SCIENTIFIC ARTICLE

The Relationships Between Surface Measurements and Underlying Tendon Autograft Length for Upper Extremity Reconstructive Surgery

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Purpose The availability of tendon grafts is an important consideration for successful upper extremity reconstructive surgery, including flexor or extensor tendon reconstructions, tendon transfers, and ligament reconstructions. Graft selection is based on availability, expendability, ease of harvest, and length. Given variations in patient height and extremity length, existing average values may provide suboptimal insight into actual tendon lengths available. The purpose of this study is, therefore, to pursue a method of estimating available donor tendon lengths based on easily measured anatomical surface landmarks.

Methods Thirty cadaveric upper and lower extremity limbs were dissected and the length of commonly harvested tendon grafts including the palmaris longus, extensor indicis proprius, extensor digiti minimi, plantaris, and second long toe extensor was measured. Surface forearm length (from finger tip to cubital fossa) and surface fibular length (from lateral malleolus to fibular head) were also measured. Correlations between surface measurements and underlying tendon lengths were analyzed, and linear models were generated that predicted tendon length as a function of surface measurements.

Results Surface measurements were correlated with underlying tendon length ($R = 0.46 - 0.66$). Linear models could predict tendon lengths based on surface measurements ($P < .05$). A ratio of donor tendon length compared with the limb segment measured was established for each tendon and can be applied to estimate donor tendon length. For the upper extremity tendons, the multipliers for the palmaris longus, extensor indicis proprius, and extensor digiti minimi were 0.51, 0.20, and 0.18, respectively. Lower extremity tendon ratios for the plantaris and extensor digitorum longus were 0.69 and 0.60, respectively.

Conclusions Although length of available donor tendon can be a limiting variable at the time of surgery, surgeons may be better able to estimate underlying tendon lengths using easily obtained superficial measurements.

Clinical relevance Information obtained from these cadaveric measurements may aid in preoperative planning in hand and upper extremity surgery. *(J Hand Surg Am. 2017;■(■):1.e1-e5. Copyright © 2017 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Upper extremity, reconstruction, autograft, anatomy, cadaver.

Online Exclusive

THE HARVEST AND USE OF AUTOGENOUS tendon grafts is an important task for the upper extremity surgeon. In addition to primary flexor tendon reconstruction, autogenous grafts are often used to treat chronic tendon lacerations and failed repair in either single- or 2-stage flexor tendon reconstructions.[1–7] Autogenous grafts are also employed in segmental extensor tendon injuries,

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Received for publication August 10, 2016; accepted in revised form May 15, 2017.

No benefits in any form have been received or will be received related directly or indirectly to the subject of this article.

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0363-5023/17/■■-0001$36.00/0
http://dx.doi.org/10.1016/j.jhsa.2017.05.015

tendon transfers for the treatment of various traumatic and acquired conditions,[8–22] and reconstruction of elbow, wrist, hand, and finger ligaments.[23–29]

The most commonly utilized donors are the palmaris longus (PL), plantaris (Pt), extensor digitorum longus of the second toe (EDL), extensor digiti minimi (EDM), and extensor indicis propius (EIP).[6] Factors to consider include availability, expendability, and length, which is of importance when planning for longer or multiple tendon reconstructions.

In 1992, Wehbe[30] performed a cadaveric study of 480 extremities from 120 cadavers, in which the length and width of these commonly used autografts was described. Although he reported ranges, pure tendon, and total length including intramuscular portions, only the abbreviated mean total lengths have been described in textbooks, review papers, and American Academy of Orthopedic Surgeons Instructional Lectures.[4,6,31] This is likely due to the wide ranges Wehbe[30] reported for lengths of the pure tendinous portions. Given variations in patient height and extremity length, an average value may provide little insight into the actual tendon lengths available when planning reconstructive surgery.

Knowledge of available tendon lengths would aid the surgeon not only in preoperative planning but also with consenting and counseling patients before surgery on available tendons for harvest, the likelihood of location of graft fixation, and expected incisions. The purpose of this study was to use cadaveric specimens to (1) record donor tendon lengths and easily reproducible surface measurements; (2) establish a method of estimating available donor tendon lengths based on easily measured anatomical surface measurements, and (3) assess the accuracy of historically reported mean values on predicting the tendon lengths.

MATERIALS AND METHODS

The investigation was performed at the New York University Langone Hospital for Joint Diseases, New York, NY. Thirty right-sided cadaveric upper and lower extremity limbs from 30 cadavers (15 female, 15 male) were dissected by fellowship level hand surgeons (M.S. and O.A.). Thirty cadavers were selected to ensure a normal or near-normal distribution of tendon and surface measurement lengths.[32] Prior to dissection, surface anatomical measurements for forearm length and fibula length were measured with a ruled tape measure. Forearm length was defined as the distance from the antecubital fossa to the middle finger tip, measured in maximum elbow, wrist, and finger extension. Although these measurements may be affected by position, trauma, and contractures, we elected to use these end points to avoid measuring landmarks that may be obscured by overlying orthoses that might be present during preoperative evaluation. Fibula length was defined as the distance from the fibular head to the tip of the lateral malleolus. For each patient, the PL, EIP, EDM, Pt, and EDL were then dissected. The pure tendon lengths of these commonly harvested tendons were then measured with a tape measure from their proximal musculotendinous junction to the distal bony insertion site. Tendon width was measured at a point halfway along the length of the tendon. Tendon length and width were measured while the cadavers were still well hydrated.

For each tendon, a univariate ordinary least squares (OLS) regression model was employed to generate a tendon multiplier that predicted tendon length as a function of surface measurements. The OLS is a method for estimating unknown parameters (in this case, the tendon multiplier and constant term) in a linear model that minimizes differences between observed responses (tendon lengths) and those predicted by a linear function of a variable (surface measurements). In short, we input paired dissected tendon lengths and surface measurements, and the model generates the tendon multiplier and constant term. In detail:

$$\text{Tendon length}_i = \beta_o + \beta_1 \text{ Surface measurement}_i + \varepsilon_i \quad (1)$$

where the dependent variable, Tendon length, is the measured tendon length for cadaver i, and the independent variable, Surface measurement, is the anatomical fibula or forearm length for cadaver i. For any patient, $\beta_{1,}$ the coefficient on Surface measurement, can be interpreted as the "Tendon multiplier," or incremental increase in predicted tendon length per increase in surface measurement. β_o can be interpreted as the constant, and ε_i is an error term that describes variations not described in a model, which is inherently simplified.

To highlight the rationale for this undertaking, the ability of the previously reported mean pure tendon lengths of Wehbe[30] to predict the tendon lengths of this study's cadavers was assessed.

RESULTS

The mean donor lengths and widths for PL, Pt, EDL, EDM, and EIP tendons are reported in Table 1. Six