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Morphometric Profile of Distal Biceps Tendon: A Cadaveric Approach

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SUMMARY

Background. The biceps muscle has proximal tendons that attach the muscle to the shoulder and one distal tendon that attaches at the elbow, called the distal biceps tendon. Normal morphometric measurements of the distal biceps tendon serve as an important landmark in restoring its biomechanical characteristics and anthropometric evaluation during surgical tendon repairs. Hence the objective of this study was to provide a detailed morphometric profile of the distal biceps tendon.
Methods. A total of 50 dissected adult limbs were studied. Out of the 50 limbs, 25 belonged to the right side while 25 were of the left side. The insertion pattern of the distal tendon was dissected and recorded. Total length, post aponeurotic length, the proximal, and distal thickness of the tendon was measured. Results were tabulated and correlated using SPSS.
Results. The mean length of the tendon was 8 cm. The proximal thickness varied from 2 to 4 cm, distal thickness from 1 to 3 cm. Tendon length and thickness showed no statistically significant differences between the right and left sides. However, significant correlation ($p < 0.001$) was observed between length and thickness, proximal and distal thickness of the tendon.
Conclusions. The variation in length, width of distal biceps footprints and radial tuberosities may be significant in the anatomical restoration of the distal biceps tendon. This morphometric study of distal biceps tendon would be beneficial to sports medicine physicians for diagnosis and treatment of biceps tendon tear and tendinopathy.

KEY WORDS

Anatomic biceps repair; biceps rupture; distal biceps tendon; radial tuberosity; tendinopathy; graft.

BACKGROUND

The biceps brachii is one of the key muscles in the flexor compartment of the arm. It has three attachments: long and short heads proximally and a distal tendon at insertion. The long head of the muscle has intracapsular origin and arises from the supraglenoid tubercle of the scapula, whereas the short head is attached to the coracoid process of the scapula. The distal tendon is attached to the posterior rough area on the radial tuberosity. From the medial border of the biceps tendon, a fibrous expansion known as bicipital aponeurosis is given out, which expands and gets attached to the posterior subcutaneous border of ulna (1). Biceps is the chief supinator of the forearm and contributes to flexion at the elbow joint along with the brachialis muscle.

Biceps brachii has been described as one of the muscles with the most frequent anatomic variations mainly concerning its proximal attachment. However, there is a little description regarding the normal and surgical anatomy of the Distal Biceps Tendon (DBT) or its anatomic variations in the literature. Anatomy textbooks provide an ambiguous description regarding the tendon's morphology and its insertion onto the radial tuberosity. Hence, the DBT anatomy is poorly understood. Despite the increase in clinical knowledge, the prevalence of complications following DBT repairs remains high (2). A precise understanding of the anatomy of the DBT and its relationship to the radial tuberosity is crucial to the successful surgical repair of a ruptured tendon (3). Thorough knowledge is essential to optimize the treatment outcome and to avoid complications when repairing a DBT.

During our literature review, we found that there is a paucity of data on the morphometric measurements of the DBT anatomy. Hence, the purpose of the present study was to determine the key morphology of the DBT (length, width, and thickness) in preserved cadaveric elbows from a surgical perspective.

MATERIALS AND METHODS

A total of 50 dissected upper limbs from formalin fixed, adult human cadavers was studied. Out of the 50 limbs, 25 belonged to the right side while 25 were of the left side. These limbs were obtained from the Department of Anatomy of our Medical College. The study meets the ethical standards of the journal (4). Diseased, fractured limbs were excluded from the study. After removal of skin, superficial and deep fascia, the muscles of the front of the arm were exposed, from origin to insertion. The long and short heads of biceps were dissected, and their relationships with each other and the proportions of each relating to the formation of the distal tendon were observed and recorded. The bicipital aponeurosis and the insertion pattern of the distal tendon were dissected and recorded. The various morphometric measurements of the tendon were measured using a ruler (accuracy, 0.5 mm). Following parameters were measured for each tendon: total length (from the musculotendinous junction of the muscle till its attachment to the radial tuberosity), post aponeurotic length (length of the tendon from bicipital aponeurosis till its insertion) (**figure 1**), proximal thickness (after bicipital aponeurosis), distal thickness (near its insertion) were measured and documented.

The distal thickness of the tendon was noted at the closest point of insertion to the radial tuberosity. These values were then tabulated statistically using SPSS v 16.0. Mann-Whitney U test was used for comparison of the parameters between two independent variables (right and left limb) to find whether there is a statistically significant difference in the morphometric measurements between the two groups. Spearman's correlation analysis was done to determine the level of positive correlation between the measured parameters of the DBT. P value less than 0.05 was considered statistically significant.

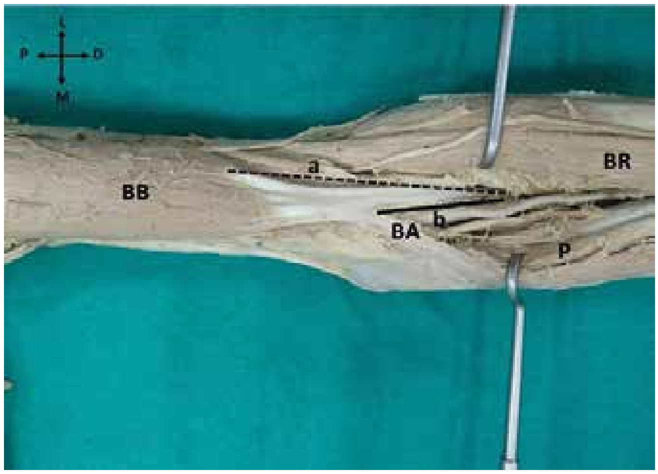

Figure 1. Figure showing the various measurements of the distal biceps tendon. a: total length of tendon, b: post aponeurotic length of tendon. BB: biceps brachii, BA: bicipital aponeurosis, P: pronator teres, BR: brachioradialis.

RESULTS

The mean values of the various morphometric measurements of the DBT are shown in **table I**.

DBT length and thickness did not show a statistically significant difference between the right and left side tendons. The average length of the tendon was 8 cm. However, the longest tendon was observed which measured 11.5 cm (**figure 2**) and the shortest tendon being 5.5 cm (**figure 3**). The proximal thickness of the tendon varied from 2 to 4 cm and the distal thickness from 1 to 3 cm. No statistically significant difference was observed in these measurements between the right and left limbs. In all elbows, the insertion of the DBT was situated on the posterior rim of the radial tuberosity of the radius. Further, we could not compare these measurements with other body measurements because all the limbs studied were isolated limbs.

Table I. Table showing the various morphometric measurements of the Distal Biceps Tendon (DBT). Values are expressed as mean ± SD.

	Total length (cm)	Post aponeurotic length (cm)	Proximal thickness (cm)	Distal thickness (cm)
Right limb (n=25)	8.1 ± 1.5	1.9 ± 0.8	3.1 ± 0.6	2.1 ± 0.5
Left limb (n=25)	8.6 ± 1.4	2.4 ± 0.7	3.0 ± 0.4	2.0 ± 0.3

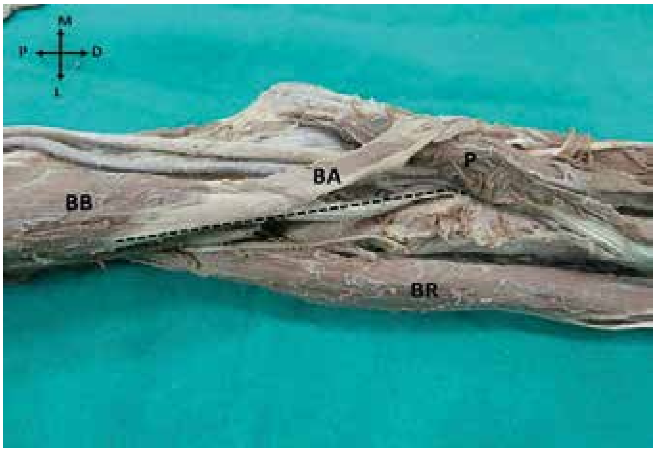

Figure 2. Figure showing a long distal biceps tendon (dotted line). BB: biceps brachii, BA: bicipital aponeurosis, P: pronator teres, BR: brachioradialis.

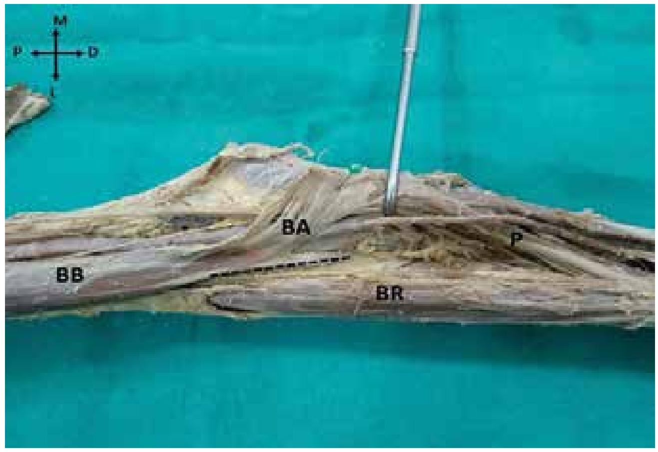

Figure 3. Figure showing a very short distal biceps tendon (dotted line). BB: biceps brachii, BA: bicipital aponeurosis, P: pronator teres, BR: brachioradialis.

Spearman's correlation analysis showed significant correlation between total length and post aponeurotic length (r=0.30, p=0.01). Slight correlation existed between the length of the tendon and its thickness (r=0.20) but was not statistically significant. Significant correlation was observed between the proximal and distal thickness of the tendon (r=0.5, $p < 0.001$).

Regarding the formation of the tendon, it was observed that in most of the specimens, the DBT was mainly formed from the elongation of the tendon of the long head. Medial fibers of short head contributed to the formation of bicipital aponeurosis, while lateral fibers contributed to the formation of DBT. However, in few specimens, the DBT was formed equally from both long and short heads (6 specimens). A Uniform pattern was observed in most of the specimens at the Musculotendinous Junction (MTJ). There were few specimens with straight (**figure 4**), 'U' shaped (**figure 5**), and 'V' shaped MTJ patterns (**figure 6**).

DISCUSSION

The purpose of this anatomic study was to focus on the morphometric profile of the distal biceps tendon. Variations in biceps brachii muscle have been observed mainly

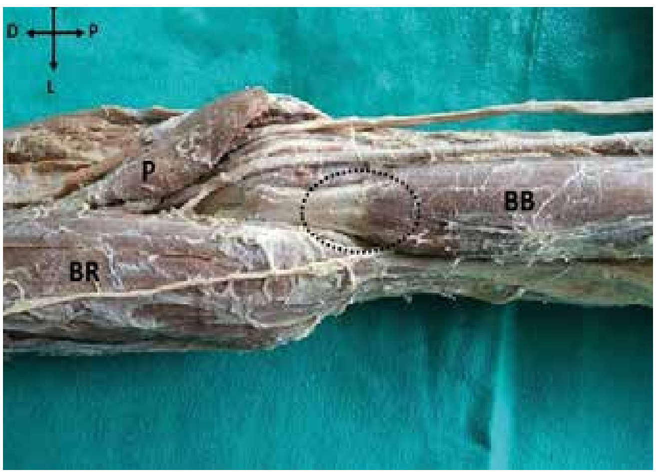

Figure 4. Figure showing a 'straight' musculotendinous junction (circle). BB: biceps brachii, BA: bicipital aponeurosis, P: pronator teres, BR: brachioradialis.

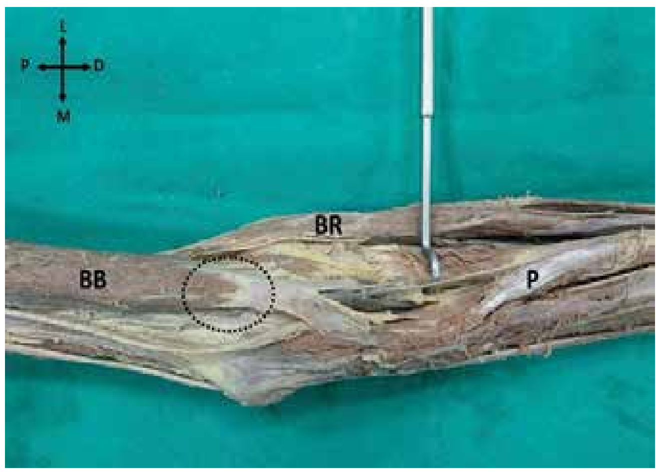

Figure 5. Figure showing a 'U shaped' musculotendinous junction (circle). BB: biceps brachii, BA: bicipital aponeurosis, P: pronator teres, BR: brachioradialis.

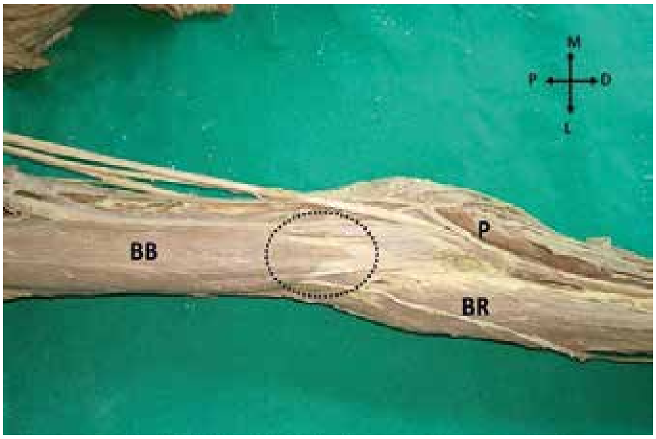

Figure 6. Figure showing a 'V shaped' musculotendinous junction (circle). BB: biceps brachii, BA: bicipital aponeurosis, P: pronator teres, BR: brachioradialis.

in the number of heads of origin (5). Variations or study on the biceps distal tendon at insertion are comparatively rare. Bryce stated that morphological variations associated with the biceps muscle could be due to its characters being attained late in the human phylum. According to him, phylogenetically, biceps was a single-headed muscle arising from the coracoid bone, which merged with brachialis at its insertion point at ulna and radius. Later, the second head of the biceps developed at the base of coracoid bone. This represents the long head of biceps muscle. As the development advanced, the radial head of insertion became the main insertion of the muscle, while the bicipital aponeurosis denoted the ulnar part of the muscle (6). The DBT is of clinical interest as it can show partial or complete tears that need to be distinguished from other naturally occurring anatomical variations (5). A clear understanding of these anatomic variations and its relationship with radial tuberosity is vital in planning and performing a distal biceps tendon repair and also in determining if a graft is required to supplement or replace the native tendon. There are studies done previously which describe the gross morphological anatomy of the distal biceps with main focus on distal footprint types and characteristics (7, 8). But these studies do not give the normal morphometric measurements of the tendon. There are very limited studies which focus on the cadaveric anatomy of the tendon. Cucca *et al.*, in their study, have reported the mean length of DBT as 5.7 cm (9), and Joshi *et al.*, have mentioned the length of the tendon as 7.5 cm in their study on North Indian population (10). The observed dimension of Joshi *et al.*, relates to the present study where the mean length of the tendon was measured as 8 cm. The authors opine that the difference in the findings is due to observational difference. Cucca *et al.*, considered the length of the tendon as visible length, wherein, they measured the tendon from the point of muscle fiber termination to its insertion. In contrast, Joshi *et al.*, have considered the length as the maximum visible length of the tendon, in which, the tendon was measured from the point of its beginning to its insertion on the radial tuberosity. In the present study, the technique used in the latter study was followed and the maximum visible length of the tendon was measured. We also noted the post aponeurotic length (length of DBT from bicipital aponeurosis to its insertion) and thickness of the tendon at two points (before insertion, at insertion) which would be beneficial for graft selection as a more accurate representation could be obtained by taking the average of multiple points of the tendon. Kulshreshtha *et al.*, examined the width and thickness of the DBT at the antecubital fossa in 74 cadaveric arms but did not measure the tendon length (11). The values of proximal and distal thickness of the tendon (3.1 cm and 2.1 cm, respectively) noted in the present study was in range with the previous studies (11, 12). In the present study, significant correlation between the lengths and thickness of the tendon was observed, which indicates that the morphometric measurements are interrelated. Thinner tendons are more susceptible to the risk of tendinopathy and exhibit a higher tendency of rupture when compared to thicker tendons.

Injury to the DBT at its insertion at radial tuberosity is the most common tendinous injury at the elbow (13). Other injuries of DBT include, tearing of the musculotendinous junction and rupture of the tendon itself. Precise understanding of the DBT anatomy and biomechanics in the past years has greatly enhanced a surgeons ability to advise treatment options and treat patients with ruptured DBT (14). Gilcreest has done a comprehensive study regarding the injuries of the entire biceps brachii from origin to insertion. His study of over 100 cases shows that 6 of the cases were of the DBT injuries. Of those, 3 were complete avulsions of the tendon at the point of insertion, 2 were at the musculotendinous junction, and 1 was complete tendon rupture (15). Several authors have expressed their concern over significant loss of range of supination and muscle strength after DBT repair. They have opined that the variation in length, width, area, and shape of the DBT is important in anatomical restoration of the DBT. The radial tuberosity and distal biceps insertion footprint are critical structures which affect the forearm supination mechanics, and anatomical repair of a ruptured tendon is necessary for the restoration of power, endurance, and terminal forearm rotation (16). If the biceps tendon is not repaired to its anatomic location and is merely inserted into the radial tuberosity, the power of supination will never be restored to preinjury levels (17). During our literature review, we found an incidence of bifurcated distal biceps tendon insertion (18). However, in all the specimens studied by us, the distal biceps tendon was united. The distal biceps tendon was inserted on the posterior rim of the radial tuberosity, which is in accordance with previous study (19). The anatomy of the DBT and radial tuberosity is important to understand the pathophysiology of tendon rupture. It is postulated that the distance crossed by the tendon over the raised ridge on the radial tuberosity, functions as a pulley and increases the mechanical advantage of the musculotendinous unit (20). Nevertheless, in the present work we did not study the measurements of radial tuberosity as our focus was mainly on DBT anatomy. Eames *et al*., in their study on the insertional anatomy of DBT have observed that the posterior attachment of the long head tendon on the radius, potentially increases its supination power, while, the more distal attachment of the short head, generates greater flexion power for the muscle (21). Previously, the anatomy of the DBT has received little attention. Detailed data on the insertion footprint of the tendon and its relationship to radial tuberosity have been reported. Most of the reported studies are computed tomography studies or cadaveric studies on frozen limbs which have focused mainly on the insertional footprint of the DBT, biomechanical studies and surgical reconstruction articles. Very little focus has been given to basic morphometric measurents of the DBT.

A variety of grafts (autografts, allografts, and synthetics) have been reported in the literature to reconstruct the DBT. The decision to proceed with graft and also the choice of the graft should be guided by the understanding of normal DBT morphology. Also, knowledge of the orientation of the tendon fibers near the musculotendinous junction (MTJ) can help guide graft-weaving orientation and suture placement, which improves the proximal fixation (12). In the present study different patterns of MTJ were observed. However, the relationship between the MTJ patterns and the DBT rupture currently lacks in the literature.

Limitations of this present study include small sample size, the use of embalmed cadaveric specimens, and the lack of consideration of demographic information, such as height, weight, and hand dominance. Although it was observed that the distal biceps tendons were slightly thicker in the right limbs than the left limbs at the elbow level, it might reflect the hand dominance of the population. However, we did not find any relevant studies in the literature supporting this assumption.

CONCLUSIONS

The present study attempts to describe the various morphometric measurements of the DBT that might be of relevance to the surgical inventions in distal biceps tendon repair. The variations in MTJ patterns, length and thickness of the tendon at various points and its insertion at radial tuberosity has received renewed interest as these factors manily contribute in tendon reattachment. Surgeons can use these cadaveric morphometric dimensions of the DBT when deciding whether reconstruction is necessary, as well as for graft selection of similar morphology. Nonanatomic reconstruction of a ruptured biceps tendon can lead to some amount of rotational weakness and loss of supination strength. Hence, it is rational to assume that surgical repair should replicate the normal anatomy as close as possible to ensure an excellent clinical outcome. Thus such studies are essential in the anatomical restoration of the DBT and for sports medicine physicians for diagnosis of tendinopathy.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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