Orthopaedics & Traumatology: Surgery & Research 103 (2017) 165–169

Available online at
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com/en

Original article

Biomechanical strength and failure mechanism of different tubercula refixation methods within the framework of an arthroplasty for shoulder fracture

J. Fleischer[a,*], A. Schleyer[b], R. Nassutt[c], U. Grittner[d], I. Ojodu[e], S.J. Hopp[f]

[a] Department of trauma and orthopedics, Marien hospital, Am Hirschberg, 66606 St. Wendel, Germany
[b] Biomechanic laboratory, university of Lübeck, Lübeck, Germany
[c] Stryker Trauma, Kiel, Germany
[d] Department for biostatistics and clinical epidemiology, charité medical university, Berlin, Germany
[e] Department of orthopedic surgery, Cedarcrest hospital, Abuja, Nigeria
[f] Department of trauma, hand and reconstructive surgery, university hospital of Saarland, 66421 Homburg, Saarland

ARTICLE INFO

Article history:
Received 12 August 2015
Accepted 5 December 2016

Keywords:
Biomechanical tests
Tuberosity refixation
Failure mechanism
Shoulder fracture prosthesis
Suture materials

ABSTRACT

Background: Tuberosity repair in shoulder fracture prosthesis implantation still remains a challenge often leading to poor functional outcomes, despite a variety of materials and suggested suture patterns. We aimed to evaluate, which forces currently used suture and cerclage materials withstand and to assess whether they are useful with regard to stability of reconstruction of tuberosities and which failure modes they display.
Material and methods: Using sheep infraspinatus tendons with attached tuberosities three different suture materials (suture 1: Ethibond size 2; suture 2: Orthocord size 2; suture 3: Fiberwire size 5) and a 0.8 mm titanium cerclage wire were investigated. For each suture material as well as the cerclage wire 6 tests were carried out. A material testing machine was used to perform cyclic loading tests (20 mm/min, F_{min} = 50 N, F_{max} = 100 N, respectively after 50 cycles: F_{max} + 50 N until failure). Outcome measures and thus comparison criteria were the maximum holding force, number of cycles reached, total elongation of the system (tendon and suture) and qualitative appraisal and documentation of the mechanism of failure.
Results: Overall average maximum forces between the fixation materials differed significantly (P = 0.003), especially suture 3 (braided polyethylene coating, non-resorbable polyfile UHMW core) displayed superior results in comparison to the cerclage wire (P = 0.016). Although, primary elongation of the cerclage technique was significantly lower compared to the suture materials (P = 0.002). All tests showed a high initial lengthening and caused incision-like defects in the bone or tendon and led to failure and huge displacement of the tuberosities.
Discussion: Currently used suture and cerclage materials have a limited usefulness for refixation of tuberosities due to an increased risk of obstruction for bony consolidation.
Level of evidence: Basic science, Biomechanics.

1. Introduction

The current technological possibilities for the refixation of the tubercula to the prosthesis and the humerus shaft usually require postoperative positioning of the arm operated on in a thorax abduction orthosis as well as physiotherapeutic restrictions, respectively. Postoperative treatment protocols vary significantly [1]. Secure and load-resilient tendon and tuberosity reattachment is thus an elementary prerequisite for regaining functionality [2].

The specific problems arise from the tension forces in the tendons which occur immediately after surgery – before ingrowth processes are finished – and therefore may cause further destruction.

From a biomechanical point of view, there should be a high primary stability allowing for early rehabilitation as well as a secondary stability ensuring permanent connection. There is a paucity of literature considering the stability of different reconstruction methods [3]. Up to the present, the surgeon's alternatives consist of different suture techniques with resistant or bioresorbable

* Corresponding author.
E-mail address: joerg.fleischer1@freenet.de (J. Fleischer).

http://dx.doi.org/10.1016/j.otsr.2016.12.001
1877-0568/

materials, wire cerclages as well as (for some types of prosthesis) screw and pin fixation techniques. Suture repair of tuberosities has mechanical weaknesses which leads to failure [4]. Cerclages are recommended as supplementation for sutures or, in some prosthesis systems, for sole use for refixation. Examinations indicate that these reconstructions display higher stability at the refixated tubercula [5,6]. Dietz et al. for instance describe a significantly higher stability in prosthesis systems refixating with cerclage [5]. Krause et al. compared refixations of tubercula with non-resorbable sutures and cerclages as well as supplementary cancellous bone plasty [7]. Some publications indicate that the cerclage should ideally be arranged horizontal which leads to a better healing of the tubercula [8,9].

Therefore, the purpose of this biomechanical investigation was to determine the magnitude of the forces currently used suture and cerclage materials for tuberosity repair in fracture shoulder prostheses may withstand. Failure modes during biomechanical testing were documented. Hypothetically we assume, that cerclage wire reconstruction displays higher stability than reconstructions with various currently used suture materials.

2. Materials and methods

The present study was based on tensile tests of various suture materials and a titanium cerclage wires with a diameter of 0.8 mm in preparations of infraspinatus tendons with tubercula of sheep (German blackhead and texel sheep, average age: 12.7 months). No institutional review board approval was needed, because the tendons were freshly taken from the local butchery. Three different suture materials and one cerclage wire were tested. For each suture material as well as the cerclage wire 6 tests were carried out. Using a positioning device enabling a reproducible tuberculum size, the preparations were taken fresh from the shoulders of the sheep, wrapped in gauze, soaked in Ringer's solution and frozen at –20 °C. Before the tests began, the tendons were continuously defrosted at room temperature (20–22 °C).

An electromechanical material testing machine type UPM 145670 manufactured by the Ulm-based company Zwick with a 2 kN sensor (resolution 1 N) was used for the tests. The mechanical tests were performed under cyclic load (lower limit 50 N, after 50 cycles each the upper limit was raised by 50 N) until mechanical failure occurred. The testing software "Hysterese-, Relaxations- und Retardationsprüfung" (PC software Z1007, standard testing: DIN 53835) was used for the dynamic measurements with the following settings:

- constant testing velocity 20 mm/min;
- lower limit 50 N, first upper limit 100 N;
- lower limit constant, upper limit raised by 50 N after every 50 cycles until mechanical failure occurred.

To this sensor, a base plate bearing a fixture similar to a fin design in shoulder fracture prostheses was attached. On the opposite side, a mechanical clamp fixture was positioned for the free part of the tendon (Fig. 1). The suture ends were knotted to the center of the clamp fixture, comparable to the procedure during a shoulder prosthesis implantation. The tendons and tubercula were secured by a modified Mason-Allen suture using a crossed knot in two-hand technique.

For the refixation tests using cerclage wiring, the same procedure used during transosseous tubercula refixation in a prosthesis fin was employed. The wire was guided centrally through the bone and the drilled holes in the clamp fixture. The ends of the wire were twirled as it would also have been performed during surgery.

The following refixation materials were tested:

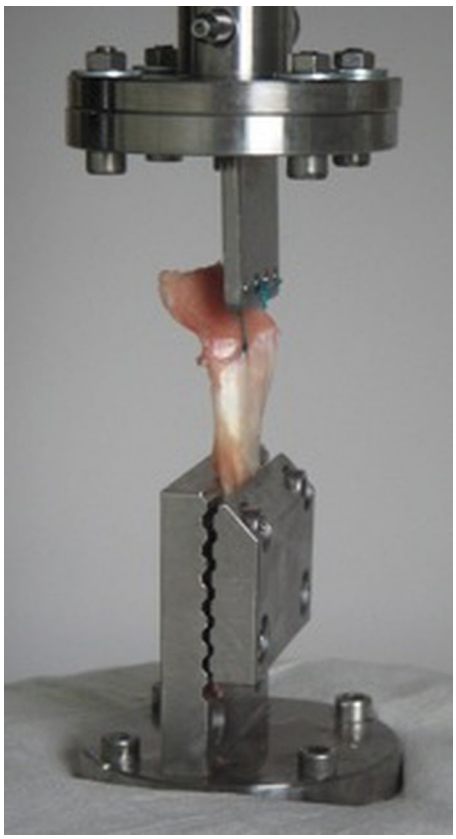

Fig. 1. Experimental set-up with fin-like design at the upper support and a clamp at the bottom base, with suture refixation.

- suture 1 – size 2 (USP), braided, polyester-coated, non-resorbable (Ethibond, Johnson & Johnson Medical GmbH, Ethicon Germany, Norderstedt, Germany);
- suture 2 – size 2 (USP), braided, ultra high molecular weight polyethylene (UHMWPE) with polydioxanone (PDS) component, partially resorbable (Orthocord, DePuy Synthes, Umkirch, Germany);
- suture 3 – size 5 (USP), braided polyethylene coating, polyfile ultra high molecular weight (UHMW) core, non-resorbable (Fiberwire, Arthrex, Naples, FL, USA);
- titanium cerclage wire with diameter 0.8 mm.

All sutures and cerclages were attached by the same surgeon.

Measurement values and thus comparison criteria were the maximum holding force, number of cycles reached, total elongation of the system (tendon and suture) and qualitative appraisal and documentation of the mechanism of failure.

For the explorative data analysis, average values and standard deviations (SD) for the maximum forces reached and the elongation are reported. A Kruskal-Wallis test was performed in order to compare the maximum force reached with regard to the different materials. For the comparison of the different suture materials and the cerclage wire, explorative post hoc analysis with the Mann-Whitney test was performed. Differences in primary elongation between the cerclage and the suture materials over the whole range of different loads were tested using linear mixed models by using all available data without aggregation. Statistical evaluation was performed using IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.