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Original Article

The Relevant Anatomy of the Biceps Tendon When Performing Tenodesis in Filipino Cadaveric Specimens

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Abstract

Background: Biceps tenodesis is a technique frequently performed in shoulder surgeries. Various techniques have been described, but there is no consensus on which technique restores the length-tension relationship. Restoration of the physiologic length-tension relationship has been correlated to better functional outcomes, such as decreased incidence of residual pain or weakness of the biceps. The objective of this study was to measure the anatomic relationship of the origin of the biceps tendon with its zones in the upper extremity. This would provide an anatomic guide or an acceptable placement of the tenodesis to reestablish good biceps tension during surgery. **Methods**: The study used nine adult cadavers (five males, four females) from the [withheld for blinded review]. Nine shoulder specimens were dissected and markers were placed at five points along each biceps tendon: (1) Labral origin (LO) (2) Superior bicipital groove (SBG) (3) Superior border of the pectoralis tendon (SBPMT) (4) Musculotendinous junction (MTJ) and (5) Inferior border of the pectoralis tendon (IBPMT). Using the origin of the tendon as the initial point of reference, measurements were made to the four subsequent sites. The humeral length was recorded by measuring the distance between the greater tuberosity and the lateral epicondyle as well as the tendon diameter at the articular surface. **Results:** The intraclass correlation coefficient was excellent across all measures. A total of nine cadavers were included. Mean age of patients was 66.33 years old, ranging from 52-82 years old. These were composed of five male and four female cadavers. The mean tendon length was 24.83mm ± 4.32 from the origin to the superior border of the bicipital groove, 73.50mm ± 6.96 to the Superior Border Pectoralis Major Tendon, 100.89mm ± 6.88 to the Musculotendinous Junction, and 111.11mm ± 7.45 to the Inferior Border Pectoralis Major Tendon. The mean tendon diameter at the articular origin was 6.44mm ± 1.76. **Conclusion**: This study provided measurement guidelines that could restore the natural length-tension relationship during biceps tenodesis using the interference screw technique in Filipinos. A simple method of restoring a normal length-tension relationship is by doing tenodesis close to the articular origin and creating a bone socket of approximately 25mm in depth, using the superior border of the bicipital groove as a landmark.

Keywords: long head of the biceps tendon, biceps tenotomy, biceps tenodesis

INTRODUCTION

Lesions of the long head of the biceps tendon (LHBT) are common shoulder pathologies that can result to persistent pain and functional impairment. LHBT lesions can be isolated but are frequently associated with complex shoulder conditions, such as shoulder instability or rotator cuff tears. The decision of whether to do conservative or surgical management of LHBT lesions might depend on the associated shoulder pathology and the chronicity of symptoms.[1]

Surgery is indicated for isolated biceps tendinitis, subluxation or tears, concomitant subscapularis tendon repair, pain associated with massive rotator cuff tears, and some Superior Labrum Anterior and Posterior (SLAP) lesions.[2, 3] Treatment can be tenotomy or tenodesis. Tenotomy is simpler but has been associated with deformity due to distal migration, fatigue with resisted elbow flexion, and supination strength loss.[4] Tenodesis, on the other hand, is associated with improved cosmesis, lower rates of deformity, weakness with supination, and continued spasm requiring reoperation.[2]

Tenodesis of the biceps tendon is a common procedure performed for shoulder pathology. Multiple surgical tenodesis techniques have been described. However, little consensus exists about which technique best reproduces the physiologic length-tension relationship found in the native shoulder. There are few papers that studied the anatomy of the biceps tendon and the optimal tenodesis position to restore length-tension relationship.

In one study, they recommended that for arthroscopic suprapectoral tenodesis using interference screws, the superior border of the bicipital groove is an effective landmark for tenodesis. They have recommendations regarding the amount of tendon that can be resected and the ideal location for tenodesis (both arthroscopic and subpectoral) to restore the normal length-tension relationship.[7]

However, no study has been done on Asian/Filipino cadavers. Therefore, the recommended measurement guidelines cannot be applied in our setting. With this in mind, this anatomic study specifically investigated the length and possibly, the optimal location for biceps tenodesis in Filipinos. The resting tension produced by the tenodesis may lead to unfavorable clinical outcomes that depend on this said location. We hypothesized that the length and diameter of the biceps tendon would differ between male and female specimens.

METHODOLOGY

Upon approval from The University of Santo Tomas – College of Rehabilitation Sciences Ethics Review Committee, nine embalmed cadavers were dissected for analysis. There were five male and four female cadavers used in this study. There were nine right-sided and nine left-sided shoulders included.

All dissections were performed by one of two examiners: a fellowship-trained shoulder specialist or a fellowship-trained joint/tumor specialist and a senior orthopedic resident.

Each specimen was composed of the shoulder girdle, clavicle, scapula, and all accompanying soft tissue structures, from the arm down to the hand.

Dissection started with the excision of skin and subcutaneous tissue from the anterior half of the shoulder, distally to the elbow. A standard deltopectoral approach was used. The insertion of the pectoralis major tendon was left intact and uninjured. The humeral insertion of the pectoralis tendon was used as a landmark. Removing the anterior half of the deltoid exposed the rotator cuff. The cuff was ensured intact and free of any pathology (e.g., rotator cuff tears, evidence of prior arthroscopic surgery). Next, the biceps tendon was identified and used as a reference point to develop the rotator interval. Some parts of the supraspinatus and subscapularis tendon were released at their insertions to permit enhanced visualization of the biceps tendon and its course from the labral origin to the intertubercular groove.

The measurement technique was adapted from the study of Kovack, Idoine and Jacob.[7] Figure 1a showed the specific locations along the biceps tendon where tagging sutures and pins were placed to enable anatomic length measurements. (1) Labral origin (LO) (2) Superior bicipital groove (SBG) (3) Superior border of the pectoralis tendon (SBPMT) (4) Musculotendinous junction (MTJ) and (5) Inferior border of the pectoralis tendon (IBPMT).

All measurements were done twice by two examiners to determine similarity in measurements. Measurements were taken based on the corresponding landmarks as seen on Figure 1a.

The total biceps tendon length (TTL) was measured from the labral origin to the musculotendinous junction (LO-MTJ). Next, the distance from the labral origin to the superior biceps groove (LO-SBG) was measured. This measurement was taken laterally to the articular margin of the humeral head at the superior aspect of the bicipital groove, just before it transitioned inferior and distal. Next, the superior and inferior borders of the pectoralis major tendon were identified. Measurements from the labral origin (LO to the musculotendinous junction (LO-MTJ), superior border of the pectoralis major tendon (LO-SBPMT), and inferior border of the pectoralis major tendon (LO-IBPMT) were obtained. These values were then gathered from the biceps MTJ

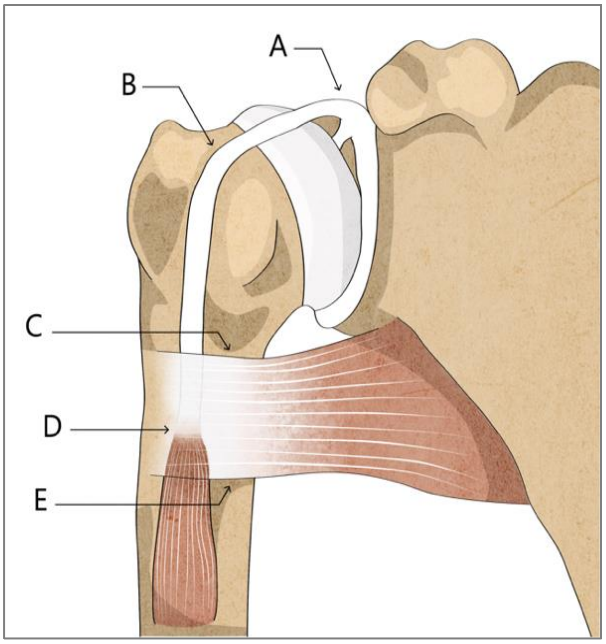

Figure 1a. Location landmarks in relation to the long head of the biceps tendon (LHBT). **(A)** Labral Origin (LO); **(B)** Super Bicipital Groove (SBG); **(C)** Superior Border of the Pectoralis Tendon (SBPMT); **(D)** Musculotendinous Junction (MTJ); **(E)** Inferior border of the pectoralis tendon (IBPMT).

Figure 1b. Cadaveric set up during dissection showing the location landmarks in relation to the long head of the biceps tendon as pinned. **(Green)** Labral Origin (LO); **(White)** Super Bicipital Groove (SBG); **(Red)** Superior Border of the Pectoralis Tendon (SBPMT); **(Blue)** Musculotendinous Junction (MTJ); **(Yellow)** Inferior border of the pectoralis tendon (IBPMT).

Figure 1. Location landmarks in relation to the long head of the biceps tendon.

to the inferior (MTJ-I) and superior (MTJ-S) borders of the pectoralis tendon by subtracting the measurements gathered from above (MTJ – SBPMT) (IBPMT – MTJ). The diameter of the long head biceps tendon was also determined from its articular origin accordingly. Lastly, the distance between the greater tuberosity and the lateral epicondyle measured the humeral length. All measurements were tabulated as seen on Table 2 (Length of Biceps Tendon from Origin to Anatomic Landmark and Tendon diameter at labral origin).

Statistical Analysis. Data were encoded in MS Excel 2016 by the researcher. Stata MP version 14 software was used for data processing and analysis. The Intraclass correlation coefficient (ICC) for absolute agreement was utilized to assess the reliability between the two outcome assessors. Depending on the ICC value, the agreement was rated as excellent (>0.75), good (0.60-0.74), moderate (0.40-0.59), or poor (<0.40).[5] The average measure of the two outcome assessors was used for the analysis. Continuous variables were presented as mean/ standard deviation (SD) while categorical variables were presented as median/interquartile range (IQR) depending on data distribution. An Independent t-test was used to compare the continuous variables by sex. Paired t-test was used to compare the continuous variables by laterality (left/ right). Correlation between humeral length and each tendon length was determined using Pearson's correlation coefficient (r). Correlation coefficient was interpreted as follows: 0.90-1.00: very high, 0.70-0.90: high; 0.50-0.70: moderate; 0.30-0.50: low; 0-0.30: negligible. values ≤0.05 were considered statistically significant.[6]

RESULTS

The intraclass correlation coefficients were excellent across all measures (Table 1).

A total of nine cadavers were included. The mean age of patients was 66.33 years old, ranging from 52-82 years old. It composed of five male and four female cadavers. The overall length of the biceps tendon from the origin to every anatomic landmark was illustrated in Table 2.

The mean tendon length was 24.83mm ± 4.32 from the origin to the superior border of the bicipital groove, 73.50mm ± 6.96 to the Superior Border Pectoralis Major Tendon, 100.89mm ± 6.88 to the Musculo-tendinous Junction, and 111.11mm ± 7.45 to the Inferior Border Pectoralis Major Tendon. The mean tendon diameter at the labral origin was 6.44mm ± 1.76 and did not show a difference between male and female specimens. Moreover, measures across all borders showed no statistically significant difference by sex and laterality as seen in Table 3 (comparison of measures by sex) and Table 4 (comparison of measures by laterality).

Furthermore, the total length of the biceps tendon had a high negative correlation to tendon diameter as demonstrated on the scatterplot matrix (Figure 4).

Table 1. Intraclass correlation coefficient between two outcome assessors.

VARIABLES	ICC (95% CI)
Superior Border Bicipital Groove- Right	0.80 (0.25 – 0.95)
Superior Border Bicipital Groove- Left	0.79 (0.36 – 0.95)
Superior Border Pectoralis Major Tendon- Right	0.81 (0.03 – 0.96)
Superior Border Pectoralis Major Tendon- Left	0.91 (0.66 – 0.98)
Musculo-tendinous Junction- Right	0.82 (0.27 – 0.96)
Musculo-tendinous Junction- Left	0.76 (0.21 – 0.94)
Inferior Border Pectoralis Major Tendon- Right	0.79 (0.36 – 0.95)
Inferior Border Pectoralis Major Tendon- Left	0.76 (0.22 – 0.94)
Humeral Length- Right	1.00 (0.97 – 1.00)
Humeral Length- Left	0.99 (0.72 – 1.00)
Tendon Diameter at Articular surface- Right	0.96 (0.85 – 0.99)
Tendon Diameter at Articular surface- Left	0.96 (0.85 – 0.99)

Table 2. Length of Biceps Tendon from Origin to Anatomic Landmark and Tendon diameter at labral origin

VARIABLES	(n=9) Mean ± SD	Range
Superior Border Bicipital Groove	24.83 ± 4.32	24 – 30
Superior Border Pectoralis Major Tendon	73.50 ± 6.96	61.50 – 82.50
Musculo-tendinous Junction	100.89 ± 6.88	90 – 105.2
Inferior Border Pectoralis Major Tendon	111.11 ± 7.45	101.50 – 122.50
Tendon Diameter at Articular surface	6.44 ± 1.76	5 – 11
Humeral Length	267.22 ± 42.36	162.50 – 300

Table 3. Comparison of measures by sex (n=9)

VARIABLES	MALE (n=5) Mean ± SD	FEMALE (n=4) Mean ± SD	P VALUE[a]
Superior Border Bicipital Groove- Right	24.50 ± 2.74	22.25 ± 6.28	0.8150
Superior Border Bicipital Groove- Left	24.20 ± 3.88	22.25 ± 4.37	0.7138
Superior Border Pectoralis Major Tendon- Right	73.30 ± 5.73	72 ± 7.49	0.1944
Superior Border Pectoralis Major Tendon- Left	73.80 ± 7.55	72.50 ± 6.42	0.1492
Musculo-tendinous Junction- Right	100.20 ± 8.19	98.75 ± 5.92	0.7610
Musculo-tendinous Junction- Left	100.60 ± 4.87	99.75 ± 5.25	0.6009
Inferior Border Pectoralis Major Tendon- Right	111.20 ± 7.97	111 ± 7.95	0.9712
Inferior Border Pectoralis Major Tendon- Left	107 ± 5.39	108.38 ± 11.24	0.8144
Tendon Diameter at Articular surface- Right	6.10 ± 0.22	6.88 ± 2.78	0.5474
Tendon Diameter at Articular surface- Left	6.40 ± 0.42	7.00 ± 2.71	0.6346
Humeral Length- Right	288.50 ± 12.20	240.63 ± 53.75	0.0906
Humeral Length- Left	282.50 ± 8.10	240.63 ± 53.75	0.1240

[a]*Independent t-test was used*

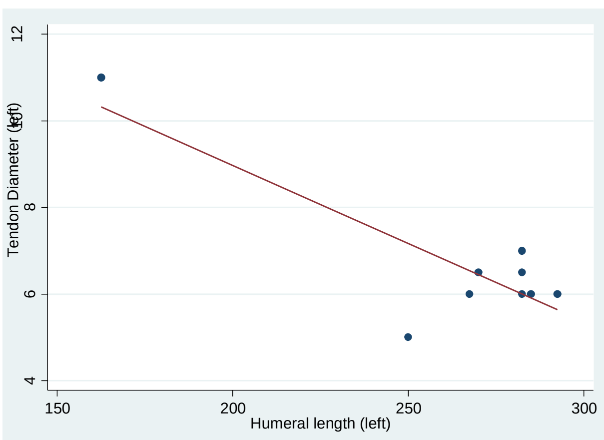

Figure 4a. Humeral length is significantly correlated with tendon diameter in the left side (r = -0.8417; p value = 0.0044). A high negative correlation was observed between the two measures.

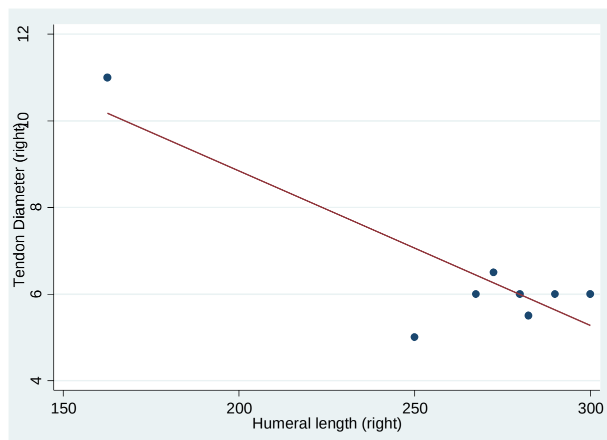

Figure 4b. Humeral length is significantly correlated with tendon diameter in the right side (r = -0.8584; p value = 0.0031). A high negative correlation was observed between the two measures.

Figure 4. Scatterplot matrix of Humeral length and Tendon Diameter (a) Left; (b) Right

DISCUSSION

The purpose of this study was to postulate anatomically based values of the normal length of the biceps tendon and possibly, provide surgical recommendations for LHBT tenodesis based on the findings.

Biceps tenodesis using an interference screw has been reported to be strongest biomechanically.[7,8] However, restoring the length-tension relationship can be challenging when using this technique. The information gathered in this study could help restore the length-tension relationship during biceps tenodesis using the interference screw technique.

In performing biceps tenodesis using an interference screw, a bone tunnel or socket was created to contain the length of the screw. The tip of the tendon was contained at the bottom of the bone tunnel, adjacent to the interference screw. Hence, to be able to restore the length-tension relationship of the biceps tendon, the length of the tendon and length of the screw was considered. Tendon length was attributed to its anatomic location and the length of tendon resected. Screw length was flexible and established the depth of the bone tunnel, as well as the depth of tendon insertion. In this paper, the length of the biceps tendon from the articular origin of the proximal humerus to the bicipital groove was at 24.83mm ± 4.32. Therefore, if biceps tenotomy will be done at the level of the glenoid margin for tenodesis, creating a 25mm bone tunnel at the superior border of the bicipital groove would restore the length-tension relationship. With this in mind, a 23mm interference screw was suitable to allow for 2mm of the tendon at the tip of the screw within the bone tunnel. (Figure 2 Biceps tenodesis above the bicipital groove, adjacent to the articular margin of the humeral head).

This is in line with a study by Denard et al.,[10,] which used the superior border of the bicipital groove as an effective landmark in performing tenodesis. In reference to this paper, the mean length of the biceps tendon from the labral origin was at 25mm. Therefore, doing a tenotomy at the level of the glenoid for tenodesis, which created a 25mm bone socket, restored length-tension relationship. As a result, a 23mm interference screw was used to allow for 2mm of the tendon to remain at the tip of the screw. The authors further stressed the advantage of doing tenodesis at this location. Based on the mean tendon length at this area, no tendon resection was needed because the tendon's length from the labral origin was at 25mm. Therefore, doing a tenotomy at the level of the glenoid for tenodesis, which created a 25mm bone socket, restored length-tension relationship. As a result, a 23mm interference screw was used to allow for 2mm of the tendon to remain at the tip of the screw. The authors further stressed the advantage of doing tenodesis at this location. Based on the mean tendon length at this area, no tendon resection was needed because the tendon's length remaining after tenotomy at this level matched the length of the interference screw. Hence, doing tenodesis at the articular margin was the preferred choice by most surgeons.

However, restoring the length-tension relationship was more complex with a distal tenodesis because both tendon length and screw length changed. In performing subpectoral tenodesis, the goal was to position the musculotendinous junction of the biceps at the lower border of the pectoralis major. In an anatomic study by Jarrett, McClelland and Xerogeanes,[11] it was established that the musculotendinous junction of the biceps was at approximately 22mm distal to the upper border of the pectoralis major tendon and 31mm proximal to the lower border of the pectoralis major tendon. Moreover, in a paper by Denard et al.,[10] the musculotendinous junction was determined 25mm distal to the superior border of the pectoralis major tendon and approximately 20mm proximal to the lower border of the pectoralis major tendon.

In this study, the musculotendinous junction was approximately 27mm distal to the upper border of the pectoralis major tendon and 12mm proximal to the lower border of the pectoralis major tendon. The measurements obtained were different from the abovementioned studies since the specimens used were amputated above the elbow that could have affected the values. For this study, the cadaveric specimens included the entire arm from the scapula to the hand. This possibly helped us obtain more accurate measurements. It showed that to restore the normal biceps length-tension relation, a subpectoral tenodesis should be performed above the lower border of the pectoralis major tendon, approximately 12mm proximal to the lower border of the pectoralis major tendon. For example, if a 10-15mm interference screw will be utilized, 10 to 15mm of biceps tendon should be removed, and the tendon should be 12mm proximal to the lower border of the pectoralis major tendon (Figure 3).

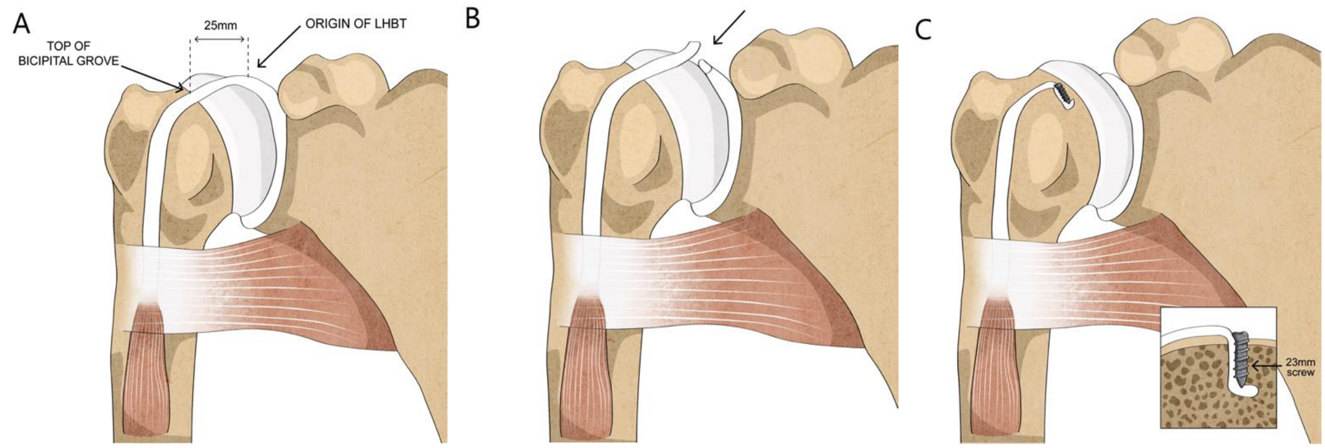

Figure 2. Biceps tenodesis above the bicipital groove, adjacent to the articular margin of the humeral head. **(A)** The normal biceps tendon averages 25mm in length from its origin to the humeral head. **(B)** The tenotomy site (arrow) at the level of the glenoid. **(C)** a bone socket is created adjacent to the articular margin of humeral head, and the tendon is secured in this socket with a interference screw. As shown in the inset, allowing for 2mm of tendon to be at the tip of the screw, a 23 mm long interference screw at this location will maintain the length-tension relation of the biceps because the native tendon is 25mm long from its origin to this location of tenodesis. (PMT pectoralis major tendon).

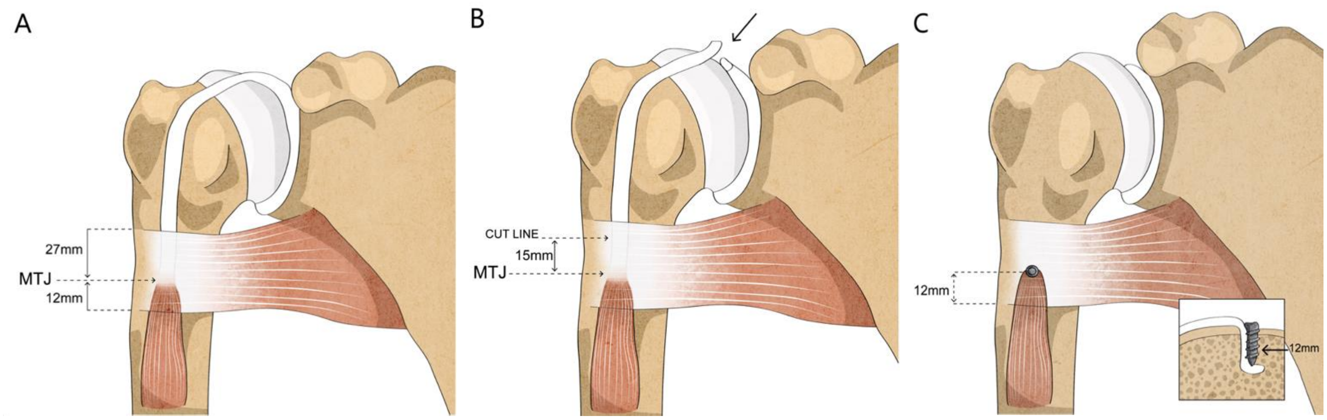

Figure 3. The proper location for a subpectoral tenodesis. **(A)** the musculotendinous junction (MTJ) of the long head of the biceps tendon is located beneath the pectoralis major tendon (PMT). The MTJ is approximately 27mm below the upper border of the PMT and 12mm above the lower border of the PMT. **(B)** The tenotomy site (arrow) at the level of the glenoid, and a proximal portion of the tendon is resected until there is only 15mm of tendon remaining above the MTJ. **(C)** A bone socket is created 12mm above the lower border of the PMT, and the tenodesis is performed at this location to maintain the normal position of the biceps tendon. As shown in the inset, a 12mm long interference screw at this location will allow for a small amount of tendon at the base of the screw and maintain the length-tension relation of the biceps

This study also provided anatomic diameters of the biceps tendon at the labral origin measured at 6.44mm ± 1.76 with no difference seen by sex and laterality. Biomechanically, the smallest diameter screw was recommended.[11] Taking into mind the suture preparation of the biceps tendon (whipstitch placement) slightly increased its diameter. In most cases, a 7 to 8mm diameter interference screw was suitable when doing tenodesis at the proximal humerus. If no suture preparation were done to the biceps tendon, a 6 to 7mm diameter interference screw would be appropriate at this level.

This study also demonstrated that there were no differences in tendon length and diameter at the labral origin across gender and laterality. This was consistent in a study by Hussain et al.[15] and Denard et al.[10] that showed no difference in mean length of the long head of the biceps tendon between male and female specimens. Furthermore, this paper demonstrated a negative correlation between humeral length and tendon diameter. A longer humeral length resulted in a decreased tendon diameter.

The strength of this study was that it provided guidelines for surgeons regarding the amount of tendon to be resected. It also demonstrated the ideal location for tenodesis, which would help in restoring the anatomic relationship of the biceps tendon. This would be theoretically appealing since complications such as pain and fixation failure were known complications after tenodesis. These can be ideally minimized if the length-tension relationship was regained. In addition, using the specimens that included the entire arm and scapula improved the measurements obtained in this study. Since Filipino cadaveric specimens were utilized, these results were deemed applicable in the local setting. Furthermore, this study will provide an in-depth explanation of how to perform biceps tenodesis. It can help further broaden the knowledge of allied health professionals to help in their practice.

This study presented several limitations. The tendon measurements may not apply to all cases since histopathology reports were undetermined. Moreover, the study did not consider tendon measurements after tendon preparation that may affect the tendon diameter. The small sample size is also a limitation. More cadaveric specimens must be included if another similar study will be conducted in the future.

CONCLUSION

This study provided measurement guidelines that could restore the natural length-tension relationship during biceps tenodesis in Filipinos. A simple method to restore the normal length-tension relationship is to do tenodesis close to the articular origin and by creating a bone socket 25mm in depth. However, tenodesis at a more distal location varies depending on the tendon length and depth of the bone tunnel.

Individual Author's Contribution

C.V., C.T., P.L.; conceptualized the study, helped in drafting and revising study content, substantially contributed to design of work and acquisition of data, and helped in revision of content

Disclosure Statement

The authors have no disclosures for this paper.

Conflicts of Interest

The authors of this paper declare no conflicting interest.

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