Available online at www.scholarsresearchlibrary.com

Scholars Research Library

European Journal of Sports & Exercise Science, 2017, 5 (2): 16-22

(http://www.scholarsresearchlibrary.com)

Scholars Research Library

ISSN: 2278-005X

Nice Knot and Surgical Knot Security in Reverse Shoulder Arthroplasty with Different High Strength Suture Materials - An *In Vitro* Mechanical Study

Dhrumil M Patel[1*], Ashish S Babhulkar[2], Nishanth P Kurian[3]

[1]*Department of Joints and Sports Medicine, Navrang Hospital, Vadodara, India*

[2]*Department of Shoulder and Sports Injury, Deenanath Mangeshkar Hospital, Pune, India*

[3]*Department of Joins and Sports Medicine, Deenanath Mangeshkar Hospital, Pune, India*

ABSTRACT

Purpose: *Tuberosity Repair in Reverse Shoulder Arthroplasty (RSA) for proximal humerus fractures with deficient Rotator Cuff (RC) is a challenging task. With the advent of newer generation high strength hybrid suture materials, the entire burden of the repair lies on the Knot Security. We hereby want to study the biomechanical strength and tensile load to failure (LTF) of the most commonly performed the surgical knot and the nice knot with different suture materials available in the market.*

Methodology: *This study included the use of second and third generation non-absorbable hybrid polyethylene core sutures. The knot tying methods that were tested included the Surgical knot and the Nice Knot. The instrument, used to measure the tensile load to failure of each of these knots using different sutures, was Autograph-Shimadzu. 3 mm slippage or opening of the suture loop was taken as knot failure.*

Results: *Knot security varied based on the method used to tie it. Average LTF for surgical knot was 0.316 KN against 0.582 KN for Nice Knot. Nice Knot was most secure with Striated Ultrabraid (0.968 KN LTF).*

Conclusion: *Knot-suture combinations affect strength of fixation. In our study, statistically significant difference was found between the knot security by Surgical and Nice techniques (p value<0.044, t-value 2.130). Nice knot had higher load to failure and hence should be favored over surgeon's knot, when using newer generation suture materials, for a robust tuberosity repair.*

Keywords: Suture strength, Knot security, Tensile load to failure (LTF), Nice knot, Surgical knot, Tuberosity repair, Reverse shoulder arthroplasty (RSA)

INTRODUCTION

Proximal humerus fracture is the third most common fracture to occur in elderly population after vertebral and hip fractures [1]. Most fractures (70-80%) are displaced or only minimally displaced and they are treated conservatively [1]. The role of tuberosity repair is critical in Hemiarthroplasty for fractures and also repairs of tuberosities during osteosynthesis of proximal humerus fractures [1-3].

Reverse shoulder arthroplasty (RSA) is an excellent procedure in elderly patients >70 years with comminute proximal humerus fractures with severe osteoporosis and deficient rotator cuff [2]. The important step in this procedure is the anatomical repair of the lesser and greater tuberosities by virtue of which internal and external rotation is restored. The repair of tuberosities is a very challenging task [2-4]. It is carried out routinely by passing non-absorbable sutures through holes drilled in humeral shaft and the tuberosities. A standard surgical knot with three alternate half hitches is used to tie the threads of the sutures passed through the tuberosities [2-4]. The most common suture used is second generation high strength non-absorbable suture-ethibond (Ethicon, Somerville, USA)

[4]. We have been using a special double-stranded dynamic locking "Nice knot", described by Boileau et al., for repair of the tuberosities [5]. Tuberosity migration or detachment is a disastrous consequence leading to loss of movement and power in patients who have undergone hemiarthroplasty or reverse shoulder replacement [5]. The entire burden of the repair lies on the knotting technique used and the type of the suture used in the procedure. Different suture materials are available to the surgeon with differences in tensile strength, knot security, cost and tissue reaction. Often, the suture selection is not based on scientific evidence but on personal preference or availability of material in operation theatre.

In our study, we tested the nice knot and the standard surgical knot for their security and tensile load to failure (LTF) using different high strength non-absorbable suture materials routinely used in orthopedic practice today.

METHODS

Suture materials used in our study included: Ultrabraid - White and Striated (Smith and Nephew, London, UK), Fiberwire (Arthrex, Naples, US), Orthocord (Depuy-Mitek, Warsaw, Indiana), Ethibond no. 2 and no. 5 (Ethicon, Somerville, US). We tested two knotting techniques for each suture - Nice knot and Standard surgical knot for failure on dynamic sequential loading.

Each type of suture was tied with Nice knot (double-looped dynamic locking knot) and Standard surgical knot (alternate three half hitches) [6-8]. Each knot was tied by the same surgeon in an identical manner on a fixed diameter post (Figure 1).

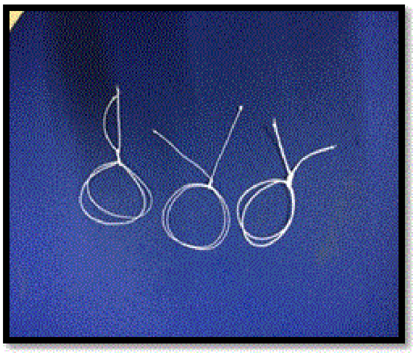

Figure 1: Suture loops under study

The diameter of the loop formed after tying the knot was also kept identical in all cases.

The tensile load to failure of each knot was tested in a Materials Bio-Lab. The instrument used was Autograph, Shimadzu from Japan which can test loads from 1 N to 300 KN (Figure 2).

Figure 2: Autograph, Shimadzu machine to test tensile load to failure of each knot

Serial continuous dynamic tensile load was applied to the suture loop, till breakage point, without directly impacting the knot at a uniform speed of 10 mm/min, which was standard for all tested sutures and knots.

We tested the tensile load to failure of all sutures and also obtained graphical readings of individual testing's (Figures 3 and 4).

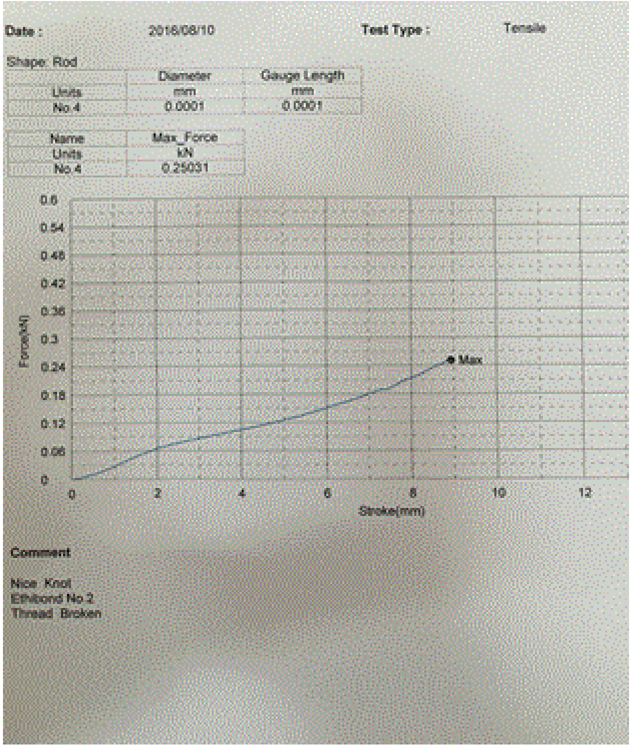

Figure 3: Graph showing tensile load to failure of Nice Knot with Ethobind no. 2

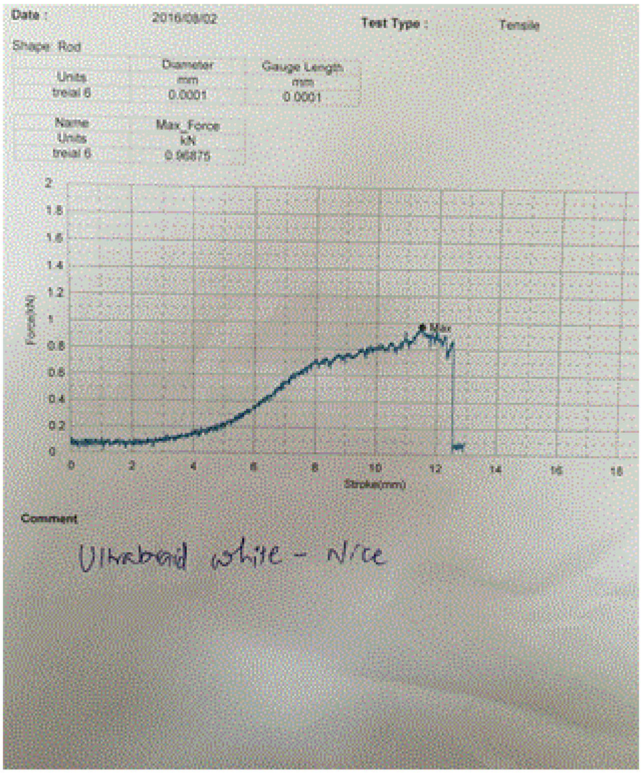

Figure 4: Graph showing tensile load to failure of nice knot with Ultra braid-White suture

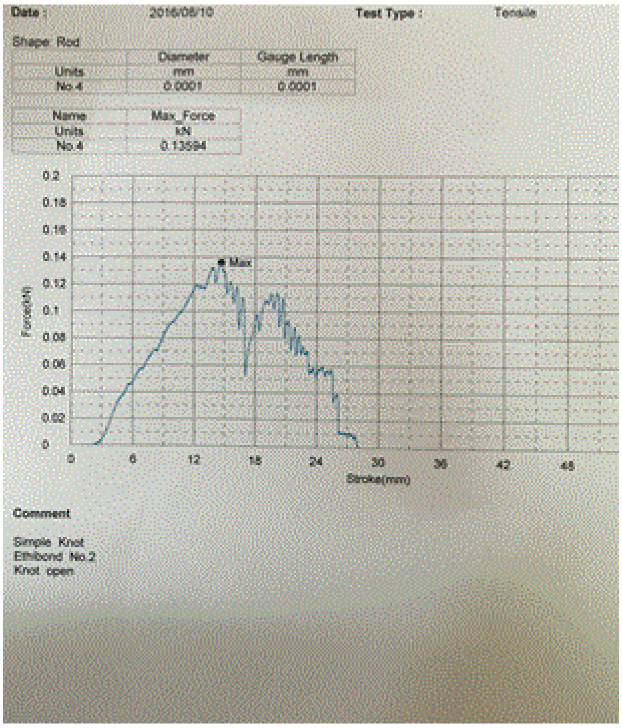

Figure 5: Graph showing tensile load to failure of surgical knot with Ethibond no 2.

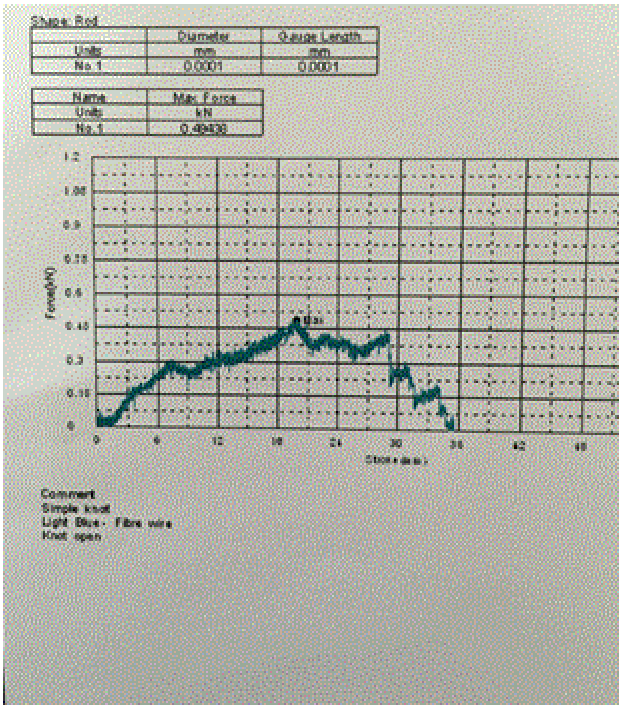

Figure 6: Graph showing tensile load to failure of surgical knot with fiber wire

Defining knot failure: 3 mm slippage or opening of the suture loop was taken as knot failure. Mode of ultimate failure, opening of the loop past clinical failure, was also recorded [9] (Figures 5 and 6).

OBSERVATIONS AND RESULTS

There was variability in the Knot security between the two tested techniques.

The following Table 1 shows the tensile load to failure of the knot- suture combinations tested in our study:

Table 1: Tensile load to failure of knot-suture combinations in our study

LTF (KN) – Surgical vs. Nice Knot Readings		
Suture Name	**Type of Knot**	**Load to Knot Failure**
Orthocord (Depuy)	Surgical	0.273 KN
	Nice	0.581 KN
Ultrabraid-Striated (S&N)	Surgical	0.492 KN
	Nice	0.617 KN
Ultrabraid-White (S&N)	Surgical	0.343 KN
	Nice	0.968 KN
Fiber Wire(Arthrex)	Surgical	0.494 KN
	Nice	0.523 KN
Ethibond #2 (Ethicon)	Surgical	0.135 KN
	Nice	0.25 KN
Ethibond #5 (Ethicon)	Surgical	0.156 KN
	Nice	0.555 KN

Average LTF for the standard surgical knot was 0.316 KN against 0.582 KN for Nice Knot (Figure 7).

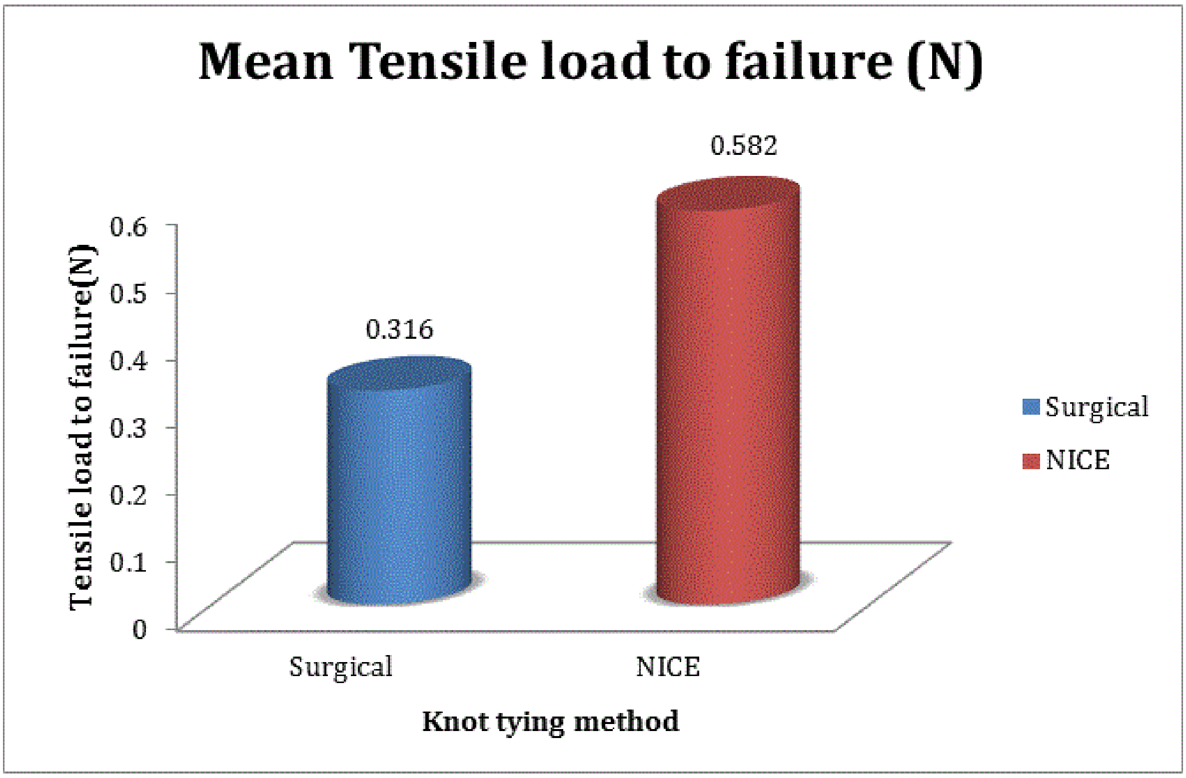

Figure 7: Mean tensile load to failure (LTF) – Surgical vs. Nice knot

Nice Knot was most secure with Striated Ultrabraid (0.968 KN LTF) and least secure with Ethibond no 2 (0.25 KN LTF). Standard surgical knot was the weakest with Ethibond No.2 (0.135 KN LTF) and it was strongest with fiber wire (0.494 KN LTF).

The following is a line diagram of surgical v/s nice LTF for various suture materials (Figure 8).

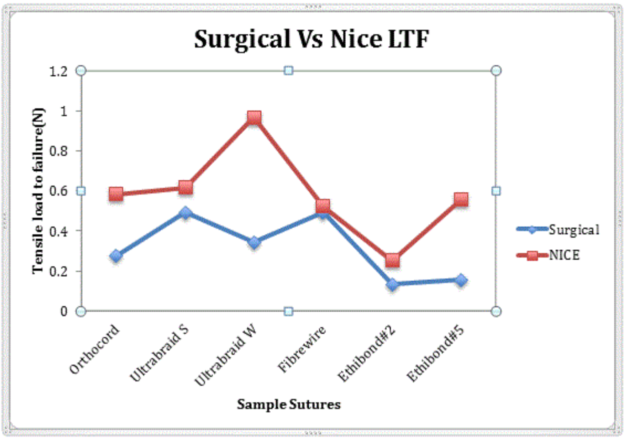

Figure 8: Line diagram of tensile load to failure of Surgical vs. Nice knot for various suture materials

There is a slight difference between two sutures of Ultrabraid-striated and white. Each super suture was significantly stronger than Ethibond. Ethibond #2 remained the weakest suture on tensile loading for both the types of knots.

DISCUSSION AND ANALYSIS

In vivo, there are many factors affecting the strength of fixation like bone quality, tendon length, muscle quality, suture anchor, suture type, knot type. A few of these features are beyond the surgeon's control such as bone & muscle quality. The Surgeon's choice of suture may also be limited by its availability in the operation theatre. However, the choice of knot can be under the Surgeons' control. *In vitro* we found that knot-suture combinations affect the strength of fixation [7,9]. Different knotting techniques are used in surgical practice like surgical knot, square knot, sliding knot and non-sliding knot [9]. Nice knot is a specialized double-looped dynamic locking knot, which is used, in special situations like tuberosity repair in RSA and open cuff repair [6,7].

An ideal knot should be easy to place, reproducible, with good loop security and knot security. Loop security refers to the capacity to keep the suture loop closed once tension is released on the post strand and the knot is tied. Knot security refers to slip resistance under distractive load once the knot is completed and locked with successive half-hitch throws [9]. According to our study the third generation super sutures are far stronger than conventional Ethibond #2 which uniformly was the weakest link. It thus makes more sense to use super suture for critical repairs like the tuberosity repair. Within the knots that were compared, nice knot had a stronger LTF vis a vis all sutures tested across the study. This association was statistically significant. The Nice knot had higher load to failure and hence should be favored over surgeon's knot, when using newer generation suture materials, for a robust tuberosity repair.

We have used dynamic loads on the suture loop, which resembles the loads on the shoulder repair during initial rehabilitation after operation. Previous studies have used only static loads to test the strength of the construct [9]. The results were statistically tested using two independent sample t-test (Table 2):

Table 2: Statistical analysis of LTF of surgical and nice knot with different high strength suture materials

	Surgical Knot LTF(KN)	NICE Knot LTF(KN)
Orthocord	0.273	0.581
Ultrabraid Striated	0.492	0.617
Ultrabraid White	0.343	0.968
Fibrewire	0.494	0.523

Ethibond #2	0.135	0.25
Ethibond #5	0.156	0.555
Min	0.135	0.25
Max	0.494	0.968
Average	0.316	0.582
SD	0.157	0.23
Median	0.308	0.568
p-value	0.044	
t-value	2.13	

P value was 0.044 and T value was 2.130, which meant that difference between the two knotting techniques was statistically significant.

In terms of our limitations - previous studies on suture knots have tested load to failure of various sliding and non-sliding knots. We have tested only the nice knot and standard surgical knot on various sutures used in orthopedic practice. This is an *in vitro* study, which takes into consideration only the suture and knot type for assessing the strength of repair. *In vivo*, there is biochemical and biomechanical loads on the knot-suture construct, which could not be assessed with this study. Furthermore, many of the sutures tested in this study can cut through bond-and Ethibond sutures may actually cut through bone less! Cutting through bone impacts all factors tested in this model–knot security, load to failure, and slippage.

The strength of our study was robust dynamic testing on Shimadzu machine, which gave us detailed graphs of suture decompensation over mm/s, defining the behaviors of each suture. Since this is an objective comparison study between like materials and dissimilar materials, the results are valid and have clinical application.

CONCLUSION

Ethibond though favoured commonly, for tuberosity repair has been demonstrated as the weakest suture of all the ones tested. The nice knot was stronger across the board for all sutures tested. This association was statistically significant. Since the study revealed higher LTF with Nice against the standard surgical Knot, it is recommended that nice knot be used for critical repairs such as tuberosity repair and open cuff repairs.

REFERENCES

[1] Murray, I.R., et al., *J Bone Joint Surg Br*, **2011**. 1: p. 1-11.
[2] Jones, K.J., et al., *Curr Rev Musculoskelet Med*, **2013**. 6(1): p. 63-70.
[3] Cadet, E.R., *J Am Acad Orthop Surg*, **2012**. 20(1): p. 17-27.
[4] Panayiotis, D., Georgios, K. and Andreas, P., *J Bone Joint Surg Am*, **2007**. 89(8): p. 1700-1709.
[5] Boileau, P., et al., *J Shoulder Elb Surg*, 2002. 11(5): p. 401-412.
[6] Hill, S.W., et al., *Int J Shoulder Surg*, **2016**. 10(1): p. 15-20.
[7] Collin, P., et al., *Orthop Traumatol Surg Res*, **2016**. 102(3).
[8] Loutzenheiser, T., et al., *Arthroscopy*, **1995**.
[9] Marturello, M., et al., *Vet Surg*, **2014**.