Retention and Load Transfer Characteristics of Implant-Retained Auricular Prostheses

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Purpose: *The use of osseointegrated implants for maxillofacial prostheses reduces the need for adhesives, provides for a more stable and more esthetic prosthesis with thinner margins, and results in increased patient acceptance and confidence. The purpose of this study was to compare the retention and load transfer characteristics of differently designed implant-retained auricular prostheses.* ***Materials and Methods:*** *A photoelastic model was fabricated of the auricular-temporal region of a human skull. Craniofacial implants 3.75 mm in diameter and 4 mm long were embedded in locations typically selected to retain auricular prostheses. Two retention mechanisms were evaluated on the implants: a Hader bar with 3 clips and the use of 3 Locator attachments. The retentive capacity of the prostheses was determined on an Instron test machine. Initial retention and changes with multiple removals were examined. Dislodgment forces were applied to each retentive device in the field of a circular polariscope. Resulting stresses were monitored and recorded photographically.* ***Results:*** *The highest initial retention demonstrated by the Locator device was 12.4 ± 0.9 lb, and the highest retention value for the Hader bar with clips was 7.5 ± 1.1 lb. All attachments decreased in retention after multiple removals. The Locator devices produced higher peri-implant stresses compared to the Hader bar–with-clips design.* ***Conclusions:*** *Since higher retention is associated with higher stresses, results of this study suggest that a balance between retention and stress production is necessary in selecting a retention mechanism for the specific requirements of the patient being treated. The Locator attachment was correlated with higher retention values as well as with higher peri-implant stress compared to the Hader bar–and-clip attachment design. Retention decreased and then stabilized after multiple removals.* INT J ORAL MAXILLOFAC IMPLANTS 2007;22:366–372

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The clinical use and placement of facial prosthetic appliances present multiple challenges for the prosthodontist, lab technician, and patient. The traditional application of skin adhesive–retained prosthetic devices presents several limitations to patient comfort and function.[1–4]

The usefulness of skin adhesives may be limited clinically in comparison to the support gained by craniofacial implants.[1–6] Skin adhesives may not ensure repeated positioning of an appliance and are less effective with adjacent movable soft tissues.[2,4] Furthermore, adverse skin reactions may occur. Retention of the prosthesis is also dependent upon temperature and is affected by perspiration.[1,2] Cleaning and adhesive buildup may be lead to greater wear and affect the durability of a prosthesis.[2] McKinstry states that routine use of adhesives may damage the external coloring of the prosthesis and will negatively effect thin margins, causing curling.[7]

Titanium craniofacial implants have significantly improved the ease of use and patient comfort by improving stability and retention of various facial prostheses and devices.[1,2] Location and placement of the prosthesis are more predictable with indexed

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positioning of the appliances, which provides tactile feedback from the bone-anchored implant attachment. The improved placement and positioning also assists the overall esthetics, resulting in improved retention with margins that might be otherwise affected by movable tissue areas.[1,2,6] Several authors have published studies reporting the success and longevity of implant-retained extraoral protheses.[1,2,8] Parel showed that an implant-retained prosthesis lasted 3 to 4 times longer than adhesive-retained prostheses.[5] The overall effect of maxillofacial prosthetic treatment with osseointegrated implants is very positive. Patient confidence is increased because of the improvements in retention, esthetics, and support provided by these implants.

Craniofacial implants differ from conventional dental implants in size and design. These implants have an incorporated crestal flange about the coronal aspect to compensate for the reduced overall length (4.0 mm). The crestal flange is designed to engage the bone surface. These implants may be connected to the prosthesis with attachment devices of various designs and retention levels. The selection and use of specific attachments may depend upon the alignment and specific positions of individual supporting implants. Several types of retention mechanisms developed for use with intraoral prostheses are also being used for extraoral applications.[9]

These attachment designs may be utilized in a splinted or nonsplinted manner. Use of individual direct abutments (nonsplinted) requires specified relative parallelism and positioning in relation to the confines of the prostheses. The use of a splinted connection between the individual implants allows repositioning of the attachment devices independent of the specific implant locations and positions in relation to the prostheses. While splinting has not been shown to increase the retentive value of the attachment,[9] it facilitates more favorable placement of any attachment in relation to the function, placement, and removal of the prostheses. A splinted implant bar not only allows positioning of the selected attachments but may provide an increase in lateral surface to assist in horizontal stability and thus improve the overall resistance of an appliance to lateral displacement. The retention and load transfer characteristics of several of these attachment designs have been evaluated for intraoral appliances.[9–11] Although these attachments have been used in intraoral applications, comparison of these various attachment designs for craniofacial implants is needed. Furthermore, their effects upon the supporting structures in a specified facial prosthetic application are not well known. The purpose of this study was to compare the retention and load transfer characteristics of 2 retention designs of implant-retained auricular prostheses using a photoelastic model of the temporal region supporting an auricular prosthetic device.

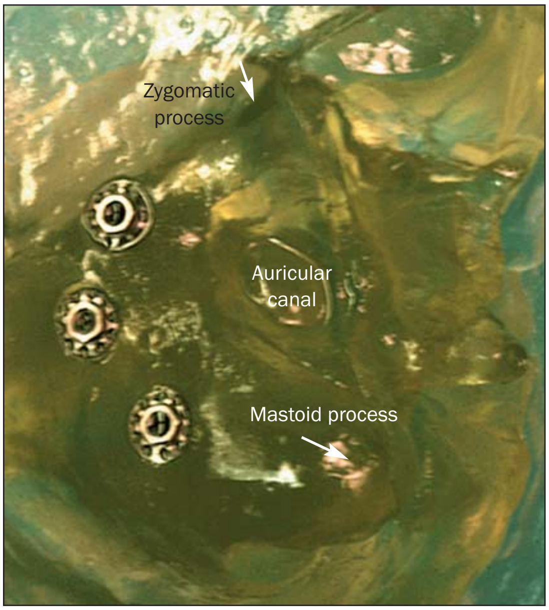


Fig 1 Three 4-mm-long craniofacial implants were embedded at 7, 9, and 11 o'clock in relation to the auditory canal.

MATERIALS AND METHODS

A 3-dimensional, life-size photoelastic model of the right temporal area of an adult human skull was fabricated using photoelastic resin Pl-2 (Photolastic, Raleigh, NC). The model included the zygomatic area of the temporal bone, the mastoid process, and the temporal and auricular areas. Craniofacial implants 3.75 mm in diameter and 4 mm long (Entific Medical Systems, Göteborg, Sweden) were embedded at 7, 9, and 11 o'clock in relation to the auditory canal (Fig 1). A 2-piece positioning base was fabricated to provide passive support and repeatable positioning for the photoelastic model. This base was used for both retention and stress distribution studies.

The 2 attachment-retention designs tested were a splinted Hader bar with 3 clips (APM-Sterngold, Attleboro, MA) and 3 direct 4.0-mm nonsplinted Locator abutments (Zest Anchors, Escondido, CA; Fig 2). The splinted Hader bar was cast using gold palladium alloy (Identalloy, 550 SL, Leach and Dillon, Cranston, RI). The alloy was cast to machined gold cylinders using conventional techniques. Soldering procedures were utilized to ensure passivity of fit and alignment. The fit of the bar was verified and checked for passivity. The resilient attachments for

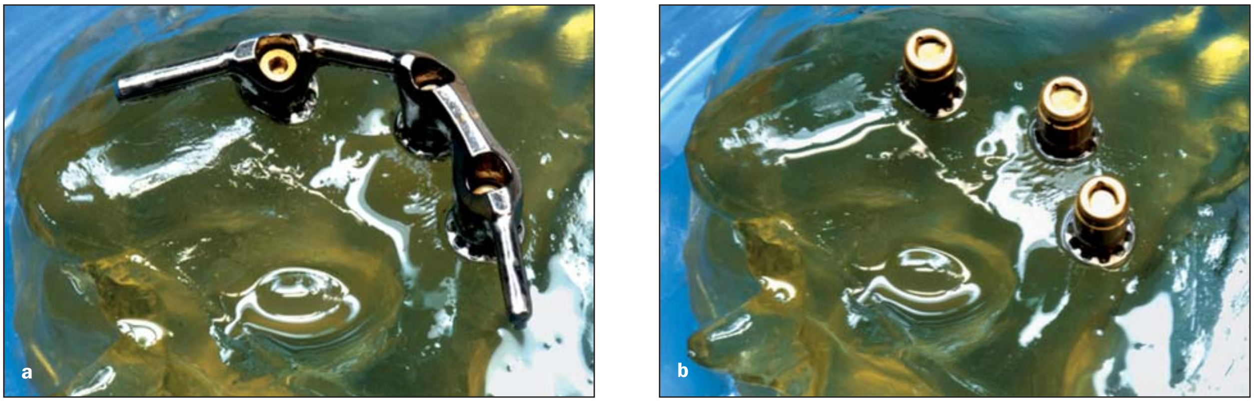


Fig 2 Attachments on photoelastic model. *(a)* Hader bar. *(b)* Locator attachments.

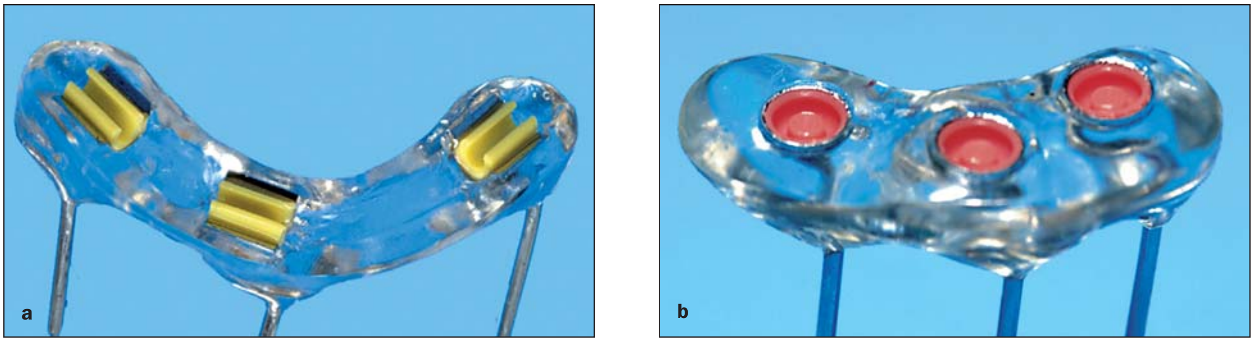


Fig 3 Experimental attachment prostheses. *(a)* Hader attachments with clips. *(b)* Locator attachments.

Fig 4 Retention test setup.

each design tested were embedded with the specific attachment housings in a clear substructure simulating the implant-retained auricular prosthesis (Fig 3). Three stainless removal hooks were attached to the superior surface for connection to the testing apparatus.

The retentive characteristics of the prostheses were evaluated for the 2 different attachment devices and designs. The retentive capacity was determined as the force required for dislodgment of the prostheses using an Instron test machine (Instron, Norwood, MA), with removal parallel to the axes of the implants (Fig 4). The force to dislodge the devices was determined at a crosshead rate of 2 in/min. Each device was subjected to 10 pulls on the Instron followed by an additional 10 nonmeasured pulls by hand, followed by a final recorded and measured Instron pull. Both initial retention and the changes that occurred with multiple removals were examined; multiple removals were carried out to simulate long-term use. The retentive components were replaced, and the procedure was repeated. Five replications for each retention design were recorded. The data were collected and analyzed using an analysis of variance and a *t* test with post-hoc corrections for multiple tests.

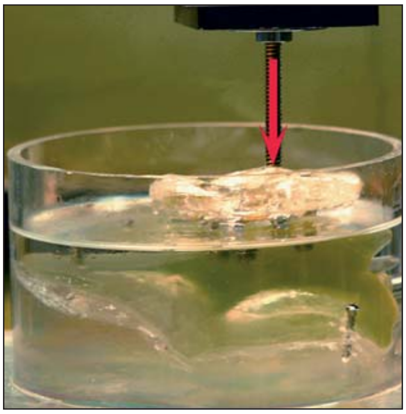
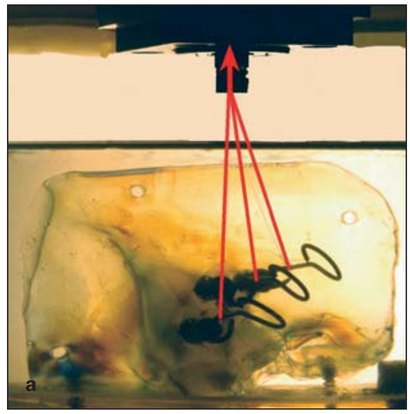


Fig 5 Test setup for determination of stress during placement.



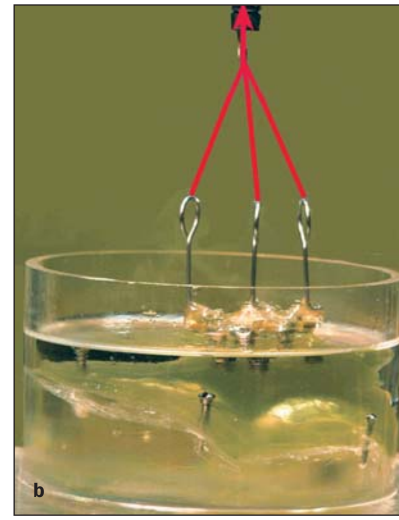


Fig 6 Test setup for determination of stress during removal. *(a)* Perpendicular to axes of implants. *(b)* Parallel to axes of implants.

The load transfer characteristics under simulated placement and removal conditions were determined photoelastically. Placement and removal loads (Figs 5 and 6) were applied to each of the auricular prosthetic devices with a calibrated load cell (Model GM 2, Universal Transducer Cells, Camarillo, CA) with digital read-out (Model 12130 and 2120Am Measurements Group, Instrument Division) in the field of a circular polariscope. The model was immersed in a tank of mineral oil to minimize surface refraction and thereby facilitate photoelastic observation. Resulting stresses were monitored and recorded using digital photography. Forces were applied along the long axes of the implants and then perpendicular to the implants. Each loading and observation sequence was repeated at least twice to ensure reproducibility of results.

RESULTS

Retention

There were variations in retentive capacity between replicates of the 2 devices. The retention values are summarized in Fig 7. Each bar represents the mean values for 21 pulls. The Locator attachment demonstrated significantly higher retention than the Hader bar with 3 clips ($P < .05$). Figure 8 illustrates retention level differences with increasing number of pulls. The Locator device demonstrated the highest initial retention (12.4 ± 0.9 lb). The highest value recorded for the Hader bar with clips was (7.5 ± 1.1 lb). For both attachment designs, retention decreased as the number of removals increased. The largest loss of measured retention with simulated usage was shown with the Hader bar with clips.

Load Transfer Results

The stresses developed in the simulated temporal bone during vertical placement of the devices are shown in Fig 9. Stresses with the Locator attachment were observed to communicate between the individual implants and also were localized directly adjacent to the implant flange collar. Similar observations of lower stress intensity were made for the Hader bar attachment. The stresses developed were similar around each of the implants. However, the viewing angle shown in Fig 9 precluded visualization of the stresses around the superiorly placed implant.

The stresses developed in the simulated temporal bone during perpendicular removal of the devices are shown in Fig 10. The stresses demonstrated with the Locator attachments were higher for the middle position implant. The stresses with the Hader bar design were observed to be higher around the superiorly positioned implant. Stresses were localized due to the contact of the implant collars with the bone simulant. This observation was made with both attachment designs. In general, the most intense stresses were generated by the Hader bar–attached prosthesis during perpendicular removal.

The stresses developed in the simulated temporal bone during parallel removal of the devices are shown in Fig 11. For the Locator attachment, the stresses observed were higher for the middle and inferiorly positioned implants. The Hader bar stresses observed were higher on the inferiorly positioned implant. In general, for parallel removal, the Locator was somewhat higher in overall stresses generated.

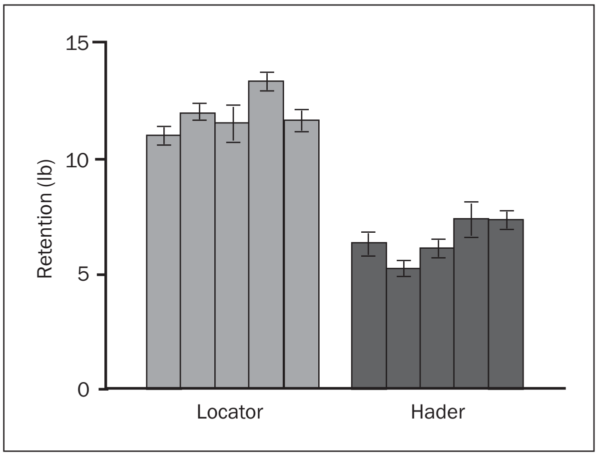


Fig 7 Mean retention values for auricular designs. Vertical bars represent ± standard deviation.

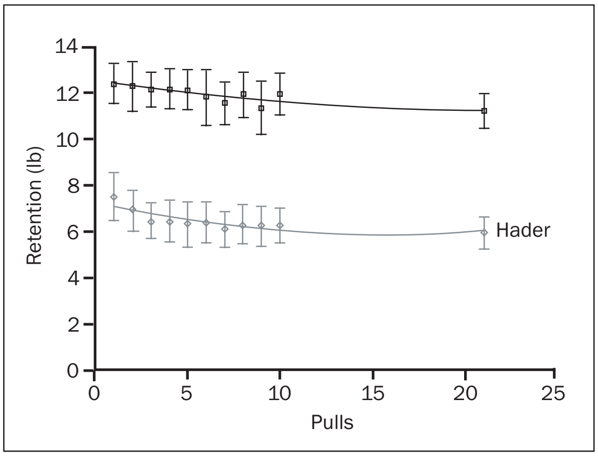


Fig 8 Retention of auricular designs as a function of number of removals. Vertical bars represent ± standard deviation.

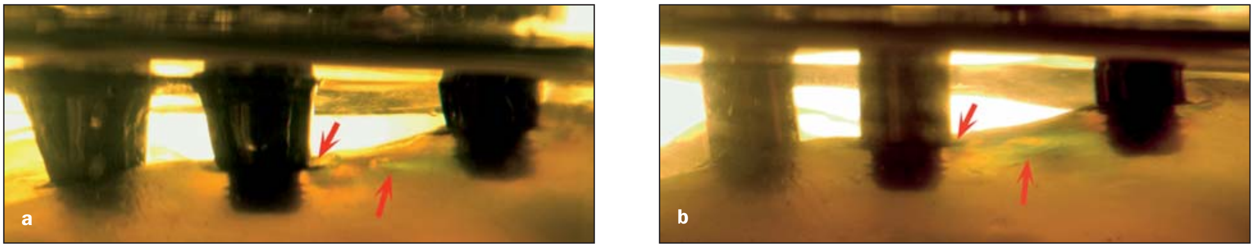


Fig 9 Load transfer during prosthesis vertical placement. *(a)* Hader bar. *(b)* Locator.

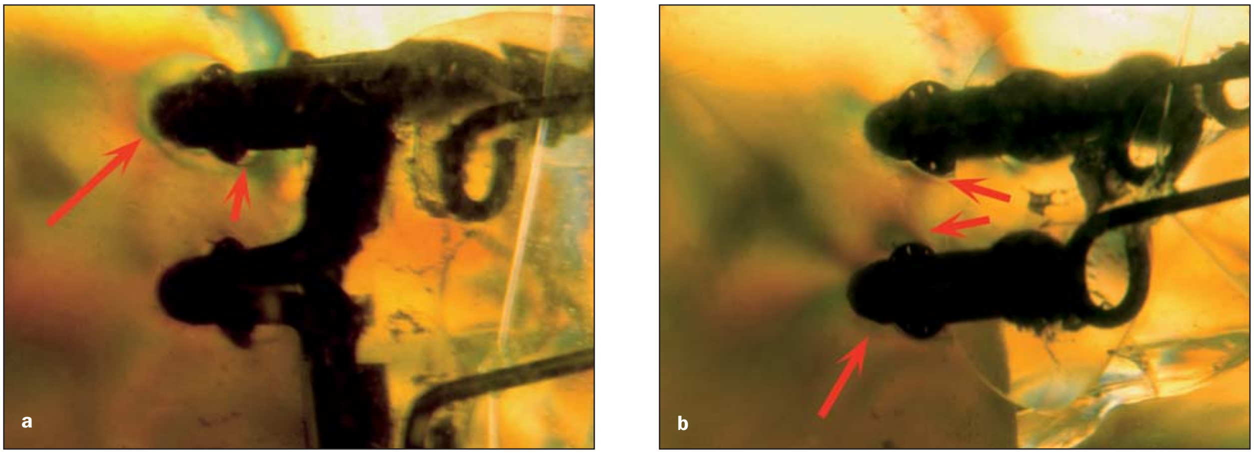


Fig 10 Load transfer during perpendicular prosthesis removal. *(a)* Hader bar. *(b)* Locator.

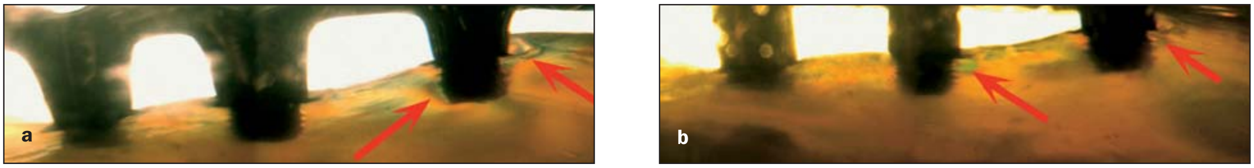


Fig 11 Load transfer during parallel prosthesis removal. *(a)* Hader bar. *(b)* Locator.

DISCUSSION

The considerations for attachment design selection with craniofacial implants involve several clinical application factors. The defect location and size, as well as the resulting prosthetic appliance size, have been shown to be affected by, and are directly related to, implant prognosis. Presurgical evaluations determine the number, position, and angulation of the implants considered required for a given prosthesis. Surgical evaluation may result in modification of implant number or location based on the condition and appearance of the supporting bone.

An idealized placement situation for craniofacial implants results in implants that are well within the defect to facilitate esthetic coverage by the appliance as well as to provide integrated implants. Since craniofacial implants are short in length, their placement should be perpendicular to the osseous surface to allow complete seating of the crestal implant flanges. The stabilizing effects of flange support were demonstrated and reconfirmed by the stress analysis findings of this study.[11]

Unlike oral appliances, craniofacial extraoral appliances generally are not subjected to high functional loads. Loads on facial appliances are expected to be highest at times of insertion and removal. In some situations there may be a cantilever effect exerted during the lateral removal of the appliance from the implants. Other loads, such as eyeglasses or hearing-enhancement devices, are expected to place low levels of longer-term load upon the supporting implants. The overall load and the potential cantilever effects on craniofacial implants by various types of prostheses may affect the selection and application of the attachments utilized. The movement of the soft tissues, patient's activity and lifestyle, cost, and retentive characteristics of the device are also considerations that affect treatment planning and design.

Hygiene remains an important factor for the success and longevity of the supporting implants. Proper surgical preparation of the implant placement site requires removal of excess tissue thickness, reduction of peri-implant moveable tissues, tissue grafting, and electrolysis for excess hair removal. The stress analysis findings within this study confirmed that interimplant splinting and connection may be utilized to improve attachment positioning and provide increased lateral support and resistance to dislodgment. However, splinting of closely adjacent implants may also impede access for cleaning and hygiene. Further, nonsplinted direct implant abutment designs may be less expensive than splinted designs.

Several proprietary resilient attachment systems designed for intraoral implant restorations may be also available for facial prosthetic appliance applications. Devices designed for dental use have high durability and retention consistent with their intended use in a high-load environment. However, although these attachments can be used for craniofacial prosthesis support, this use differs greatly from their expected function with implants with much different size and support requirements.

In the present study, the measured level of retention for the 2 designs of auricular prostheses evaluated ranged from 7.5 to 12.4 lb during removal. Resilient attachments may have multiple proprietary levels of retention available for each design. The Locator attachments used were based on the level of expected retention per attachment (5 lb). Increasing the number of repetitions of placement and removal may be expected to result in further decrease in expected retention. However, a prior investigation performed by the authors demonstrated that the initial relative levels of retention may be significant upon comparison of different designs of use and application.[10] Clinical reports of long-term craniofacial implant use with the attachment designs evaluated have not been reported.

The basic design of the short craniofacial implant does not support or require high overall retention. Optimal retention may be the level of retention that allows a patient to easily manipulate a device into position and remove it with the expectation that it remain in place without dislodgment during normal use. Initial delivery of a prosthetic device has the greatest potential to place a high load on supporting craniofacial implants. The reduction of initial retention for both devices after 20 removals was significant. It is suggested that predelivery laboratory preparation include a series of simulated placements and removals of the prosthesis on a laboratory model. The wear on the attachments utilized may reduce the risk of placing extreme high loads on the supporting craniofacial implants prior to prosthesis delivery.

CONCLUSIONS

This study compared the retention and load transfer characteristics of a nonsplinted design (Locator) and a splinted design (Hader bar) for the retention of implant-retained auricular prostheses. The attachment mechanisms differed in retention values at initial delivery and after simulated use. The Locator attachments used in the nonsplinted design demonstrated the highest retentive values. Both attachment designs exhibited reduced retention after simulated long-term use.

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