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# Mechanical properties of sutures for orthopedic surgery

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**Abstract**

The surgical sutures commonly used in surgeries have been assessed by characterizing their behaviour through tensile tests and determining which one has greater mechanical strength. Tensile tests of two different sutures have been performed. Tests have been performed under controlled conditions. The findings have been highlighted in this article.

**Keywords:** Suture, Surgery, Biomechanical, Anatomical, Mechanical tests

## Introduction

The main objectives of orthopedic surgeries are total biomechanical and anatomical restoration [1,2]. As such, there is a great variety of materials and methods for the treatment of dislocations and fractures, such as plates, screws, intramedullary nails, and pins, among others. Similarly, there are also several types and models of surgical materials for suturing and ligament repair. The literature recommends a variety of procedures to treat acromioclavicular joint injuries, including pin attachment through the acromioclavicular joint, coracoacromial ligament transfer using the Weaver-Dunn technique, fixation between the clavicle and the coracoid process, plaques, muscle transfer, and coracoclavicular binding with large-diameter non absorbable suture [3].

### Mechanical properties

The suture materials that maintain the surgical reduction of the acromioclavicular joint, for instance, in the coracoclavicular binding technique, need to withstand the tensile forces to which these ligaments are normally subjected to keep joint stability; this is especially true for the coracoclavicular ligaments, which are responsible for the vertical stability of the joint. In addition, the ideal suture material must be easy to handle, allowing effortless knots with minimal discomfort to the fingers of the surgeon, and presenting good fastening capacity [4]. The tensile strength aspect led us to study the properties of the various suture materials to define those most suited for orthopedic surgeries. The present study aims to evaluate the properties of the suture materials normally used in orthopedic surgeries and to characterize their behavior through tensile tests to determine those with the greatest mechanical resistance. Suture materials are used in orthopedic surgeries to close wounds, repair fasciae, muscles, tendons, ligaments, and joint capsules, and to cerclage or perform tension bands in certain fractures. The quality of the tissue repair depends on multiple variables, including characteristics of the tissue, properties of the suture material, and the surgical technique used. The choice of the suture material has important implications in tissue repair, so adverse surgical outcomes can be avoided by selecting the suture material according to the diagnostic.

Indication [5]. Traditionally, braided, and non-absorbable polyester sutures were used in surgery because they were more resistant and less likely to slip than absorbable polydioxanone (PDS) monofilament sutures. However, factors such as frequent suture uptore and reduced resistance led to the development of braided and nonabsorbable mixed sutures, consisting of polyethylene, polyester and PDS. Thus, several suture materials with these characteristics have emerged, such as *FiberWire*® and *HiFi*®,8 and their use became common in orthopedics. To maintain the surgical reduction of the acromioclavicular joint, for instance, as in the coracoclavicular binding technique, the sutures must withstand the tensile forces to which joint stability-involved ligaments are subjected; this is especially true for the coracoclavicular ligaments, responsible for vertical stability [6]. The literature shows that the intact coracoclavicular ligament supports a maximum traction force of 500+134 N, a stiffness of 103+30 N/mm, and an elongation at rupture of 7.7+1.9 mm, with no significant difference between the contribution of the trapezoid and conoid ligaments in this configuration. The isolated conoid ligament presented a maximum strength of 394+170N, a stiffness of 105+45N/mm, and an elongation of 7.1+2.1 mm, whereas the isolated trapezoid ligament presented a maximum strength of 440 +118 N, a stiffness of 84+18N/mm, and an elongation of 9.2+2.6 mm [7]. A study by Wüst et al. [8] aimed to compare the mechanical properties of the mixed braided nonabsorbable sutures *FiberWire*®, *Hi-Fi*®, Orthocord (DePuy Synthes, Rayham, MA, USA),® and Ultrabraid (Smith & Nephew, London, UK)® with conventional braided polyester suture, Ethibond®, and the PDS absorbable monofilament sutures, PDS II and *Ethicon*®; all of the sutures were #2. The initial hypothesis was that the polyester sutures are superior to the conventional braided polyester and degradable monofilament sutures regarding tensile strength and maximum elongation but require more configurations of stable knots. The tests were performed at 60mm/minute and at room temperature. Compared with the results obtained by Wüst et al., our work confirmed that mixed sutures had advantageous mechanical properties. However, mixed sutures have significant differences in their properties. All the mixed sutures tested without knots were 2-2.5 times more resistant than the polyester and PDS sutures. The tensile strength tests of non-knotted sutures showed that *FiberWire*® had the highest maximum rupture load value, 263 N, whereas *Ethibond*® had a maximum force of 110 N. These values are in line with those obtained in the present study: 240.17 N and 97.98 N for *FiberWire*® #2 and *Ethibond*® #2, respectively [8]. Wright et al. [9] studied the behavior of non-damaged and damaged sutures in tensile tests, as well as the wear of sutures passed through anchors. The tensile force was applied at 90° and at 180° while the suture was drawn through the anchor hole. A total of 20 samples, 10 damaged and 10 intact of each #2 suture from different materials were tested: PDS, *Ethibond*®, Tevdek (Teleflex Medical OEM, Gurnee, IL, USA)®, *Orthocord*® and *FiberWire*®, always in a dry environment at room temperature. From the tensile tests for the rupture of the suture, the modulus of elasticity and tensile strength were determined. The tensile test until rupture was performed in a Bionix MTS 858 test machine at a speed of 60 mm/minute. Among the non-damaged sutures, *FiberWire*® had the highest values of maximum rupture load (255.3 + 10.37 N), followed by *Orthocord*® (214.22+11.63 N), PDS (141.22+7.62 N), *Tevdek*® (116.61 + 1.13 N) and *Ethibond*®(114.58+1.58 N).

These values are in line with those obtained in the present study, which were 240.17 N and 97.98 N, for *FiberWire*® #2 and *Ethibond*® #2, respectively [9] Jhamb et al. studied the biophysical properties of the high strength suture materials *FiberWire*® *#2, Orthocord*® *#2, HiFi*® *#2, and Ultrabraid*® #2, using light microscopy, scanning electron microscopy, and mechanical testing.10 Different types of sutures without knots were loaded until rupture in a Bionix 858MTS test device with a 2kN loading cell to register load displacement curves. The samples tested were 5cm in length and the speed used in the test was 10 mm/minute. The *Ultrabraid*® suture presented the maximum strength of 264N in traction tests, followed by *FiberWire*® with 238 N, *HiFi*® with 215N, and *Orthocord*® with 212N. The rupture force for *FiberWire*® was 240.17N, and 221.96N for *HiFi*®; these values are in line with those obtained by Jhamb et al. [10]. The review of these literature reports showed different speeds adopted for suture tensile tests, ranging from 10 mm/minute to 60mm/minute. The speed of 20mm/minute is at a level between these values and so it was adopted by us. We believe that this small speed difference had no relevance in the results. Our study demonstrated the superiority of polyethylene, polyester and PDS mixed sutures (*FiberWire*® *#2 and HiFi*® *#2*) over braided, multifilament polyester sutures covered with polybutylate (*Ethibond*® *#5 and #2). FiberWire*® *#2 and HiFi*® *#2* presented, respectively, a mean rupture strength of 240.17N and 213.38N; while *Ethibond*® *#5.* resisted until 207.38 N and *Ethibond*® #2, until 97.98N. No suture material presented a tensile strength higher than that described in the literature for the coracoclavicular ligaments. However, the present study did not use sutures like in vivo coracoclavicular binding techniques, but assays with isolated suture samples fixed in metal claws [11]. Therefore, new tensile studies must be performed with biomechanical models representing the anatomy of the shoulder and of the coracoclavicular ligaments in a simplified way, allowing a better comparison between the resistance of the ligaments and bindings with suture materials.

## Conclusion

The more recent braided non absorbable polyester sutures are superior to the braided conventional polyester sutures. Among the sutures tested, the most resistant to tensile forces is Fiber *Wire*® *#2*, followed by *HiFi*® *#2. Ethibond*® *#5 and Ethibond*® *#2* were shown to be less resistant, the latter being the least resistant.

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