Anatomic and Biomechanical Study of the Biceps Vinculum, a Structure Within the Biceps Sheath

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Purpose: To evaluate the anatomic, biomechanical, and histologic properties of the biceps vinculum and its potential role as a restraint to distal migration of the biceps after tenotomy. **Methods:** Eight human shoulders were dissected to define the anatomic parameters of the biceps vinculum. Histologic studies were performed by sectioning through the vinculum-tendon attachment and performing H&E staining. The strength of the vinculum was tested biomechanically after sectioning the biceps origin and applying a uniaxial tension at a rate of 1 mm/s until failure. **Results:** With regard to anatomy, the vinculum was present in all specimens, attached to the biceps tendon and proximal humerus. Excursion testing showed that the vinculum prevented the biceps origin from migrating distal to the groove entrance. The mean dimensions of the structures and excursion were as follows: biceps origin to vinculum, 43.4 mm; vinculum width on biceps side, 46.2 mm; vinculum width on bone side, 69.3 mm; length of tendon with proximal pull, 42.6 mm; and length of tendon with distal pull, 2.25 mm. With regard to histology, the membranous tissue of the biceps vinculum consisted of loose soft tissue with fat, arteries, and veins. The vinculum was seen to loosely attach to the biceps tendon and more intimately attach to the periosteal/bone side. With regard to biomechanical testing, the maximum force to failure of the vinculum was variable, ranging from 17.4 N to 227.6 N, with a mean value of 102.7 $\pm$ 76 N. **Conclusions:** The biceps vinculum was a consistent membranous structure intimately associated with the biceps tendon and attached to the proximal humerus. After tenotomy at the biceps origin, the vinculum prevented distal migration of the proximal biceps tendon past the groove entrance in all specimens. Biomechanical testing showed that the vinculum provided variable resistance to distal pull. **Clinical Relevance:** The properties described may help to explain why biceps tenotomy does not routinely result in a Popeye biceps deformity. **Key Words:** Biceps—Tenotomy—Popeye—Tendon.

Shoulder pain due to biceps pathology has been successfully treated with arthroscopic biceps tenotomy or tenodesis.[1-7] Recent controversy exists about which treatment method yields a more favorable outcome. Some authors advocate biceps tenodesis, suggesting that it helps to maintain strength and avoid complications of the Popeye biceps deformity.[1,3,8,9] A tenodesis secures the proximal biceps stump into the proximal humerus, allowing for healing of tendon to bone.

Those authors who advocate biceps tenotomy believe that this procedure affords the same benefits as a tenodesis without the morbidity of hardware and an extra incision.[4,5] The concern about performing a tenotomy is that there is no restraint to distal pull, thus increasing the risk of a Popeye biceps deformity developing. Some authors have reported persistent soreness of the biceps after a tenotomy.[5,10]

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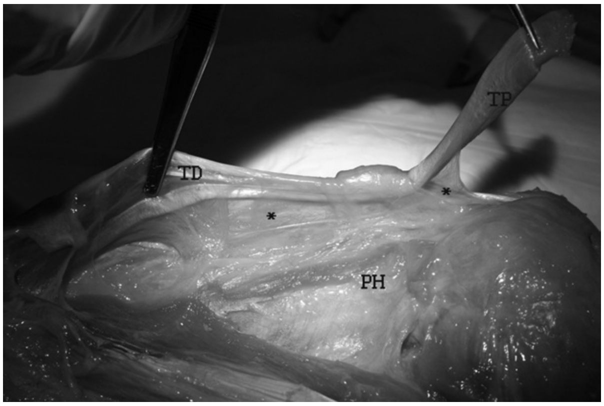

FIGURE 1. Biceps vinculum (asterisks) and its attachments to biceps tendon distally (TD), biceps tendon proximally (TP), and proximal humerus (PH).

The reported incidence of a Popeye deformity after biceps tenotomy has been variable. Boileau et al.[2] reported a 63% incidence after arthroscopic biceps tenotomy. Gill et al.[4] reported a 3% incidence of cosmetic deformity.

Some authors have mentioned that the biceps tendon can scar in the groove after a tenotomy.[7] However, little is known about how a tenotomized tendon remains in the groove. Suggestions have been made that hypertrophy of the tendon allows it to become "stuck" in the groove.[7,11,12]

This article describes the presence of a biceps vinculum within the sheath surrounding the long head of the biceps tendon (LHBT). The anatomy of this structure was examined, and its histologic and biomechanical properties were investigated. The purpose of this study was to investigate this structure and its role as a secondary restraint to distal pull of the biceps tendon after biceps tenotomy. We hypothesized that the biceps vinculum was a consistent component of the biceps sheath that can prevent distal migration of the biceps tendon after a tenotomy because of its direct attachments both to the bone of the proximal humerus and to the biceps tendon.

METHODS

An anatomic dissection, histologic study, and biomechanical testing of the biceps vinculum were performed by use of 15 cadaveric shoulders.

Anatomic Dissection

Eight cadaveric shoulders were used for the anatomic dissection phase of this study. The mean age of the specimens was 75 years (range, 61 to 83 years). Dissection was performed in a similar fashion for all specimens. The outer skin and subcutaneous tissue were removed. The deltoid muscle was detached from the acromion and clavicle and reflected to expose the rotator cuff. Care was taken not to damage any portion of the biceps sheath while performing dissection. First, an incision was made in the rotator interval and through the transverse humeral ligament to expose the biceps tendon. Without any further dissection, the biceps tendon was lifted away from the proximal humerus and sheath, showing the biceps vinculum and its attachments both to the biceps tendon and to the proximal humerus (Fig 1).

Measurements were then taken with a digital caliper (Mitutoyo, Kawasaki, Japan). Measurement A was taken from the biceps origin to the most proximal portion of the vinculum attached to the biceps tendon (Fig 2). This was done before cutting of the proximal biceps tendon. The proximal biceps tendon was then incised at its origin on the superior labrum. Measurements B (width of the vinculum on the tendon side) and C (width of the vinculum on the bone side) were then taken, defining the attachments of the vinculum on the tendon side and bone side, respectively. Means and SDs were calculated based on the 8 shoulders by use of SPSS software for Windows (SPSS, Chicago, IL).

Excursion was evaluated in a qualitative fashion on the dissected specimens under a manually applied tensile force to the limits of the vinculum. The biceps tendon was pulled proximally and then distally to the limits of movement (Fig 3). A measurement of proximal excursion (D) was taken from the entrance of the bicipital groove at the articular surface of the proximal humerus to the proximal origin of the biceps tendon. The tendon was pulled proximally until the vinculum was under tension, limiting further movement. A measurement of distal excursion (E) was then taken. A distal pull was performed in the same fashion, until the vinculum was under tension preventing further distal migration. Measurement E was the distance between the articular surface of the proximal humerus at the entrance to the bicipital groove to the proximal origin of the biceps tendon (Fig 2).

Histologic Study

Two of the shoulders used during the anatomic study were used for the histologic phase. Distally, the biceps was cut several centimeters distal to the vinculum. The vinculum was then detached from the prox-

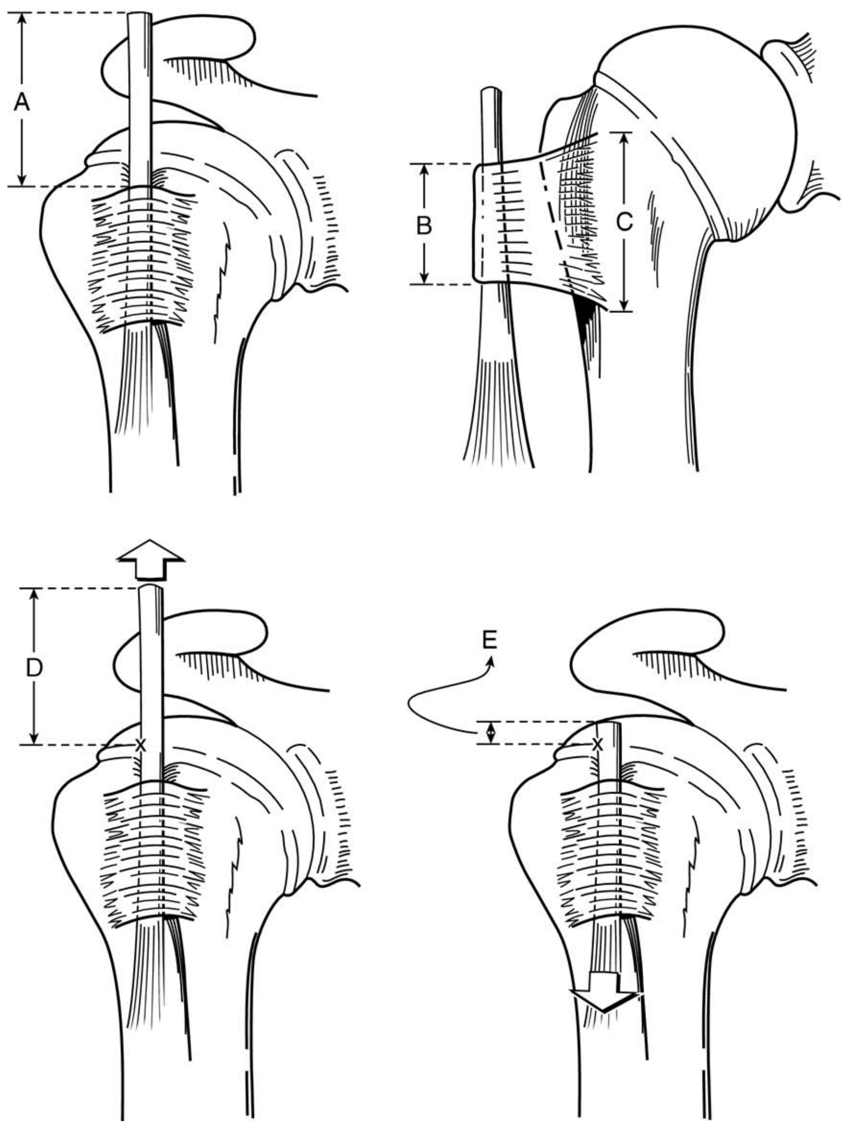

FIGURE 2. Measurements taken. (A) Biceps origin to vinculum (i.e., from the most proximal portion of the biceps tendon [attachment at the superior labrum] to the most proximal portion of the vinculum); (B) vinculum width on biceps side; (C) vinculum width on bone side (i.e., the width of the vinculum at its attachment to bone); and excursion proximally (D) and distally (E), measured from the articular edge at the entrance of the biceps groove to the most proximal portion of the biceps tendon.

imal humerus, preserving its attachments to the periosteum. Proximally, the vinculum was attached to the rotator interval tissue. This attachment was preserved by cutting around the attachment and including rotator interval tissue in the specimen (Fig 4). The specimen was then sectioned, fixed in formalin, and embedded in paraffin. Six-micrometer slices were cut by use of a Leica microtome (Leica Microsystems, Wetzlar, Germany) and stained with H&E. Slides were examined with an Olympus BH2 microscope (Olympus, Center Valley, PA).

Biomechanical Testing

Seven cadaveric shoulders were used for the biomechanical phase. These specimens were not used in the anatomic study, ensuring that the structures surrounding the biceps tendon and sheath were undamaged.

In all specimens the proximal biceps origin was detached at its connection with the superior labrum, and the structures around the biceps sheath were preserved. Specimens were tested on an MTS 858 Bionix mechanical testing machine by use of a 2-kN load cell

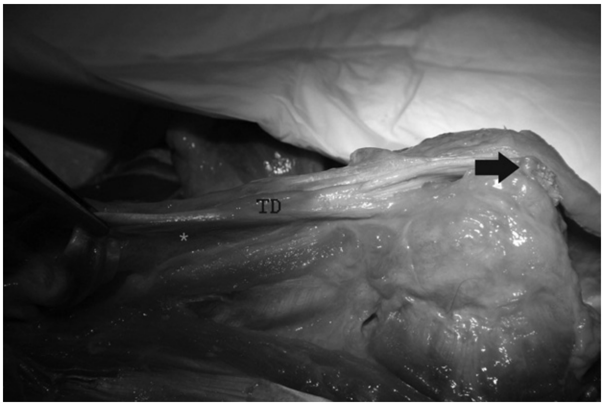

FIGURE 3. Distal excursion is shown with tension placed on the tendon distal to the vinculum (white asterisk). The biceps origin is seen stopping at the entrance of the biceps groove (arrow). (TD, biceps tendon.)

(MTS Systems, Eden Prairie, MN). The humerus was secured by placing 2 drill holes in the bone and attaching them to an apparatus that was secured to the MTS machine. The biceps tendon was clamped distally in a brass grip and frozen with liquid carbon dioxide for a maximum of 2 minutes.[13] A uniaxial tension (distal pull of biceps tendon) was applied at a rate of 1 mm/s until failure was observed. Failure was defined as a sudden decrease in measured force during tensile loading. Load and displacement were recorded at a rate of 20 Hz throughout the test. The mean and SD for the peak load, stiffness in the linear region of the load-versus-displacement curve, and elongation at failure were summarized by use of SPSS software for Windows.

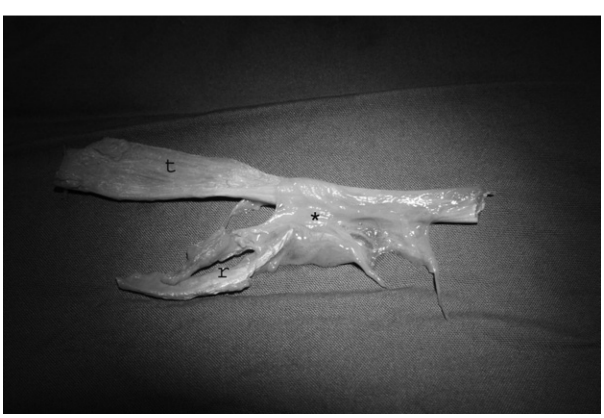

FIGURE 4. Attachment of the vinculum (asterisk) to the biceps tendon (t) is shown. The vinculum has been detached from the humerus, leaving attachments to the periosteum and the rotator interval tissue (r).

RESULTS

Anatomic Study

All specimens had a similar presence of a biceps vinculum that surrounded the biceps tendon and inserted into the proximal humerus. The vinculum was a membranous structure, with attachments at the rotator interval, biceps tendon, and bone of the proximal humerus at the biceps groove. After sectioning of the transverse humeral ligament, excursion testing showed that the vinculum was responsible for restraining the biceps with a proximal or distal pull. Mean dimensions of the structures and excursion are presented in Table 1. With distal excursion testing, the biceps origin remained proximal to the groove entrance in all specimens.

Histologic Study

The membranous tissue of the biceps vinculum consisted of loose soft tissue including fat, arteries, and veins. Synovial tissue was identified within the sample. The vinculum was seen to loosely attach to the biceps tendon and more intimately attach to the periosteal/bone side (Fig 5).

Biomechanical Study

The force to failure of the vinculum was variable, ranging from 17.4 N to 227.6 N, with a mean value of 102.7 ± 76 N. In addition, stiffness and elongation at failure were also variable, at 11.6 ± 8.5 N/mm and 17.6 ± 15.6 mm, respectively (Table 2).

DISCUSSION

The vinculum described in the hand literature is a structure intimately associated with the flexor digitorum profundus (FDP).[14-16] Authors have shown that this vinculum was an essential structure, providing nutrition to the tendon.[15,16] Reports have described a

TABLE 1. *Measurements of Anatomic Structures and Excursion of Biceps Vinculum*

Measurement	Mean (mm)	SD	Range (mm)
A: Biceps origin to vinculum	43.4	10.27	25.6-56.6
B: Vinculum width on biceps side	46.2	10.08	35.7-59.4
C: Vinculum width on bone side	69.3	15.98	52-92.3
D: Length of tendon with proximal pull	42.6	8.71	31.7-53.8
E: Length of tendon with distal pull	2.25	3.00	0-8.33

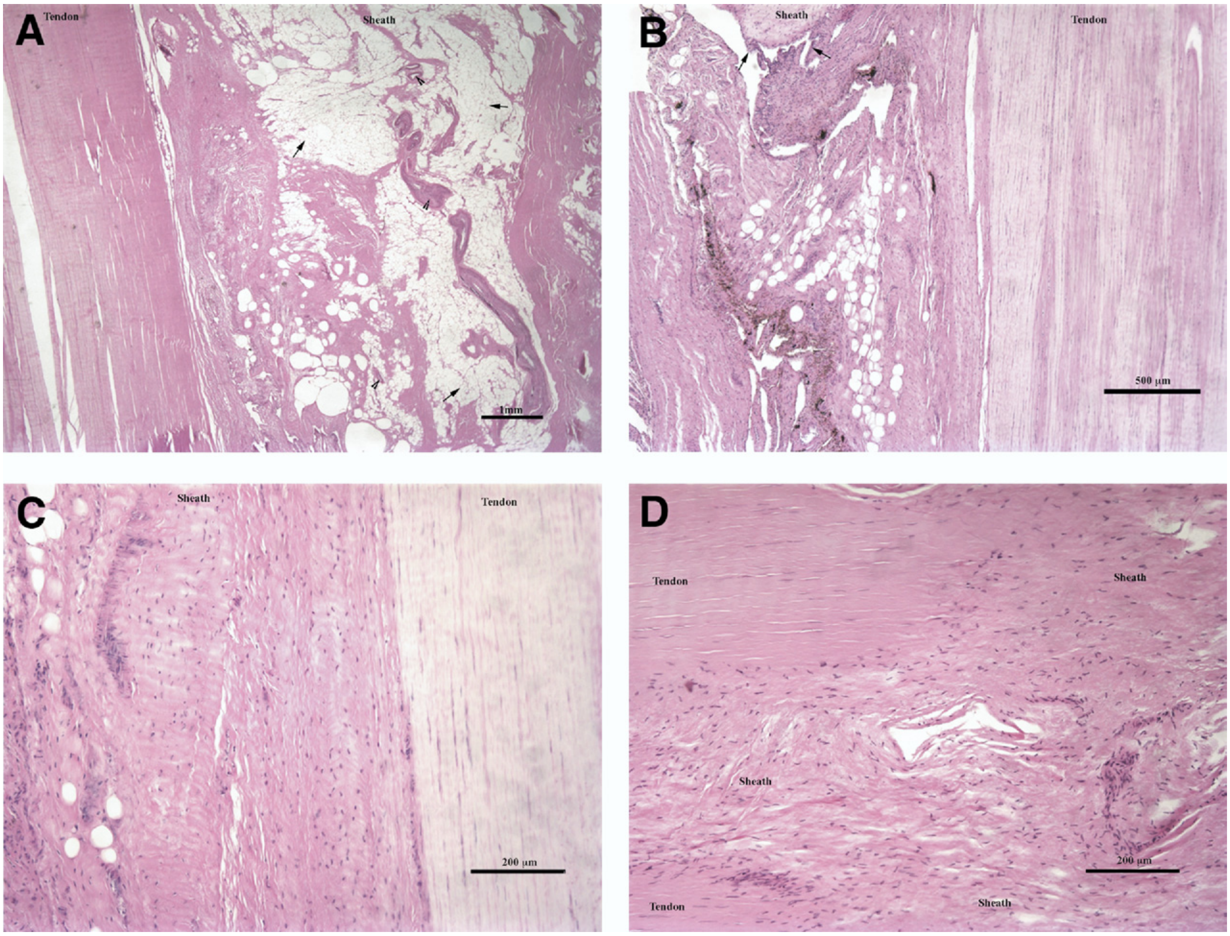

FIGURE 5. H&E staining of biceps vinculum and biceps tendon. Under a microscope at objective magnification ×1.25, (A) the biceps vinculum is composed of loose fibrous tissue, adipose tissue (arrows), and blood vessels (arrowheads); (B) at the proximal end of the biceps vinculum, synovial lining cells are noted (arrows). (C, D) Tendon-vinculum interface at objective magnification ×10. A smooth transformation from tenocyte to fibroblast horizontally (C) and vertically (D) is seen.

role for the vinculum in preventing proximal pull after a distal FDP rupture.[14] The vinculum can remain attached after FDP rupture and facilitate motion of the distal interphalangeal and proximal interphalangeal joints.[17] We believe that the structure described in this study behaved similarly to the vinculum of the FDP. The vinculum of the biceps tendon, similar to the vinculum of the FDP tendon, can prevent migration because of its intimate attachment to tendon and bone.

This study described a similar structure in the LHBT. Histologic investigation showed blood vessels, suggesting a nutritional role for the biceps sheath. Attachments of the vinculum to the LHBT, rotator interval, and proximal humerus were also shown by anatomic and histologic study. Biomechanical testing showed that the vinculum provided resistance to distal pull. The large variation in the measured properties reflected the variability in the cadaveric population as well as the potential normal anatomic variation.

After an atraumatic arthroscopic tenotomy, the presence of a vinculum may explain why a Popeye deformity is not always seen. Distal excursion measurements showed that after the tendon was cut at its origin and pulled distally, the proximal end consistently stopped at or near the articular surface, at the proximal entrance to the groove. If the vinculum remains intact postoperatively, holding the tendon within the biceps groove, it may scar in the groove during healing, thus avoiding a Popeye deformity.

Wolf et al.[18] performed a biomechanical study comparing the strength to distal pull after a tenotomy and after a tenodesis. The tenotomy portion of their study is similar to our setup. Interestingly, their mean value to pullout strength was comparable to our results

TABLE 2. *Maximum Force to Failure and Maximum Displacement for Each Tendon Tested*

	Maximum Force to Failure (N)	Stiffness (N/mm)	Maximum Elongation to Failure (mm)
Biceps Tendon No.			
1	159.61	26.11	7.97
2	227.57	19.67	36.56
3	97.50	11.10	11.21
4	17.39	2.27	9.16
5	129.75	9.40	43.86
6	23.71	3.61	7.01
7	63.34	9.28	7.71
Mean	102.7	11.6	17.6
SD	76.0	8.5	15.6

(110.7 N compared with 102.7 N). Although they mentioned possible reasons for strength to pullout as a result of entrapment and the presence of a vinculum, this structure was not described.

A recent study by Ahmad et al.[11] looked at the cross-sectional area of the proximal LHBT and its relationship to distal pullout strength. Diseased LHBTs with larger flattening had higher pullout strengths through the groove. The authors concluded that a cosmetic deformity may not result after biceps tenotomy in tendons with disease causing hypertrophy and flattening. Their study did not mention the presence of a biceps vinculum and its role in preventing distal migration of the biceps tendon.

We believe that with an atraumatic arthroscopic biceps tenotomy, which preserves the vinculum, a Popeye deformity is less likely to occur because of the presence of the biceps vinculum. In contrast, a traumatic proximal biceps rupture, which likely occurs more distal at the level of the vinculum and with greater force, is more likely to rupture the vinculum and allow distal migration of the tendon. Thus, in practice, after an arthroscopic biceps tenotomy, it may be appropriate to initially control load on the biceps muscle to less than 100 N to avoid tearing the biceps vinculum, thus keeping the tendon within the biceps groove, allowing it to scar in this position.

There were several limitations to this study. Because the vinculum is a mobile structure with a broad attachment, its origin on the tendon was not fixed, making it difficult to produce accurate measurements in the anatomic portion of this study. Nevertheless, the measurements taken helped to serve as a guide to understanding its attachments and position.

During the biomechanical testing, the groove was left intact to preserve all attachments of the vinculum to surrounding structures within the groove and to the rotator interval. It was believed that these attachments were important contributors to the strength of the construct. Keeping the groove intact, however, may have contributed to an elevated pullout strength as a result of constriction within the groove, especially if the tendon was enlarged because of disease.[11,12] This may help to explain the unusually high pullout strength of 1 of our specimens, as well as the highly variable results. Perhaps incising the outer transverse humeral ligament longitudinally would have decompressed the groove and eliminated resistance resulting from entrapment of an enlarged tendon while preserving vinculum attachments. Measurements of the proximal biceps tendon width, shape, and size, as well as groove dimensions or a description of the bony groove anatomy, may have helped to explain variations in biomechanical results.

Our sample size and aged population of cadavers were also limiting factors. Nevertheless, this study showed that the vinculum provided resistance to distal migration of the biceps tendon. Our variable results showed that the strength of this structure may vary between individuals, helping to explain why a Popeye biceps deformity does not consistently occur after tenotomy. A larger sample size and younger cadavers would help to provide a more clinically applicable value for the strength of the vinculum.

CONCLUSIONS

The biceps vinculum was a consistent membranous structure intimately associated with the biceps tendon and attached to the proximal humerus. After tenotomy at the biceps origin, the vinculum prevented distal migration of the proximal biceps tendon past the groove entrance in all specimens. Biomechanical testing showed that the vinculum provided variable resistance to distal pull.

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