Reattachment of the distal tendon of biceps

FACTORS AFFECTING THE FAILURE STRENGTH OF THE REPAIR

M. Kettler,
M. J. Tingart,
J. Lunger,
V. Kuhn

From Redcross
Hospital, Munich,
Germany

Operative fixation is the treatment of choice for a rupture of the distal tendon of biceps. A variety of techniques have been described including transosseous sutures and suture anchors. The poor quality of the bone of the radial tuberosity might affect the load to failure of the tendon repair in early rehabilitation.

The aim of this study was to determine the loads to failure of different techniques of fixation and to investigate their association with the bone mineral density of the radial tuberosity.

Peripheral quantitative computed tomography was carried out to measure the trabecular and cortical bone mineral density of the radial tuberosity in 40 cadaver specimens. The loads to failure in four different techniques of fixation were determined.

The Endobutton-based method showed the highest failure load at 270 N (SD 22) ($p < 0.05$). The mean failure load of the transosseous suture technique was 210 N (SD 66) and that of the TwinFix-QuickT 5.0 mm was 57 N (SD 22), significantly lower than those of all other repairs ($p < 0.05$). No significant correlation was seen between bone mineral density and loads to failure.

The transosseous technique is an easy and cost-saving procedure for fixation of the distal biceps tendon. TwinFix-QuickT 5.0 mm had significantly lower failure loads, which might affect early rehabilitation, particularly in older patients.

■ M. Kettler, MD, Orthopaedic Surgeon
Department of Orthopaedics
■ J. Lunger, MD, Assistant Doctor
Surgical Department
Redcross Hospital Munich,
Nymphenburger 163, 80634 Munich, Germany.

■ M. J. Tingart, MD, PhD, Orthopaedic Surgeon
Department of Orthopaedic Surgery
University of Regensburg,
Kaiser Karl V Allee, 93077 Bad Abbach, Germany.

■ V. Kuhn, MD, Scientist
Department of Trauma Surgery and Sports Medicine
Medical University Innsbruck,
Anichstrasse 36, A-6020 Innsbruck, Austria.

Correspondence should be sent to Dr M. Kettler; e-mail: mark.kettler@gmx.de

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Historically, rupture of the distal tendon of biceps represented only about 3% of all ruptures of this tendon.¹ However, in the last decade its occurrence has increased to 10%.² It occurs particularly in male, athletic patients over 50 years of age.¹ Although the rupture itself presents as an acute event, degenerative processes contribute to most tears of the distal tendon,³ but the exact pathology is not yet clear. In the literature, bicipital bursitis, narrowing of the space between the ulna and the radius in pronation and abuse of steroids and nicotine are discussed as possible aetiological factors.⁴ The treatment of choice is operative reattachment since conservative treatment results in striking loss of function.^{1,5} Transosseous suture fixation, as described by Morrey et al,¹ has been the standard procedure employed. However, bone anchors and an Endobutton-based technique have become more popular.⁶⁻⁸ The loads to failure of these new fixation techniques have only been investigated in a few biomechanical studies and the results are controversial.^{7,9,10} Berlet et al,⁹ determined the load to failure of two different anchors, the Mitek G4 Superanchor and the

Stattek 5.2 -mm anchor, and the transosseous suture technique. They found a significantly lower pullout strength for the anchors compared with the transosseous technique. In contrast, in a study performed by Greenberg et al,⁷ the failure load of the Mitek G4 Anchor was 40% higher when compared with the transosseous suture technique, and another Endobutton-based technique⁷ had a load to failure three times higher than the transosseous suture technique. These findings are in agreement with the results of Mazzocca et al,¹⁰ and Spang, Weinhold and Karas.¹¹ They also reported significantly higher loads to failure for the Endobutton technique compared with suture anchors or transosseous sutures.

One reason for these differing findings may be variation in the quality of the bone of the radial tuberosity. Only a few previous studies have attempted to correlate the bone mineral density (BMD) of the radial tuberosity to the failure strengths of the transosseous suture technique or suture anchors.^{8,12} Lemos et al⁸ found a correlation between total BMD and the load to failure of the transosseous tech-

nique and suture anchors, but Pereira et al¹² could not show such a relationship.

We therefore undertook this study in order to assess quantitatively the trabecular and cortical BMD of the radial tuberosity using quantitative computed tomography (QCT) and to investigate the effect of BMD on the loads to failure of four different techniques of repair of the distal biceps tendon.

Materials and Methods

Specimens. A total of 43 formalin-preserved cadaver elbows were dissected free of all soft tissue except for the distal tendon of biceps. Specimens with previous trauma or bony abnormalities of the proximal radius were excluded. Based on these criteria, 40 specimens were included in the study. Their mean age was 80 years (55 to 96) and there were 18 men and 22 women.

Assessment of bone mineral density of the radial tuberosity. Axial pQCT scans of each specimen were obtained to determine the volumetric BMD (trabecular and cortical) of the radial tuberosity (PQCT Scanner, XCT Research SA; Stratec Medizintechnik, Pforzheim, Germany). Scans were performed with a pixel size of 0.59 mm and a slice thickness of 0.2 mm. For QCT scanning, the proximal radius was fixed horizontally with the radial tuberosity in the 12 o'clock position. All pQCT scans were performed and analysed by the same investigator (JL). The threshold for separating between trabecular and cortical bone was set to 480 mg/cm³. Three scans were performed of the middle third of the radial tuberosity of each specimen, and the mean trabecular and cortical BMD were calculated using the XCT Series Software Version 5.40 (Stratec Medi Zintechnik).

Failure strength of reattachments of the distal tendon of biceps. According to their trabecular and cortical BMD, specimens were divided into four groups of ten specimens each for biomechanical testing. The mean trabecular and cortical BMD of the specimens in each group was comparable.

A total of 40 reattachments of the distal tendon of biceps were carried out by a single experienced surgeon (MK) using four different techniques: Endobutton (Smith & Nephew Endoscopy, Andover, Massachusetts); Twin-Fix-QuickT 5.0 mm (Smith & Nephew); FASTak II 2.4 mm (Arthrex, Munich, Germany) and Transosseous sutures (Ethibond No 2; Ethicon Products, Norderstedt, Germany).

The transosseous reattachment was undertaken using the method described by Morrey et al,¹ which is based on the Boyd and Anderson technique.¹³ The other three procedures were performed following the manufacturers' instructions (Fig. 1).

For tendon fixation, Krackow stitches were used over a distance of 4 cm.¹⁴ The distal end of each radius was removed 10 cm proximal to the head, and the proximal and distal radii secured in a custom frame which was

Fig. 1
Boxplot showing one-way analysis of load to failure. The box indicates the 25th to 75th percentile, with the median line, and the error bars the 10th to 90th percentile. Stars indicate a significant difference (Student's *t*-test, $p < 0.05$).

attached to a materials testing machine (Zwick 1440, Zwick; Ulm, Germany). The proximal tendon of biceps was fixed to a custom-made clamp at the musculotendinous junction, approximately 10 cm from the bone-tendon interface.

A preload of 10 N was applied and linear load to failure was performed with an extension rate of 400 mm/min following the protocol described by Lemos et al⁸ and Pereira et al.¹² The maximum force and the type of failure, be it of the anchor, suture or tendon, were recorded. **Statistical analysis.** A difference in load to failure of 20% was chosen as of clinical importance. A power analysis indicated that a sample size of ten specimens per group would provide statistical power of 80% to detect significant mean differences in failure load of at least 20% between the techniques of reattachment ($\beta = 0.2$, $\alpha = 0.05$).

The Kolmogorov-Smirnov test¹⁵ was used to evaluate if load to failure and BMD followed a normal Gaussian¹⁶ distribution; no significant departures were identified. Therefore, continuous data were presented as the mean (SD), and analysis of variance (ANOVA) was used to compare the load to failure and BMD between specimens. Unpaired *t*-tests were used to evaluate differences between the four different techniques. A conservative two-tailed $p < 0.05$ was chosen to declare a statistically significant result.

The Pearson product-moment correlation coefficient (*r*) was calculated to evaluate the linear association between the age of the specimens, BMD and load to failure, respectively.

Data analysis was performed using the SPSS statistical package, version 12.0 (SPSS Inc., Chicago, Illinois). Power calculations were determined using the nQuery

Advisor software package, Version 4.0 (Statistical Solutions, Boston, Massachusetts).

Results

Bone mineral density. The mean cortical BMD of the radial tuberosity was 1101 mg/cm³ (SD 25), while the mean trabecular BMD was 136 mg/cm³ (SD 25) (Fig. 1).

The trabecular BMD of male specimens (156 mg/cm³ (SD 38)) was significantly higher than those of females (115 mg/cm³ (SD 56)) ($p < 0.05$). In contrast, male specimens had a significantly lower cortical BMD (1086 mg/cm³ (SD 38)) than in the female (1116 mg/cm³ (SD 28)) (ANOVA, $p < 0.05$).

No correlation was found between the age of the specimens and the trabecular ($r = -0.01$) or cortical BMD ($r = -0.26$).

No significant differences were seen in cortical or trabecular BMD between the four different reattachment groups (unpaired t -test, $p > 0.05$).

Strength to failure. The mean strength to failure of all the techniques used was 168 N (SD 96). However, depending on the technique, the range of the mean of the load to failure varied between 57 N (TwinFix-QuickT 5.0 mm) and 270 N (Endobutton) (Fig. 1). The transosseous suture technique showed a mean failure strength of 210 N (SD 66) (Fig. 1). Comparing the transosseous suture technique with the other three methods, only the Endobutton (270 N (SD 22)) had a significantly higher load to failure (ANOVA, $p < 0.05$), while no significant differences were seen between the transosseous suture and use of the FASTak II 2.4 mm (134 N (SD 97)) (unpaired t -test, $p > 0.05$) (Table I). The TwinFix-QuickT 5.0 mm (57 N (SD 22)) had a significantly lower load to failure than all other techniques (unpaired t -test, $p < 0.05$).

No correlation was found between the cortical or trabecular BMD and the load to failure (cortical $r = 0.18$; trabecular $r = 0.06$) in any other techniques (Table II).

Mode of failure. Breakage of the suture accounted for eight (80%) failures using the Endobutton. Pullout of the anchor was the major mode of failure for the FASTak II 2.4 mm (70%) and the TwinFix-QuickT 5.0 mm (80%). With transosseous sutures 50 % of the specimens failed because of breakage of the suture and 50% by sutures cutting through the bony bridge at the suture-bone interface.

Discussion

Distal rupture of the tendon of biceps is an injury most often affecting men over 50 years of age.² Since conservative treatment was found to have inferior results, surgical fixation is becoming the treatment of choice.^{1,4} The standard surgical procedure has been by fixation with a transosseous suture,^{1,17} but recently anchor-based techniques have become more popular.^{9,18}

In two previous studies, the BMD of the radial tuberosity and its effects on the failure load of transosseous sutures and suture anchors were investigated, with varying results.^{8,12}

Table I. Mean values of loads to failure (SD) for the four techniques of fixation tested

Technique (number of devices)	Load to failure
EndoButton (Smith & Nephew) (1)	270 (22)
FASTak II 2.4 mm (Arthrex) (2)	134 (97)
TwinFix - QuickT 5.0 mm (Smith & Nephew) (1)	57 (22)
Transosseous suture (Ethibond No 2, Ethicon) (2)	210 (66)

Pereira et al,¹² found a correlation between total BMD and the load to failure for both transosseous sutures and suture anchors but Lemos et al⁸ found a correlation between total BMD and transosseous sutures only. In the study by Lemos et al⁸ females showed a higher load to failure than males, whilst Pereira et al¹² did not report any gender differences. As a result of the number of specimens ($n = 10$) in each tendon repair group, we did not see gender differences in our study. Lemos et al⁸ reported an age-related decrease in total BMD with older specimens being lower. We found a trend supporting these findings, but did not find a strong correlation between age and BMD, even though the mean age of 80 years in our study was comparable with that of the specimens of Lemos et al.⁸ This might be because of the small age range of our specimens (64 to 86 years).

We found a mean load to failure for the transosseous suture repair of 210 N. This agrees with the figure of 203 N in the study of Lemos et al.⁸ However, Berlet et al⁹ and Krushinski, Brown and Murthi,¹⁹ noted a mean load to failure for the transosseous suture repair of 307 N and 310 N, respectively, but in these studies, a cyclic load was applied which might have affected the maximum load to failure.

We found that the Endobutton technique had a significantly higher load to failure of 270 N than with the other techniques. The failure load for the Endobutton in our study is similar to the 250 N noted by Spang et al.¹¹ Further comparable results were reported by others.^{7,10,11} In the studies by Greenberg et al⁷ and Mazzocca et al,¹⁰ the Endobutton technique showed a significantly higher load to failure than the transosseous sutures or suture anchors. However, they found a maximum failure load of 584 N and 44 N, respectively, for the Endobutton technique, about twice as high as the pullout strength in our study. These differences might be a result of the stronger sutures used by Greenberg et al⁷ (No. 2 Fiber Wire), since most Endobutton repairs in our study failed by suture breakage.

Jazrawi et al²⁰ found a physiological force of 52 N in the tendon of biceps when the elbow is flexed against gravity. Based on their findings, transosseous sutures, Endobuttons and FASTak anchors in our study showed loads to failure which would allow early rehabilitation. However, the TwinFix-QuickT 5.0 mm had only a mean load to failure of 57N (SD 20), which might result in early failure, particularly in patients with poor bone quality.

Table II. Pearson correlation (r) between trabecular and cortical bone mineral density (BMD) and the load to failure of the different techniques of fixation

Technique	Trabecular BMD	p-value	Cortical BMD	p-value
Endobutton (Smith & Nephew)	-0.46	0.30	0.38	0.40
FASTak (Arthrex)	0.27	0.56	0.16	0.72
Suture (Ethicon)	-0.49	0.27	-0.50	0.25
Quick T (Smith & Nephew)	-0.58	0.17	0.44	0.32

We assessed the linear load to failure to make our results comparable with other studies.^{7,8,12,19,21} However, this is a limitation of the study, since cyclical loading is thought to be more physiological.^{10,11} Our results must be viewed in this light since the load to failure might be different under cyclical loading in the early stages of rehabilitation.

The mean age of the specimens in our study was 79 years. This might limit our results to some degree, since a rupture of the distal tendon of biceps occurs in males in the fifth and sixth decades. The bone density of the radial tuberosity in these patients is probably higher, which might affect the loads to failure of the fixation techniques. However, the age of the specimens in other studies was comparable.

The influence of formalin fixation on the biomechanical properties of bone was investigated in some previous studies.²²⁻²⁴ All authors agree that formalin fixation alters the properties of bone by increasing collagen cross-linking, but there is disagreement about the degree to which formalin changes the biomechanical properties of bone. Nevertheless, testing fixed-cadaver samples cannot depict loads which occur in the clinical setting.

We found significant gender-related differences in the trabecular and cortical BMD of the radial tuberosity. The transosseous suture technique is still an adequate procedure with a sufficient load to failure even if it is below that of the Endobutton.

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