Orthopaedics & Traumatology: Surgery & Research 102 (2016) 293–296

Available online at ScienceDirect www.sciencedirect.com

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Original article

The Nice knot as an improvement on current knot options: A mechanical analysis

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ARTICLE INFO

Article history:
Received 13 March 2015
Accepted 12 January 2016

Keywords:
Shoulder surgery
Rotator cuff repair
Nice knot
Nicky's knot
Suture
Ethibond®
Ultrabraid
Mechanical testing
Biomechanical study
Arthroscopy

ABSTRACT

Purpose: There is currently a wide range of suture knots used in rotator cuff repair. The purpose of this study was to compare a new type of self-locking sliding knot called the Nice knot to the self-locking and sliding Nicky's knot.

Methods: Nice knots and Nicky's knots were tied and subjected to mechanical testing including a pure traction stress and a series of dynamic stresses. Both knots were tied using standard braided suture and reinforced braided suture. The responses to these stresses were measured in the amount of elongation of the knot, maximum effort needed for failure, stiffness of construct and dynamic stiffness.

Results: With both knots the standard suture had a lower amount of elongation during the dynamic tests than the reinforced braided suture. The reinforced braided suture showed superior results during maximal effort in the pure traction tests. An increased failure rate occurred due to elongation when a dynamic stress was applied to the reinforced suture in both knot types. During dynamic testing the Nice knot showed a decrease in the amount of elongation ($P < 0.001$).

Conclusions: The Nice knot provides a sliding locking knot option which can decrease the risk of elongation during dynamic stress.

Level of evidence: Basic Science Study, Biomechanical Study.

1. Introduction

The resistance of a knot to fail depends on several criteria including the behavior of the knot itself [1,2] and suture material [3]. With the advent of high strength poly blend sutures, the weak link in knot biomechanics appears to the knot itself.

The purpose of this study was to test a new type of sliding and self-locking knot called the Nice knot [4] by comparing it to the Nicky's knot [5]. We hypothesized that the Nice knot is mechanically superior knot to the Nicky's knot in preventing knot slippage and, therefore, failure of knot construct.

2. Materials and methods

This was an in vitro mechanical study. Two types of sliding and self-locking knots were tested: (1) the Nicky's knot [5] (Fig. 1), and (2) the Nice knot [4] (Figs. 2 and 3). The Nice knot consists of two loops; therefore, to allow a reliable comparison, it was compared to a set of two stacked Nicky's knots. All knots were performed by the same surgeon (PC) on a 30 mm diameter cylinder without the use of a knot pusher or a cannula, to avoid any friction and subsequent risk of deterioration. Both knots were tied with a so-called standard braided suture (n° 2 Ethibond® from Ethicon, Somerville, NJ), and a high strength polyblend suture (Ultrabraid® from Smith and Nephew, Memphis, TN). All knots were cut to leave a 3- to 5-mm tag. Each knot and suture type test combination was conducted ten times with two types of experiments: a pure static traction and a dynamic study. In the former, the following parameters were recorded with a machine (Lloyd LR 30 K, Segensworth, Frameham, England) as results for this manipulation.

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http://dx.doi.org/10.1016/j.otsr.2016.01.005
1877-0568/

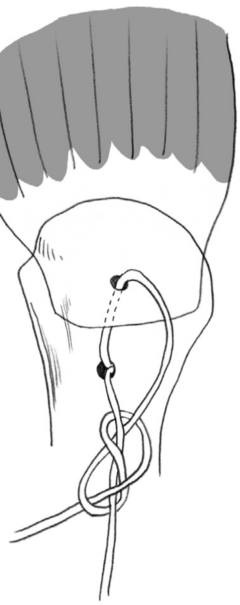

Fig. 1. Illustration of a Nicky's knot.

2.1. Preload

A 5-N preload was selected to remove slack from the system at a load well below those seen clinically in the shoulder.

2.2. Load to failure

Elongation was defined as stretching that occurred during knot testing. Previous studies have indicated that 3 mm is the point where tissue apposition is lost [6–10]. Any traction curvature consists of a non-linear charging period for weak loads, followed by a linear part representing the purely elastic domain of the suture/knot combination being tested. Elongation was measured beginning at the end of the non-linear period in order to evaluate the elastic period. The maximum value of movement in mm was recorded at maximum effort. Second, the maximum effort before failure was defined as highest value on the vertical axis before rupture or slippage occurred. Third, stiffness, defined by the force divided by the amount of elongation in mm of the construct was studied. Stiffness calculations of the construct do not accurately reflect changes in the knot construct during its entire loading period. We, therefore, calculated a dynamic stiffness by integrating the curve force, defined as the force squared in Newton divided by the displacement in mm. This was achieved by squaring the ratio of the curve force and dividing it by the amount of elongation.

2.3. Cyclic loading

According to dynamic study, two sets of monotonically increasing peak load levels [11], were performed depending on the number of loops. For constructs using a single loop, the plateaus consisted of 50 cycles at 50 Newton, followed by 50 cycles at 100 Newton, another 50 cycles at 150 Newton, 50 cycles at 200 Newton, 50 cycles at 250 Newton and then finally a 100 cycles at 300 Newton. For constructs with a double loop, the plateaus were doubled (Newton value). Stresses applied during this part of the study were intended to simulate the stresses that the knot construct will experience during the post-repair rehabilitation period. Only elongation and stiffness of the construct were recorded during these dynamic tests.

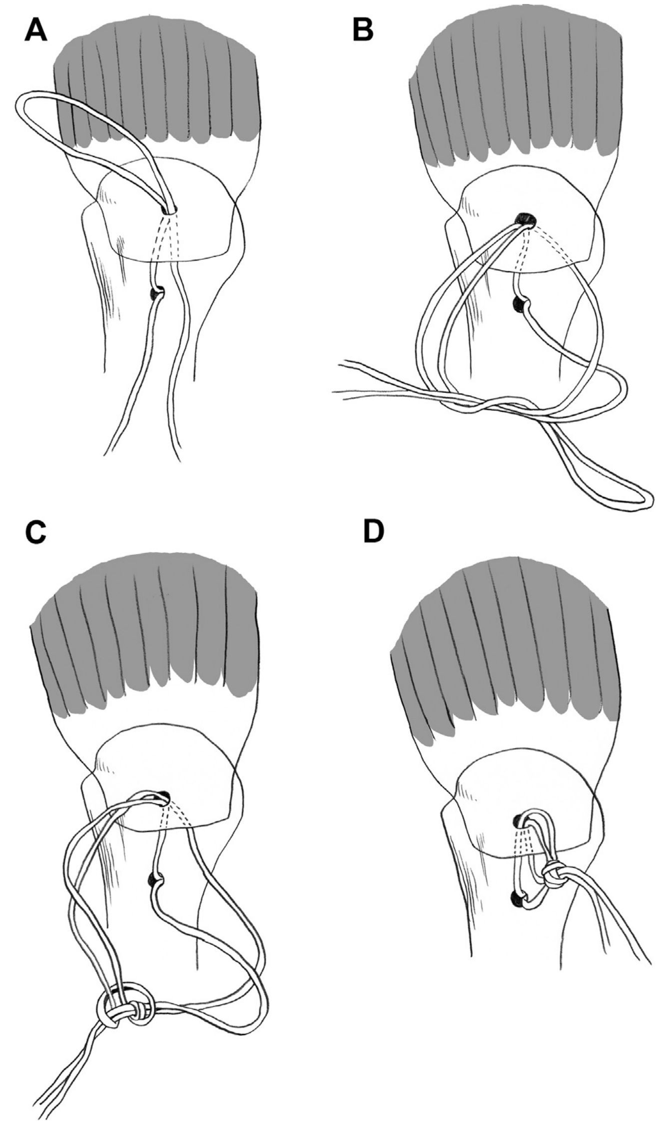

Fig. 2. Illustration of Nice double-suture knot used for an anchor repair. (A) A doubled-over suture is passed trough the rotator cuff creating a suture loop and (B) a single half-hitch is thrown. The 2 free limbs are passed through the loop. (C) The knot is dressed and slid down by pulling the 2 free limbs apart (the 2 limbs can also be pulled back towards the surgeon together or alternately). (D) The tightened knot.

2.4. Statistical analysis

Continuous data were described by mean, standard deviation, and range. The data was collected from results generated by the testing unit. Analysis of the amount of elongation, force and stiffness was performed. Differences between these measurements were tested using two-way Anova model followed by Fisher's test. Statistical analysis was performed using StatView® for MacOX (Informer Technologies Inc., Redwood City, CA, USA). Data was expressed as mean ± standard deviation. $P < 0.05$ indicated a significant difference.

3. Results

3.1. Load to failure

The results in pure static traction are summarized in Tables 1 and 2. When tied with Ethibond® the Nice knot tied had