Comparison of retention and stability of two implant-retained overdentures based on implant location

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Statement of problem. The location of dental implants and the choice of retentive attachments for implant-retained overdentures are selected based on clinician preference, expert opinion, or empirical information. Limited information is available regarding implant position and the effect on the retention and stability of 2-implant mandibular implant overdentures.

Purpose. The purpose of this investigation was to evaluate the effect of implant location on the in vitro retention and stability of a simulated 2-implant-supported overdenture and to examine the differences among different attachment systems.

Material and methods. A model that simulates a mandibular edentulous ridge with dental implants in positions that approximate tooth positions, and a cobalt-chromium cast framework attached to a universal testing machine was used to measure the peak load (N) required to disconnect the attachments. Four different types of attachments (Ball/Cap, ERA, Locator, and O-Ring) were used in sequence in various positions on the model to evaluate the effect of implant location on the retention and stability of a simulated 2-implant-retained overdenture. Means were calculated, and differences among the systems, directions, and groups were identified by using a repeated measured ANOVA (α=.05). For differences observed between measurements, the Bonferroni post hoc method at the 5% level of significance was used to determine the location and magnitude of difference.

Results. The interactions between the attachment system, direction of force, and implant location were statistically significant (*P*=.01). The vertical retention and horizontal stability of a simulated overdenture prosthesis increased with the distal implant location up to the second premolar, and the anteroposterior stability increased with distal implant location. The attachment type affected retention and stability differently by location. Ball attachments produced the highest levels of retention and stability, followed by Locator (pink), O-Ring, and ERA (orange).

Conclusions. The retention and stability of a 2-implant simulated overdenture prosthesis is significantly affected by implant location (*P*=.01) and abutment type (*P*=.01). (J Prosthet Dent 2014;112:515-521)

Clinical Implications

Retention and stability of an intimately adapted 2-implant-retained mandibular overdenture may be improved by implants located distally, for example, in the first or second premolar region, rather than in the incisor or canine region. Ball, Locator, O-ring, and ERA attachments all yielded acceptable retentive values in the canine, premolar, and molar locations.

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Tooth loss is a multifactorial and often complex interaction of multiple comorbidities, which, if left unresolved, may progress to complete edentulism.[1] Although the rate of edentulism has been decreasing throughout the past 3 decades, the increase in world population has resulted in a rise in the total number of persons who are edentulous[2] and a growing demand for treatment. Overdentures have been advocated as a means of preserving the structures associated with mandibular denture support that may augment retention and stability.[3,4] Early reports and techniques tended to direct prosthetic treatment to the availability of the remaining teeth and root forms that could support and retain a prosthesis.[5-7] In the mandibular arch, the canines and premolars have been reported as the most resilient teeth and usually are the last to be lost.[6,7] As a result, the authors developed recommendations on abutment selection, distribution, and support criteria for overdentures.[8]

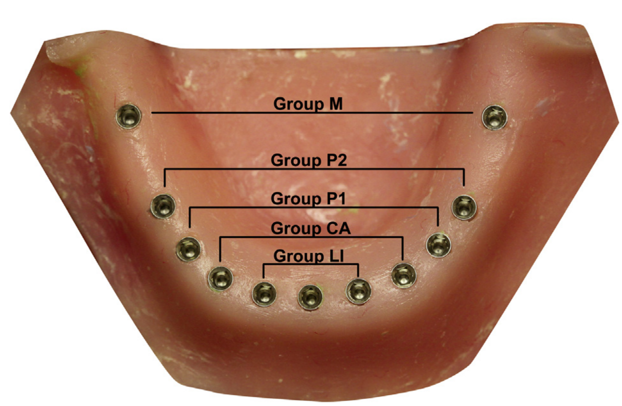
The treatment of the edentulous mandible with the 2-implant-retained overdenture is a well-accepted treatment with long-term successful outcomes for prostheses and implants.[9,10] The prosthetic and attachment system factors of successful mandibular implant overdentures have been extensively reported in the literature.[11,12] As ridge resorption occurs, the mandibular anatomy may affect available implant locations,[13,14] which, in turn, may affect surgical planning and treatment outcomes.[15-17] Furthermore, abutment and retention location affect the treatment outcomes and biomechanical effects of prosthesis design.[18,19] Missing from these discussions, however, is an analysis of the effect of implant location on these prosthetic and surgical factors.

The retention of commercially available stud attachment systems has been the subject of many in vitro studies.[20-29] Although most of these studies assumed a 2 implant model that approximated the location of the mandibular canines, none have evaluated the in vitro retention of prostheses outside the areas of the mandibular canines. Retention and stability in regard to the number of implants for implant-retained and supported overdentures have both been measured[30-34]; however, the studies focused their attention on the retention, release, and stability of the types and forms of attachments. The impact of the location of implants and attachment systems on the retention and stability of overdentures has been alluded to in several studies.[7,11,34-45] Information regarding implant position and its effect on the retention and stability of mandibular implant overdentures is limited in currently available studies. The purpose of this investigation was to provide an in vitro evaluation of the effect of implant location on the magnitude of force required to dislodge a simulated 2-implant-retained overdenture prosthesis. The null hypothesis of this study was that implant location does not affect the forces required to dislodge a simulated 2-implant-retained overdenture prosthesis.

MATERIAL AND METHODS

An experiment was carried out by using a model that simulated a mandibular edentulous ridge with dental implants in positions that approximated the tooth positions in the natural dentition. A cobalt-chromium cast framework with 3 loops, acrylic resin inside the housing, and chains attached to a universal testing machine was used to measure the peak load (N) required to disconnect an attachment. Four different types of attachments were used in 5 positions on the model in a sequence of 2 implants at a time, and vertical, oblique, and anteroposterior dislodging forces were measured. A model that simulates a mandibular edentulous ridge (Zimmer Institute) was selected, and tapered screw vent implants (Zimmer Dental) were placed bilaterally in positions based on tooth arrangements (lateral incisor, canine, first premolar, second premolar, molar) (Fig. 1). Implants were placed with a surveyor (Ney Surveyor; Dentsply Intl) and a drill press (Paraskop M; BEGO) to ensure parallelism among the components.

Four commercially available attachment designs were evaluated: ERA orange (Sterngold), O-Ring Saturno standard (Zest Anchors), Locator pink (Zest Anchors), and Ball clear (Zimmer Dental). (Fig. 2) Two patrix portions of each attachment system were placed into locations that approximated natural tooth positions: group LI (lateral incisors), group CA (canines), group P1 (first premolars), group P2 (second premolars), group M (molars) (Fig. 1). Matrix housing portions of the attachment system were attached to the prosthesis with a bis-acryl material (ERA PickUp; Sterngold), according to the manufacturer's guidelines.



1 Acrylic resin test model with dental implants separated into 5 designated groups (implant location): group LI (lateral incisors), group CA (canines), group P1 (first premolars), group P2 (second premolars), group M (molars).

2 Attachments evaluated from left to right: ERA orange, Saturno O-Ring standard, Locator pink, Ball clear.

3 Experimental test model attached to universal testing machine base with clamps; washer, eye bolts, and pivoting joint assembly allowed for adjustment of chain slack and for correction of pivoting throughout experimentation.

A cast cobalt-chromium framework (NobilStar; Nobilium) was fabricated to act as a denture base throughout treatment. Three withdrawal loops were incorporated into the framework, 1 approximated the central incisor and the other 2 approximated the first molar. Acrylic resin (Dentsply Intl) was incorporated in the intaglio and facial-lingual surfaces of the framework to allow for the attachment of the matrix portions. The metal framework remained constant throughout testing. A universal testing machine (model 5500R; Instron) was used to test the forces required to dislodge the prosthesis in various directions, as previously described.[21-23,27,34] The use of 3 chains (6.2 mm), eye bolts (no. 8-32), and a pivoting joint allowed for the precise adjustment of the chains and to ensure that all chains were pulling evenly throughout the experiment (Fig. 3). The testing machine instrumentation was calibrated and balanced by using the testing machine's computer algorithm to account for the weight of the simulated prosthesis and chains. Three chains were attached to the prosthesis, and a 3-point vertical pull was used to determine the retention against a vertically directed dislodging force parallel to the path of insertion. Two chains were attached to provide para-axial, oblique dislodging forces, 1 in the incisor region with alternating chains either in the right or the left molar region. To test the posterior dislodging forces, the incisor chain was removed, and the remaining 2 chains were attached in the molar regions.

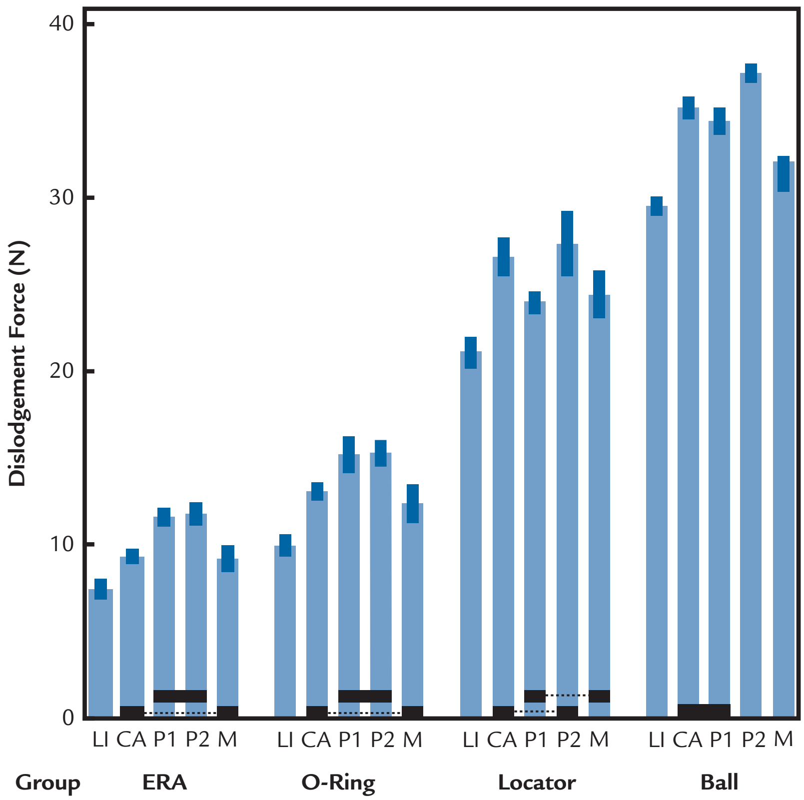
The chains were adjusted to reduce slack, and force was applied until the prosthesis separated. The dislodging force applied resulted in a peak load measurement (N) that was graphically recorded on a computer with analytical software (Partner; Instron). The horizontal load frame and load cell was set at a constant crosshead speed of 50.8 mm/min, previously described as the approximate speed of movement of a denture from the ridge during mastication.[21,27,34]

For each system and/or group, 10 measurements were made of the peak dislodging forces. The means were calculated, and differences among the systems, directions, and groups were identified with a repeated measured ANOVA (α=.05). A power analysis was performed, and the smallest differences between means were determined. The oblique dislodging forces between alternating right and left sides were averaged to report a single mean value for the oblique dislodging force (N). For the differences observed between measurements, the Bonferroni post hoc method at the 5% level of significance was used to determine the location and magnitude of significant differences (SAS v9.2; SAS Institute).

RESULTS

The results are presented in Figures 4 to 6. The values of the peak load to dislodgement ranged from 4.84 to 37.17 N for all groups. In the vertically directed test, the means of the peak load ranged from 7.43 to 37.17 N. (Fig. 4). The specimens tested in group LI showed the lowest average forces to dislodgement and the specimens in group P2 showed the highest average forces to dislodgement (group P2 > group P1 = group CA > group M > group LI). The means between the groups were statistically significant (P=.01) for all groups except between groups CA and P1 (P=.30). Statistically significant differences were found among the systems (P=.01); Ball attachments had the highest mean retentive value and ERA orange had the lowest mean retentive value (Ball clear > Locator pink > O-Ring standard > ERA orange).

In the obliquely directed test, the means of the peak load ranged from 4.84 to 20.23 N (Fig. 5). The specimens tested in group LI showed the lowest average forces to dislodgement, and the specimens in group P1 showed the



4 Mean values of vertical dislodgment force (N) of specimens and error bars, which signify 95% confidence intervals based on observed within-group standard deviation; means linked by horizontal bars were not found to be statistically significantly different (P>.05).

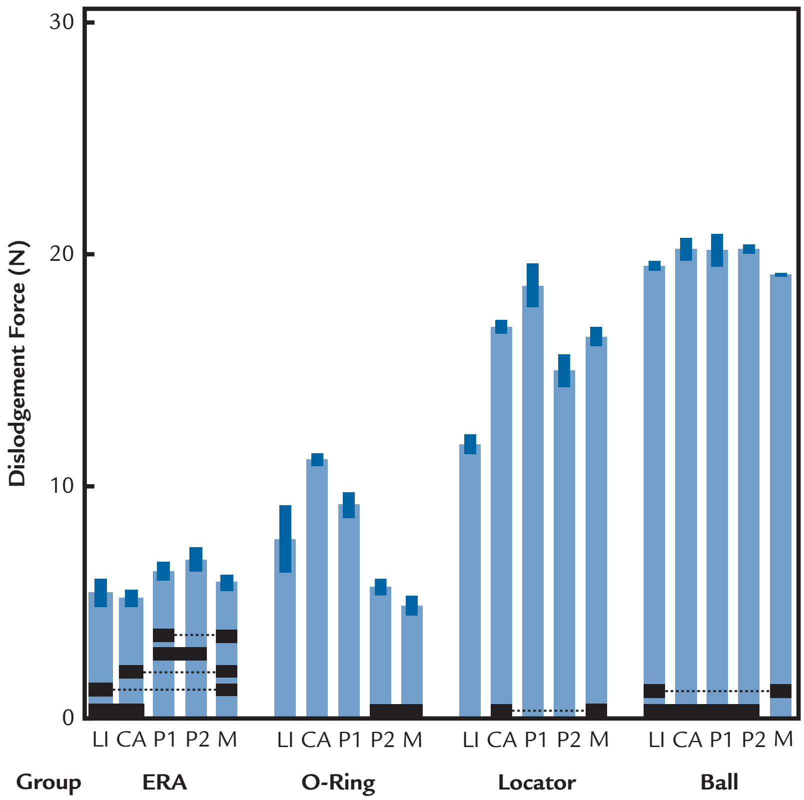
highest average forces to dislodgement (group P1 > group CA > group P2 > group M = group LI). The means between the groups were statistically significant (P=.01) for all groups except between groups LI and M (P=.13). Ball attachments had the highest mean retentive value, and ERA had the lowest mean retentive value (Ball clear > Locator pink > O-Ring standard > ERA orange). Statistically significant differences were found between the attachment systems in all groups (P=.01), except the following comparisons: Ball group P1 versus Locator group P1 (P=.054), ERA group P2 versus O-Ring group P2 (P=.21), and ERA group M versus O-Ring group M (P=.64).

In the anteroposteriorly directed test, the means of peak load ranged from 5.92 to 31.28 N (Fig. 6) The specimens tested in group LI showed the lowest force to dislodgement and the specimens in group M showed the highest force to dislodgement (group M > group P2 > group P1 > group CA > group LI). The means among groups were statistically significant (P=.01). Statistically significant differences were found among the systems (P=.01); Ball attachments had the highest mean retentive value, and ERA had the lowest mean retentive value (Ball clear > Locator pink > O-Ring standard > ERA orange). All attachment systems showed statistically that the highest anteroposterior values were in group M and the lowest were in group LI (P=.01).

DISCUSSION

The present in vitro study investigated the effect of implant position on the retention and stability of a simulated prosthesis. The results of this study indicated that implant location affects the in vitro retention and stability of an implant overdenture, thus rejecting the null hypothesis. Retention is a major concern to patients, and one of the greatest challenges that faces clinicians is in providing prosthetic treatment that provides the retention patients want.[5-8] Although retention and its effect on overdenture prosthetic factors are related, studies have not established a consensus regarding what is considered sufficient retention. An in vitro study evaluated several different types of attachments and reported that retention strengths between 5 and 8 N may be sufficient for implant-retained overdentures during long-term function.[29] A prospective cross-over clinical study evaluated patient satisfaction and the correlation to force values, and determined that approximately 10 N of retention was effective.[3] The previously mentioned measured clinical factors related to prosthetic success and acceptance by the patients at several time points throughout treatment; patients preferred the attachment that provided greater retention. Based on these 2 established studies, an effective retentive force may be between 8 and 10 N. When in place in the oral environment, mandibular implant overdentures move in complex ways, typically in 6 directions: occlusal, gingival, mesial, distal, facial, and lingual. Although true unidirectional dislodging forces rarely occur in clinical scenarios, a directional pull testing is an effective way of measuring the retention and stability of a prosthesis during in vitro laboratory evaluation.[27-34]

The current in vitro study revealed that vertical retention increases with distal implant location up to the second premolar. In the vertical pull tests, the incisor region showed the lowest mean retentive values, which steadily increased as the implant position was moved distally. The highest values were in the second premolar region, and the values dropped when the implants moved into the molar location. Regarding vertically directed forces, retentive values would not be expected to change when the implant location was modified. However, during the 3-point chain pull tests, some anteroposterior movement occurred. Although this may have affected the reported force values, the method



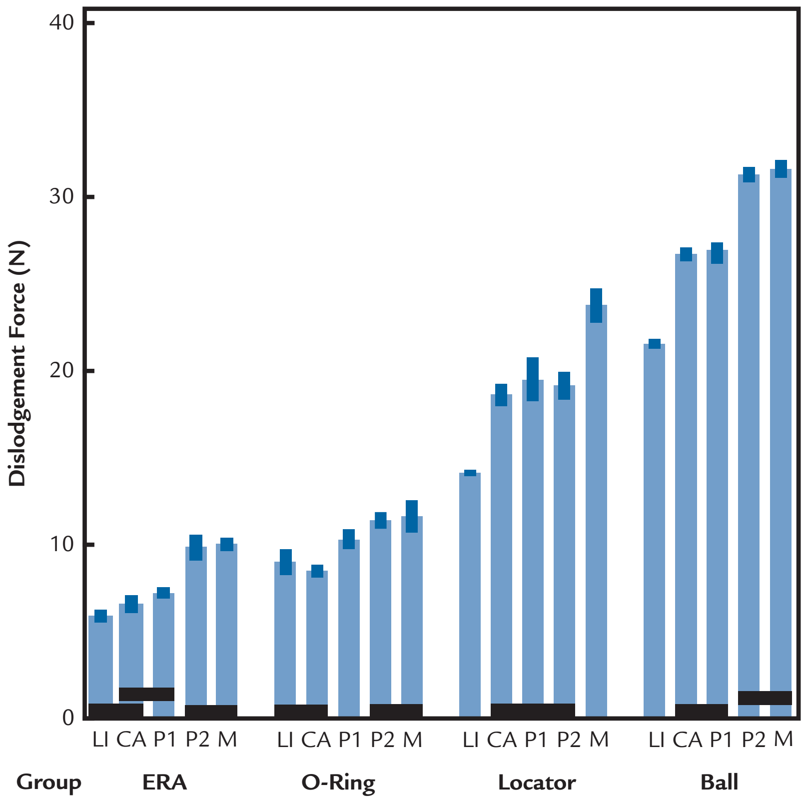
5 Mean values of oblique dislodgment force (N) of specimens and error bars, which signify 95% confidence intervals based on observed within-group standard deviation; means linked by horizontal bars were not found to be statistically significantly different (P>.05).

used better simulates the movement of overdentures in clinical situations rather than using a rigid design. The type of attachment affects the influence of vertically applied forces. ERA and O-Ring attachments showed similar trends to each other. In these attachment types, the highest level of force was required to dislodge the implants located at the first and second premolar locations, and the lowest at the incisor location. In the Locator and Ball attachment systems, the highest values were located at the second premolar location, and a significant drop in retention occurred when moving implants from the canine to the first premolar location, followed by a significant rise in retention at the second premolar location.

Horizontal displacement forces increase with distal implant location up to the first premolar. In the oblique pull tests, the results varied considerably, depending on the type of attachment tested, and the standard deviation between measurements was high. The ERA and Ball attachments showed little variation between the incisor and molar positions, and, although some results were statistically significant among the groups, the differences among them were small. The O-Ring attachment showed a substantial decrease in dislodging forces in the second premolar and molar implant positions, which indicated that the incisor positioning of O-Ring attachments is better for horizontal stability than second premolar or molar implant positions. The horizontal stability of locator attachments was affected by implant positioning, and the first premolar sites had the highest values. The results illustrate that, with ERA and Ball attachments, implant location has a minor effect on horizontal stability, whereas for O-Ring and Locator attachments, horizontal stability is significantly affected.

The dislodging forces that act on overdentures are related to patient satisfaction with the prosthetic treatment.[32] The stability of an overdenture prosthesis in an anteroposterior direction leads to increased satisfaction in incising hard foods such as carrots and apples.[3,10] In the present study, anteroposterior chain pulls were evaluated as an indirect method of determining the effect of implant location on posterior dislodging forces; this method has been reported previously in the literature.[21,27,34] In all the attachment systems tested, a general trend was determined that an increased resistance to dislodgment occurred as the implant location was moved distally. This result was statistically significant for all groups; however, variation was noted when analyzing the attachment systems separately. The ERA and O-Ring attachments showed moderate changes between incisor and canine locations, but the value was not significant. The Locator and Ball attachment systems showed that, between the canine and first premolar regions, similar anteroposterior resistance values can be expected. Interestingly, all the systems except the Locator group showed no significant increase in resistance when moving the implant location from the second premolar to the molar regions. Resistance values for all systems except for the O-Ring were not significantly different between the canine and first premolar regions.

The variation between attachment systems is of great interest in regard to the effect of implant position on retention and stability. The present study showed that the attachment type affects retention and stability differently by location. For example, in the vertical retention test, the ERA and O-Ring attachments showed comparable behavior when moving implant location but were dissimilar to that of the Locator and Ball attachments. Furthermore, in the anteroposterior dislodgement test, the ERA, O-Ring, and Ball attachments showed comparable behavior but were dissimilar to Locator attachments. The results of this study illustrate that attachment systems respond in different ways, depending on their location in the edentulous arch. Therefore, if 8 to 10 N of force is used for the retention of a prosthesis,



6 Mean values of anteroposterior dislodgment force (N) of specimens and error bars, which signify 95% confidence intervals based on observed within-group standard deviation; means linked by horizontal bars were not found to be statistically significantly different ($P>.05$).

then an ERA attachment would not provide sufficient vertical retention in the incisor region but would in the canine and premolar areas. Furthermore, when considering anteroposterior dislodging forces, the ERA and O-Ring attachments would provide sufficient retention in the first and second premolar location but not in the incisor or canine locations. When the force values reported in this study are evaluated, the interaction between the attachment systems and the implant location is statistically significant.

In the present study, dislodging forces generally increased as implants were spaced farther apart on the test model. The results of this study were similar to those found in previous studies in regard to interimplant distance.[41,42] Furthermore, the investigators of these studies found that the effect of interimplant spacing was especially evident with the ball-type attachments compared with other attachments. The magnitude of force values measured with ball attachments steadily increased from group LI through M in anteroposterior and vertical tests. These results indicate that interimplant spacing had a significant effect on all the attachment systems tested, with generally higher retention with greater interimplant spacing.

The results of this in vitro study indicate that implants placed at the first and second premolar sites may be a more-effective location for implant-retained overdenture therapy compared with the incisor or canine sites. However, these findings do not consider the clinical reality of managing patients who are edentulous. The testing performed is limited by specific conditions and methods that do not completely replicate the clinical situation. The clinical reality of the implant overdenture is much more complex than a laboratory setting can replicate. Furthermore, the findings of this study do not account for attachment wear, resiliency, and tissue effects. Although this in vitro analysis showed a statistical difference among the groups, long-term comparative prospective controlled studies are needed to reach agreement on an accepted treatment. Factors such as the type and location of implants placed, quality and quantity of bone, and type of superstructure should be part of these studies.

CONCLUSION

Within the limitations of this in vitro laboratory study, the following conclusions were made:

1. The interactions between attachment systems, direction of force, and implant location were statistically significant ($P=.01$).
2. The vertical retention and horizontal stability of a simulated overdenture prosthesis increased with distal implant location up to the second premolar.
3. Anteroposterior stability increased when the implant location was placed distally.
4. Attachment type affects retention and stability differently by location; Ball and Locator attachments reported the highest levels of retention and stability.
5. Interimplant distance had a significant effect on the retention and stability of a simulated overdenture prosthesis ($P=.01$).
6. The retention and stability of a 2-implant simulated overdenture prosthesis is significantly affected by implant location ($P=.01$).

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