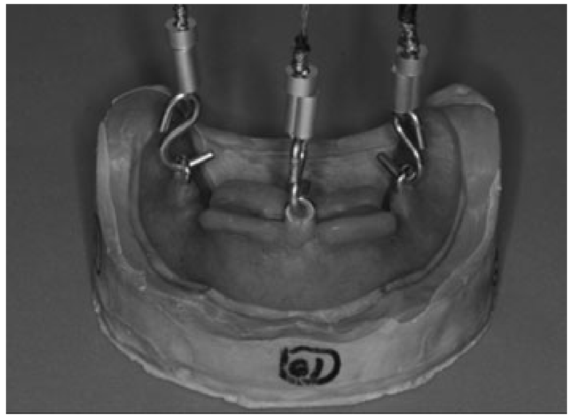

**Figure 3** Metallic hooks connect the denture base.

cast attachments with no blebs were used. After casting, the sprue was cut 9 mm below the bottom of the attachment, and the casting finished according to the manufacturer's recommendation. The attachments were placed in the holes prepared at the distal extensions of the bar, and the parallelism checked with a surveyor (Fig 2). The cast attachments were cemented with resin cement (Panavia 21, Kuraray, Osaka, Japan). Ten units of each type were prepared for testing.

### Simulating a denture-like situation

The ERA overdenture white patrices were placed over the matrices. One layer of baseplate wax was placed around the bar and patrices as the spacer. Light-activated composite resin (Triad VLC denture base material, Dentsply Trubyte) was used to form a denture base over the bar and the edentulous ridge. Three metallic hooks (#216 × 11/16", Hillman, Cincinnati, OH) were attached at the first molar areas and the area between two central incisors using Triad VLC light-activated composite resin. Using this denture base as a master, a duplicate was prepared by investing the denture base with silicone putty (Aquasil Easy Mix Putty, Dentsply Caulk) and plaster. The denture base was processed with heat-polymerized acrylic resin (Lucitone 199, Dentsply Trubyte). After processing, the denture base was tried in to ensure that there was no interference between the bar and denture base. The white patrices were placed on the matrices and transferred to the denture base with autopolymerizing acrylic resin (Repair resin). The denture base was removed and examined for any defects around the patrices. The denture was inserted and removed five times to simulate the necessary insertions and removals at the time of a denture delivery visit in a clinical situation.

### Test

Ten assemblies for each group (ERA-cast, ERA-direct, ERA-micro) were made. In total, 30 prepared models with 30 denture bases were randomly assigned to each group. Three parallel metal wires (#2, picture wire, Hillman) were used to connect the assembly from the hooks to the clamp of the universal testing machine (Instron Model 1114, Norwood, MA) (Fig 3). Tests were performed at a crosshead speed of 0.2 in/min to determine the maximum dislodging force. The denture base was inserted and removed manually. The dislodging force at baseline (the 6th pull), 100, 200, 300, 400, 500, and subsequently after every 500 pulls up to 2500 pulls were measured. The detachment load was measured in pounds.

### Statistics

The results were recorded on a liner graph, and dislodging forces were compared. The data were statistically analyzed using one-way ANOVA with significance set at $p < 0.05$. Student's $t$-test was used to compare between the two groups.

## Results

The mean retentive values and percentage of loss of retention are shown in Table 1 and Figure 4. There was no significant difference in retention at baseline among the three groups. Both custom-cast groups (ERA-cast, ERA-micro) showed greater variances at the baseline (coefficient variation 23.24 and 22.92, respectively). ERA-micro lost 50% of the retention after 100 pulls, while ERA-cast and ERA-direct lost 41% and 32%, respectively. Both cast groups (ERA-cast, ERA-micro) lost more than 80% of retention after 1000 pulls, but the prefabricated group (ERA-direct) lost only 56%. Decreased dimension (ERA-micro) reduced the retention more than the other two groups before 300 pulls but showed no difference when compared to the ERA-cast group after 400 pulls. At the conclusion of the study (2500 pulls), ERA-direct demonstrated higher retention (2.23 lbs) than the ERA-cast and ERA-micro (0.77 lbs and 0.83 lbs, respectively).

## Discussion

Dental attachments are classified as precision and semiprecision attachments. Precision attachments are prefabricated on the metal alloy, while semiprecision attachments are cast from the plastic or wax patterns.[18] The retention of attachments depends on the design and fabrication process, such as alloy or accuracy of casting. This study used ERAs because of the identical morphology of the attachments. ERAs are available for

**Table 1** Mean retentive values and percentage of loss for number of pulls (lbs)

| | Baseline | 100 | 200 | 300 | 400 | 500 | 1000 | 1500 | 2000 | 2500 |
|---|---|---|---|---|---|---|---|---|---|---|
| ERA-direct | 6.75 | 4.62 | 4.21 | 3.92 | 3.79 | 3.57 | 2.96 | 2.66 | 2.47 | 2.23 |
| SD | 0.45 | 0.47 | 0.41 | 0.47 | 0.48 | 0.49 | 0.53 | 0.5 | 0.53 | 0.54 |
| Loss (%) | | 32 | 38 | 42 | 44 | 47 | 56 | 61 | 63 | 67 |
| Coefficient variation | 6.64 | | | | | | | | | |
| ERA-cast | 6.88 | 4.07 | 2.98 | 2.52 | 2.16 | 1.83 | 1.23 | 0.99 | 0.9 | 0.77 |
| SD | 1.6 | 0.82 | 0.91 | 0.53 | 0.63 | 0.52 | 0.38 | 0.33 | 0.39 | 0.35 |
| Loss (%) | | 41 | 57 | 63 | 69 | 73 | 82 | 86 | 87 | 89 |
| Coefficient variation | 23.24 | | | | | | | | | |
| ERA-micro | 6.32 | 3.15 | 2.32 | 1.99 | 1.67 | 1.53 | 1.16 | 0.87 | 1.12 | 0.83 |
| SD | 1.45 | 0.6 | 0.57 | 0.52 | 0.53 | 0.44 | 0.42 | 0.36 | 0.42 | 0.35 |
| Loss (%) | | 50 | 63 | 69 | 74 | 76 | 82 | 86 | 82 | 87 |
| Coefficient variation | 22.92 | | | | | | | | | |

implant and natural teeth. They are categorized as extracoronal- or stud-type attachments. Extracoronal-type ERA can be used on the abutment crown for the removable partial denture or the terminal end of a bar. Stud-type ERA can be used on natural teeth or dental implants. Prefabricated stud-type micro-ERA was not available at the time this study was conducted. This study used the stud-type ERA to compare the retention among the identical morphology but differently fabricated (by casting or machine milling) matrices. The primary retention of ERAs comes from the friction between the metal matrix and nylon patrix on the inner side of the ring; however, the wall outside the ring may play a role on the retention as well. The accuracy of the casting would affect the retention. Various factors involved in the casting process may affect the accuracy of cast works. These factors were divided into two groups: procedural factors, such as alloy, sprue diameter, investing technique, and melting and casting methods; and operator factors, such as alloy casting temperature, mold temperature, and heat-soak times.[19] A type IV alloy (Sterngold 100) with Vickers hardness number (VHN) of 280 was used for both cast groups according to the manufacturer's recommendation. A VHN less than 125 makes an alloy susceptible to wear.[20] ERA-direct was made from stainless steel with titanium nitride coating. It may be more resistant to wear, even though wear is a complex phenomenon, and predicting clinical wear based on hardness is not advisable.[21]

Finishing procedures also affected the accuracy of casting. In the present study, those cast works with external heterogeneities identified by visual examination were discarded. Pickling solution (Prevox, Williams, NY) and ultrasonic cleaners were used to remove the residual investment. No polishing procedure was used to prevent the discrepancy of accuracy.

The retention of a two-implant-retained overdenture is the result of multiple factors, such as ridge height and denture border extension, parallelism of two implants, and the fit of the denture base to the tissue. Most studies have been conducted on the attachment assembly and ignored other factors that could affect the performance of the attachments. In addition, when the insertion and removal was done by a machine, the paths could be all the same (different from the clinical situation). The present study used a resilient material on the ridge part of the

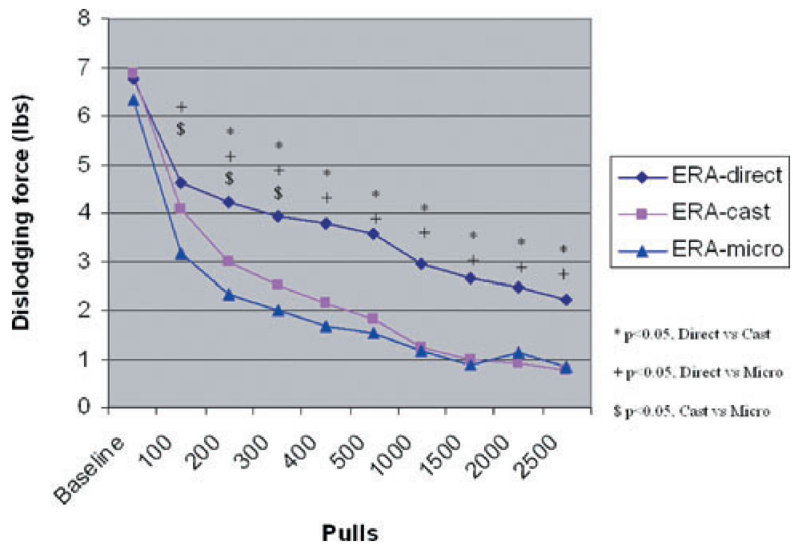


**Figure 4** Dislodging force at different pulls.

cast and a complete denture base to pick up the patrices, so each manual insertion and removal had some rocking effects on the attachment assemblies, similar to the clinical situation when a denture is in function.

Retention among the three groups at baseline was not significantly different, and this may be explained by the accuracy of the castings. For all three groups, the greatest change occurred at the first 100 pulls, which simulated 20 days after delivery. The two cast groups started to show significantly less retention than the prefabricated group after 200 pulls. This could be the wear of nylon patrix and metal matrix. For the two cast groups, because the cast works were not highly polished, the inner surface may be rougher than in the prefabricated group, therefore, greater reduced retention was noticed. After the initial wear, the retention decreased slowly, and the two cast groups showed no difference in retention at the end of study but significantly less than the prefabricated group.

ERA-micro lost 50% retention after 100 pulls and 63% after 200 pulls. The reduced dimension attachments seemed to affect the retention significantly in the early period of service but had no difference after 400 pulls when compared to the ERA-cast group. It is possible that the initial retention mainly came from the inner ring of the matrices and after the wear of the nylon patrices, the residual retention came from the general morphology of the design, that is, the ring design.

## Conclusions

Retention for cast-type attachments varied greatly. Decrease of retention occurred earlier and was greater in the cast groups. Given the same morphologic design, the smaller dimension attachment had less retentive force than the larger one in the early period of service, but had no difference compared to the cast group after 400 pulls. Machine-milled matrices showed higher retentive forces than the cast groups over time. The results of this study demonstrated that the machine-milled attachments have superior retention characteristics to those of custom-cast ones. Based on this study, whenever possible, a clinician should use an attachment fabricated by machine rather than by casting to extend the longevity of the service.

## References

1. Feine JS, Carlsson GE, Award MA, et al: The McGill consensus statement on overdentures. Int J Oral Maxillofac Implants 2002;17:601-602
2. Klemetti E, Chehade A, Takanashi Y, et al: Two-implant mandibular overdentures: simple to fabricate and easy to wear. J Can Dent Assoc 2003;69:29-33'
3. Timmerman R, Stoker GT, Wismeijer D, et al: An eight-year follow-up to a randomized clinical trial of participant satisfaction with three types of mandibular implant-retained overdentures. J Dent Res 2004;83:630-633
4. Hsu YT: Retention guide for resilient dental attachments. J Prosthet Dent 2004;92:93-94
5. Eisenburger M, Addy M: Radiological examination of dental castings–a review of method and comparisons of the equipment. J Oral Rehabil 2002;29:609-614
6. Agar K: Casting metals in dentistry: past-present-future. Adv Dent Res 1988;2:33
7. Carr AB, Brantley WA: Characterization of noble metal implant cylinders: as-received cylinders and cast interfaces with noble metal alloys. J Prosthet Dent 1996;75:77-85
8. Vallittu PK, Kokkonen M: Deflection fatigue of cobalt-chromium, titanium, and gold alloy cast denture clasp. J Prosthet Dent 1995;74:412-419
9. Agar K, Arfaei AH: Castability of crown and bridge alloys. J Prosthet Dent 1985;54:60-63
10. Burns DR: The mandibular complete overdenture. Dent Clin North Am 2004;48:603-623
11. Phillips K, Wong KM: Space requirements for implant-retained bar and clip overdentures. Compend Contin Educ Dent 2001;22:516-522
12. Berg T, Caputo AA: Maxillary distal-extension removable partial denture abutments with reduced periodontal support. J Prosthet Dent 1993;70:245-250
13. Davidoff SR, Davis RP: The ERA implant-supported overdenture. Compend Contin Educ Dent 1995;16:512-520
14. Svetlize CA, Bodereau EF: Comparative study of retentive anchor systems for overdentures. Quintessence Int 2004;35:443-448
15. Williams BH, Ochiai KT, Hojo S, et al: Retention of maxillary implant overdenture bars of different designs. J Prosthet Dent 2001;86:603-607
16. Gamborena JI, Hazelton LR, NaBadalung D, et al: Retention of ERA direct overdenture attachments before and after fatigue loading. Int J Prosthodont 1997;10:123-130
17. Epstein DD, Epstein PL, Cohen BI, et al: Comparison of the retentive of six prefabricated post overdenture attachment systems. J Prosthet Dent 1999;82:579-584
18. Phoenix RD, Cagna DR, DeFreest CF: Stewart's Clinical Removable Partial Prosthodontics (ed 3). Carol Stream, IL, Quintessence, 2003, pp. 507-517
19. Johnson A, Winstenley RB: The evaluation of factors affecting the castability of metal ceramic alloy-investment combinations. Int J Prosthodont 1996;9:74-78
20. Wataha JC: Nobel alloys and solders. In Craig RG, Powers JM (eds): Restorative Dental Materials (ed 11). St. Louis, MO, Mosby, 2002, pp. 449-478
21. Kohn DH: Mechanical properties. In Craig RG, Powers JM (eds): Restorative Dental Materials (ed 11). St. Louis, MO, Mosby, 2002, pp. 67-124

 