Fabrication and Tissue Anchoring performance of Nylon and Polypropylene Barbed Surgical Sutures

[1]Hui Cong, [2]Simon Roe, [3]Peter Mente, [4]Gregory Ruff, and [1, 5]Martin W. King
[1]College of Textiles, [2]College of Veterinary Medicine, [3]Dept. Biomedical Engineering, North Carolina State University, Raleigh, NC 27695, [4]Vilcom Circle, Chapel Hill, NC 27514, [5]Donghua University, Songjiang, Shanghai, China.

Introduction: Barbed surgical sutures are approved by the US Food & Drug Administration for use in plastic and cosmetic surgical procedures [1-3]. The main advantage of the barbed surgical suture is that the barbs project out, penetrate, and anchor with surrounding tissue all along the suture's length, thus eliminating the need for tying a knot. While this barbed suture technology is widely accepted clinically for skin wound closure, its suitability in other applications, such as tendon repair, has yet to be proven [4].

Objectives: The current study had two objectives: i) to fabricate barbed sutures from different polymers with different barb geometries, and ii) to evaluate the anchoring performance of the prepared sutures in skin and tendon tissues using an *in vitro* pullout test [5].

Materials and Methods: Nylon and polypropylene (PP) size "O" (diameter = 0.38 mm) monofilament sutures (Ethicon Inc.) were fabricated into barbed sutures using a special barb cutting instrument designed and assembled in our laboratory. Based on previous recommended barb geometries for skin and tendon tissues, two cut depths, namely 40% and 50% of the filament suture, were used respectively. The target cut angle of 170° and frequency of 2.5barbs/cm were kept constant. Barb geometry was measured using a Nikon H550S optical microscope at 40x magnification. The average barb cut angle and cut depth measurements were obtained from the microscopic images using an image analysis software called MB Ruler (Table 1). The tensile properties of both the unbarbed and barbed sutures were tested on a TestResources 311Q tensile testing machine using modified test method ASTM D2256. The anchoring performance of the prepared PP barbed sutures in skin and tendon tissues was determined using the *in vitro* pullout test illustrated in Fig 1. Fresh porcine dermis and superficial distal flexor tendons were harvested from the NCSU School of Veterinary Medicine and used within 12 hours.

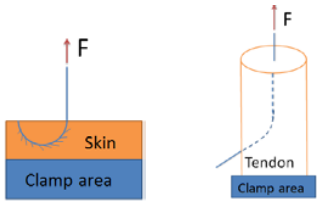

Fig 1. Suture/skin and suture/tendon pullout test methods

Results: The ultimate tensile stresses of the original unbarded and barbed sutures are shown in Table 1. The results reveal that the reduction in failure stress is not related linearly to the cut depth, but may be associated with the different crystallinity in the inner and outer layers of the original unbarbed suture. The barb configurations of the nylon and PP sutures with a 50% cut depth are shown in Figure 2. It appears that the PP barbs project out more from the suture surface and therefore are more likely to mechanically engage and anchor with surrounding tissue compared to the nylon barbs. This phenomenon may be explained by nylon's lower Young's Modulus, which was found to be 5.33±0.15 MPa, compared to that for PP, which was 10.45±0.42 MPa.

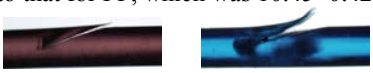

Fig 2. Light microscopic images of nylon (left) and PP (right) barbed sutures

Table 1. Measured cut angle, cut depth and ultimate tensile stress of barbed and control sutures

Sample #	Cut angle (°)	Cut depth (%)	Ultimate stress (MPa)
Nylon control	-	-	412.15±8.09
Nylon	167.61±1.65	38.6±5.1	197.34±8.76
Nylon	164.87±1.53	51.1±4.8	167.67±15.89
PP control	-	-	410.29±3.84
PP	168.48±1.16	36.7±3.3	256.53±13.53
PP	167.49±1.00	46.4±3.2	223.20±17.19

The average anchoring performance of the PP 40% cut depth barbed suture in skin and the 50% cut depth in tendon tissue was found to be 6.13N and 12.04N respectively. Typical force/time plots of the *in vitro* suture/tissue pullout test method are shown in Fig 3.

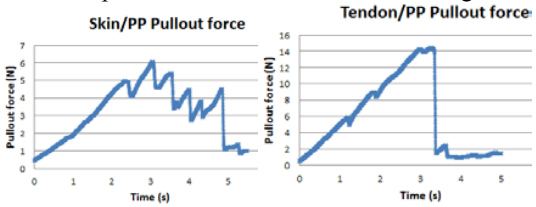

Fig 3. Changes in suture/tissue pullout force with time

Conclusions: Different barb configurations were successfully fabricated for both nylon and PP monofilament sutures by using a specially designed mechanical cutting instrument. The reduction in ultimate tensile stress of the barbed sutures is not linearly related to the cut depth. The Young's Modulus of the suture material may influence the ability of cut barbs to project out and so engage with the surrounding tissue. Despite having a lower ultimate tensile stress the PP 50% cut depth barbed suture gave a superior tissue anchoring performance in tendon tissue than the "stronger" PP 40% cut depth barbed suture in skin tissue.

References:

[1] Ingle NP. and King MW. Journal of Donghua University. 2007;24: 213-218.
[2] Ruff G. Aesthetic Surgery Journal. 2006; 26:620-628.
[3] Greenberg JA. Rev Obstet Gynecol. 2010; 3: 82–91.
[4] Parikh P., Davison, SP. and HigginsJP. Plastic and Reconstructive Surgery. 2009;124:1551-1558
[5] Ingle NP. and King MW. Journal of Biomechanics. 2010;43: 302-9.