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ORIGINAL STUDY

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Radial tuberosity anatomy in intramedullar repair of distal biceps tendon ruptures. A radiological study

Laurens Van Melkebeke, Roger Van Riet, Joris Duerinckx, Pieter Caekebeke

From the Ziekenhuis Oost-Limburg, Department of Orthopaedic Surgery and Traumatology. Genk, Belgium

The aim of this study was to measure cortex thickness and medullar canal width of the bicipital tuberosity, to evaluate the accessibility of a intramedullar fixation device and the resistance to pullout strengths of the anterior cortex. The final objective was to determine the length of tendon ingrowth size that will be expected when using this surgical technique.

A total of 144 computer tomography images of the proximal radius were used. Bone thickness of the anterior and posterior cortex and medullar canal size were measured. The possible ingrowth of the tendon was measured both for an anatomical and non-anatomical reinsertion. Statistical and concordance analyses of results were performed.

The average width of the medullar canal was 8,7mm proximal, 7,9mm distal and 7,7mm at the tuberosity. The average posterior and anterior cortex measured respectively 2,5mm and 2,9mm proximal, 3,2mm and 3,2mm distal and 2,8mm and 1,9mm at the radial tuberosity. The possible non-anatomical ingrowth was 7,6 mm on average and the possible anatomical ingrowth was 7,6mm on average. The radial tuberosity anatomy can accommodate the new distal biceps fixation device. The anterior cortex on which the new device relies for support has a similar thickness as the posterior cortex used in bicortical fixation devices which may suggest similar resistance to pull-out strengths. The availability for intra-osseous fixation of the tendon stump may avoids tendon gapping. The intra-osseous length for the tendon stump surpassed reported tendon slippage during mobilization and active contraction of the distal biceps tendon.

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INTRODUCTION

Surgical repair of complete distal biceps tendon (DBT) ruptures results in a higher flexion and supination force and endurance compared to non-operative treatment *(1)*. Widely used techniques such as the single incision techniques with bicortical button fixation *(2)* have a high load to failure allowing early active range of a motion, and loading, almost immediately after surgery *(3)*. With this technique the tendon stump is placed inside the radial bone, thus minimizing the risk of gap formation between

■ Laurens Van Melkebeke[1], MD,
■ Roger Van Riet, MD[2,3], PhD,
■ Joris Duerinckx[1], MD,
■ Pieter Caekebeke[1], MD.
[1]*Ziekenhuis Oost-Limburg, Department of Orthopaedic Surgery and Traumatology. Genk, Belgium.*
[2]*AZ Monica, Department of Orthopaedic Surgery, Deurne, Antwerp, Belgium.*
[3]*University Hospital Antwerp, Department of Orthopaedic Surgery, Edegem, Belgium.*
Correspondence : Pieter Caekebeke, ZOL Genk, Schiepse Bos 6, 3600 Genk, Belgium. Phone: +32-485-8204066.
Email : laurensvanmelkebeke@gmail.com

the DBT stump and the bone during active biceps contraction *(4)*. The biggest disadvantage of this technique is the potential iatrogenic damage to the posterior interosseous nerve (PIN) *(5)*. In recent years intramedullary fixation has been proposed to minimize the risk of PIN damage *(6,7)*. Knowledge on the load to failure and outcomes of these techniques are limited to small series biomechanical or in vivo series *(6,7)*. In contrast to the bicortical technique in which the button is supported by the thick posterior cortex, in these techniques, the bony support is by the anterior cortex. There is little known regarding the anterior cortex anatomy around the radial tuberosity, its thickness in different sections and its possible importance in assuring a good resistance to pulling out of the implants use in surgical reinsertion of the DBT. The few studies that describe the anterior cortex are small series *(8)*.

The width of the intramedullary canal, which has to allow the intramedullary fixation device, has not been described specifically around the radial tuberosity, nor has any study evaluated the possible intraosseous tendon length allowed by an intramedullary fixation device.

The purpose of the present study was to describe the osseous anatomy of the proximal radius especially concerning the radial tuberosity with clinical application regarding distal biceps tendon repair. We determined the size of the cortices and medullary canal width at the level of the tuberosity as well as proximal and distal to the tuberosity. Given the recent development of intramedullary fixation methods we determined the length of tendon ingrowth size that will be expected when using this surgical technique.

MATERIAL AND METHODS

We collected all CT scans of the elbow regardless of the indication executed by the radiology department at our institution from July 2019 until December 2020 with a total of 144. All CT scans were separately evaluated and measured by two authors of this article (LVL and PC). We used a multiple detector computed tomography (MDCT) scanner (Siemens Somatom Force, Siemens Healthineers, Germany) for the acquisition of the images. These images were transferred to Siemens Syngo.via software (Siemens Healthineers, Germany) for analysis and measurements with a calibration of 0.1mm. Inclusion criteria were the visualization of the proximal radial bone from the elbow joint to 20mm distal of the tuberosity. CT scans without the availability of reconstructed images in the axial, coronal and sagittal plane were excluded. We excluded all patients younger than 18 years, patients with dysplasia, patients with fractures of the radial tuberosity and proximal ulna or previous surgery around the elbow.

Figure 1. — Alignment of the axial images based on the perpendicular in a coronal and sagittal view.

The measurements were performed in the axial plane of the radial bone after referencing the long axis of the proximal radius in the coronal and sagittal planes perpendicular to the proximal radial joint line to become a standardized true axial view (Fig. 1).

We divided the proximal radius into three zones based on the position of intramedullary fixation methods extending outside the tuberosity region *(4)*. We measured the anterior and posterior cortex distal (Distal anterior and posterior cortex width; DAC and DPC) and proximal (Proximal anterior and posterior cortex width; PAC and PPC) and at the center (Tuberosity anterior and posterior cortex width; TAC and TPC) of the radial tuberosity. The width of the canal was measured both distal and central and proximal of the radial tuberosity (Proximal, distal and tuberosity medullar canal width; PMC, DMC and TMC) (Fig. 2).

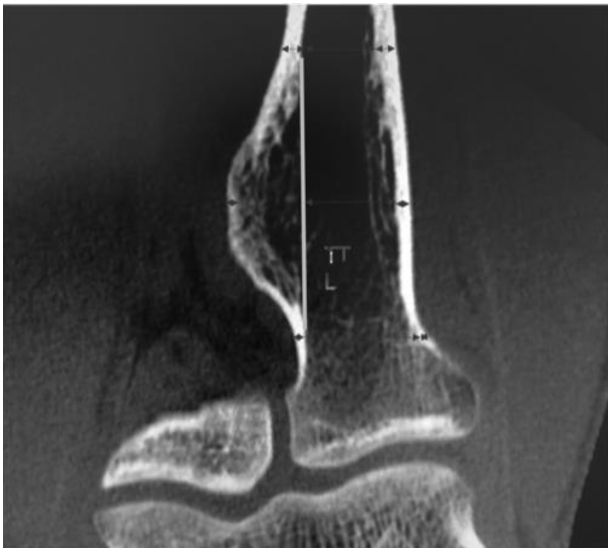

Figure 2A. — The button line (green) as reference for the intramedullar button. Measurements of cortices and medullar canal are also depicted to clarify but were measured on an axial view for accuracy.

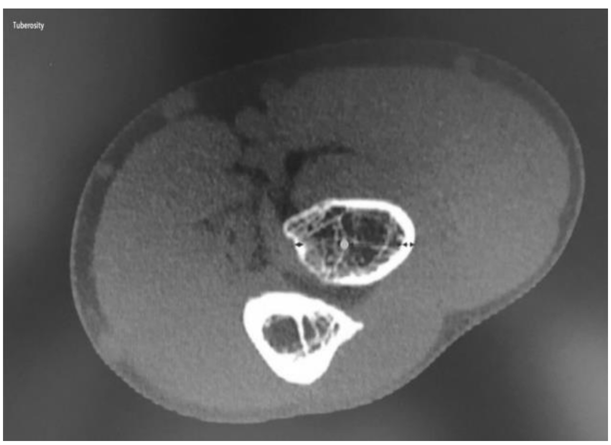

Figure 2C. — Measurements of cortices and medullar canal at the tuberosity.

To determine the possible length of ingrowth of the tendon stump we determined the distance from the 'Transtuberosity line' (TTL) to the cortex of the radial tuberosity both in an anatomical and non-anatomical fashion. The TTL was determined in a true sagittal view, as determined above, by connecting the medullar sides of the anterior cortex from proximal to distal. This represents the edge of the intramedullar button onto which the tendon is fixated (Fig. 2).

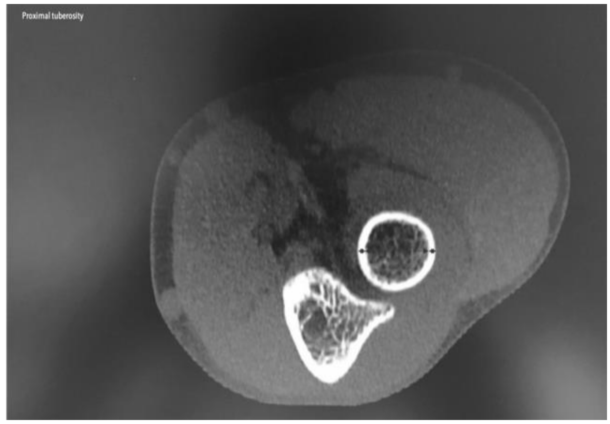

Figure 2B. — Measurements of cortices and medullar canal proximal of the tuberosity.

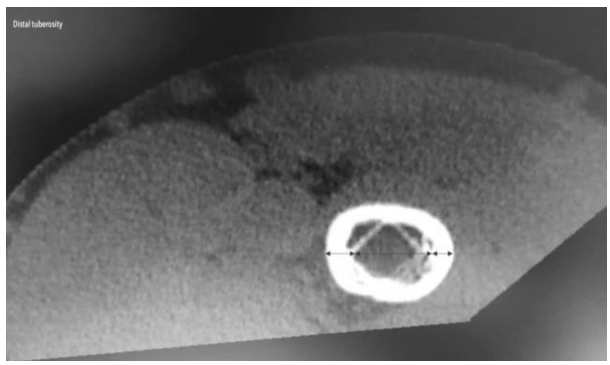

Figure 2D. — Measurements of cortices and medullar canal distal of the tuberosity.

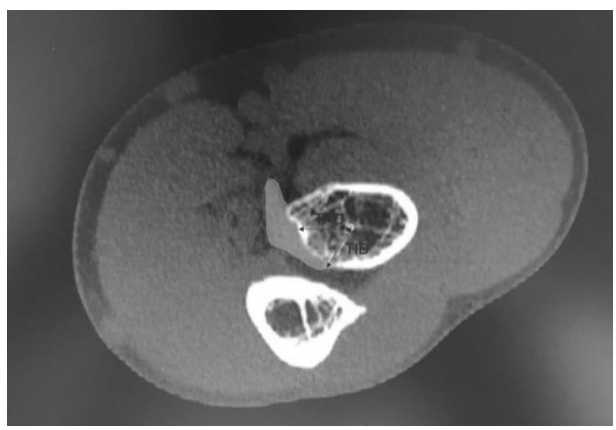

Figure 3. — Depiction of the measurement of the Tuberosity apex distance (TAD) and the Tuberosity insertion distance (TID). The tendon is depicted in green.

This line was reproduced in the axial view and two measurements were performed. First, we measured

Table I. — Averages main outcome measurements

Measurement	Male(SD) N=72	Female(SD) N=72
Proximal Anterior Cortex (PAC)	3,2 (0.6)	2,7(0,6)
Proximal Medullary Canal (PMC)	9,3(1,6)	8(1,2)
Proximal Posterior Cortex (PPC)	2,8(0,6)	2,4(0.6)
Distal Anterior Cortex (DAC)	3,5(0,6)	2,9(0,6)
Distal Medullary Canal (DMC)	8,4(0,6)	7,4(1,2)
Distal Posterior Cortex (DPC)	3,4(0,6)	3,1(0,5)
Tuberosity Anterior Cortex (TAC)	2(0,9)	1,8(0,5)
Tuberosity Medullar Canal (TMC)	8,3(1,5)	7,1(0,9)
Tuberosity Posterior Cortex (DPC)	3,1 (0,5)	2,7 (0,5)
Tuberosity Apex Distance (TAD)	8,4(1,3)	7,2(1,1)
Tuberosity Insertion Distance (TID)	8,1(1,3)	7,1(0,9)

the length of the connecting line between the TTL and the apex of the radial tuberosity representing the non-anatomical position of tendon reinsertion technique (Tuberosity apex distance; TAD). A second measurement was the line connecting the TTL to the anatomical insertion site of the distal biceps. (Tuberosity insertion distance; TID). The center of the biceps tendon insertion is slightly anterior to the tuberosity apex and the tendon was also visible on the CT scans to aid in pinpointing the true anatomical insertion place (Fig. 3). We compared measurements between male and female patients. All measurements are given in millimeters (mm).

The sample size was estimated based on a power analysis done on the first 50 patients. The required number of patients to acquire adequate representation of the general population was 125. We used descriptive statistical analysis to collect the following data of each of the previously mentioned areas for all the patients together and each gender separately. We determined the mean of each distance with its lower and upper border of the 95% confidence interval, the, standard deviation, the minimum and maximum and the 25th and 75th percentile.

RESULTS

The CT investigations of 144 patients were included in present study. Of these, 72 were male and 72 female. The average age was 51. A significant age difference was seen between the male and female group ($P<0,05$). The averages of all measurements are given in Table I.

The average width of the medullar canal was 9,3mm proximal, 8,4mm distal and 8,3mm at the tuberosity (SD: 1,6, 1,3 and 1,5 respectively) for the male group and 8mm proximal, 7,4mm distal and 7,1mm at the tuberosity (SD: 1,2, 1,2 and 0,9, respectively) for the female group. The interval of the 25th and 75th percentile across both groups was between 7,6mm and 9,6mm proximal, between 7,1mm and 8,9mm distal and between 6,8mm and 8,5mm at the center of the tuberosity. The lowest measurement was 5,1mm proximal, 5,0mm distal and 4,6mm at the center of the tuberosity. A significant difference was seen between the male and female groups (P<0,05) The average anterior cortex measured 3,2mm (SD 0,6) proximal, 3,5mm (SD 0,6) distal and 2mm (SD 0,9) at the radial tuberosity in male patients and 2,7mm (SD 0,6) proximal, 2,9mm (SD 0,6) distal and 1,8mm (SD 0,5) at the radial tuberosity in female patients. The interval of the 25th and 75th percentile across both groups was between 2,5mm and 3,5mm proximal, between 2,7mm and 3,7mm distal and between 1,5mm and 2,1mm at the center of the tuberosity. A significant difference was seen between the male and female groups (P<0,05).

The average posterior cortex measured 2,8mm (SD 0,6) proximal, 3,4mm (SD 0,6) distal and 3,1mm (SD 0,5) at the radial tuberosity in male patients and 2,4mm (SD 0,6) proximal, 3,1mm (SD 0,5) distal and 2,7mm (SD 0,5) at the radial tuberosity in female patients. The interval of the 25th and 75th percentile across both groups was between 2,1mm and 3,0mm proximal, between 2,8mm and 3,7mm distal and between 2,5mm and 3,4mm at the center of the tuberosity. A significant difference was seen between the male and female groups (P<0,05).

The tuberosity apex distance was 8,4 mm on average in male patients and 7,2mm in female patients. The interval of the 25th and 75th percentile across both groups was between 6,7mm and 8,3mm. The lowest measurement was 44mm. The tuberosity insertion distance was 8,1mm on average in male patients and 7,1mm in female patients. The interval of the 25th and 75th percentile across both groups was between 6,7mm and 8,3mm. The lowest measurement was 5,1mm. There was no significant difference between the two measurements (P= 0,59).

DISCUSSION

Distal biceps tendon ruptures are relatively uncommon comprising 3% of all biceps tendon tears *(9)*. Operative treatment has become standard to ensure recovery of elbow flexion and more important supination strength and endurance *(10)*. Various fixation devices have been proposed with intramedullary fixation being the most recent development. Intramedullary fixation has the distinct advantage to minimize posterior interosseous nerve damage and thus allowing for an optimal anatomical reinsertion through a single anterior incision. Several aspect of tendon fixation seems to be important such as a high load to failure to allow early active range of motion and loading *(3)*. Furthermore, intraosseous positioning of the repaired tendon minimize gap formation *(4)*. In recent years, two different intramedullary fixation techniques have been described. First, a double button fixation on the anterior cortex of the radial tuberosity *(11)* and second a singular intramedullary button that hooks on thicker anterior cortex on both sides of the radial tuberosity *(6,7)*. The first technique has shown to have a similar load to failure to the bicortical button technique. There is a need to place two buttons as the anterior cortex of the radial tuberosity is markedly thinner than the posterior cortex. This has been shown in small series evaluating the cortex thickness and density at the radial tuberosity *(8)*.

The dual button technique places the repaired tendon against the outer cortex which may lead to gap formation as shown in repairs with the anchor technique *(4)*. The second intramedullary fixation uses a larger button which is inserted by an 8mm drill hole in allowing an intra-osseous positioning of the tendon stump. The larger button hooks on the thicker anterior cortex on both sides of the radial tuberosity. Biomechanical evaluation seems to be promising with similar load to failure as the bicortical button technique *(6)*. Not much is known, however, regarding the anatomical factors regarding this technique. The thickness of the cortex on both sides has never been evaluated nor is the diameter of the medullary canal. This is needed to evaluate if the button will reliably fit inside the medullar canal. As the tendon is pulled inside the radial bone, risk of gap formation should be minimized. However, as of yet, no information exists on the amount of tendon that can be pulled inside the radial bone.

The goal of this study was to provide accurate measurement of the anterior cortex, both of the radial tuberosity and on both sides of the tuberosity. A second objective was to describe the diameter of the medullar canal on different sites around the radial tuberosity as well as the possible depth the tendon can be pulled inside the bone both in a non-anatomical and anatomical repair. Prior studies regarding radial tuberosity anatomy used microCT images while standard CT images where used for this study. Similar results between measurements on microCT and standard CT have been reported *(8)*. As the thickness of the anterior and posterior cortex in present study are comparable to previous mentioned results, we assumed that standard CT is indeed as proficient to measure cortical thickness. This allowed a larger cohort to perform measurements on to meet power analysis requirements.

The anterior cortex on both sides of the tuberosity are of the same average thickness as the posterior cortex with a respectively mean of 3,2mm anterior and 2,9mm posterior indicating that this part around the radial tuberosity offers similar resistance as the posterior cortex. The medullar canal averaged at 8,1 mm which would be sufficient to accommodate the proposed intramedullary fixation design.

The average tunnel depth was 8,4 mm with non-anatomical repair and 7,1 mm when measured in line of an anatomical repair. The average slippage of the tendon during mobilization and active contraction of the distal biceps tendon has been evaluated in biomechanical studies and ranged from 0,83 ± 0,13mm to 1,4 ± 1,4mm *(6,12)*. The tunnel depth seems to be sufficient to allow some slippage and to avoid tendon-bone gapping as seen with anchor fixation *(4)*.

There are several limitations to this study. First, all measurements were performed on stand CT images. Although microCT images may yield more accurate measurements, several studies shown adequate accuracy when using standard CT compared to microCT. We opted for standard CT images to obtain a large measurement cohort which significantly surpasses the number required in the power analysis. Finally, the measurement of the posterior and anterior cortex at the radial tuberosity is comparable to previous microCT measurements *(8)*. Second, given that the CT scans were taken for different indications on a non-standardized manner we manually aligned the plane of the radial tuberosity by using the sagittal and coronal planes to have standardized measurements. This may lead to a margin of error but given the fact that our results are comparable to previous studies on standardized microCT we assumed adequate measurements. Finally, although these measurements give us an adequate image of the possible tunnel depth, in vivo investigation is required to see if this depth is sufficient to prevent gap formation in clinical situation. The same goes for the strength of the anterior cortex. Although it has a similar thickness as the posterior cortex and previous biomechanical studies seems to be promising, in vivo evaluation of this intramedullary fixation has to be conducted.

CONCLUSION

The radial tuberosity anatomy can accommodate the new distal biceps fixation device. The anterior cortex on which the new device relies for support has a similar thickness as the posterior cortex used in bicortical fixation devices which may suggest similar resistance to pull-out strengths. The availability for intra-osseous fixation of the tendon stump may avoids tendon gapping. The intra-osseous length for the tendon stump allowed by the device surpassed reported tendon slippage during mobilization and active contraction of the distal biceps tendon.

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