

## Tissue Holding Performance of Knotless Absorbable Sutures

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**Introduction:** Sutures continue to be the biomaterial of choice for wound closure and tissue approximation. However, the clinical performance of a suture still depends on the security of the knot. The presence of knots at the wound site can lead to suture breakage, knot slippage, suture extrusion, infection, dehiscence and excessive inflammatory response leading to ischemia and scarring.<sup>1</sup> Attempts to overcome these deficiencies with knotless sutures in the past have gained little clinical success.<sup>2,3</sup> More recently, we have reported the development of a novel knotless suture featuring bi-directional barbs around an absorbable monofilament (Figure 1).<sup>4</sup> In addition, we have demonstrated its wound closure efficacy in a canine model.<sup>1</sup>



Figure 1. Knotless Suture Showing Region with Barbs Lying in One Direction Only

**Objective:** Given the ability to maintain wound apposition is a critical factor in wound healing, the objectives of this study were to (i) assess the tissue holding capacity and gap minimization of barbed sutures compared to conventional knotted sutures, and (ii) to determine whether the barb geometry influences the suture's biomechanical performance.

**Materials and Methods:** Knotless sutures with three specific barb geometry designs (A, B & C) were fabricated from polydioxanone monofilaments (size 2-0) by creating two equal and opposing groups of barbs distributed about the mid-point of the suture. The barb geometries were characterized by four different parameters: cut angle ( $\theta$ ), cut depth ( $D_c$ ), and calculated cut length ( $L_c$ ) for the individual barbs (Figure 2),

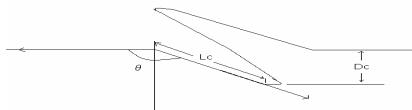


Figure 2. Geometry of Individual Barb for Knotless Suture

and the distance between cuts. Using an Optem Zoom microscope with an attached video camera, the cut angle and cut depth were measured at 32 different locations at a magnification of 22x. The cut length was then calculated with the following equation. The distance between individual barbs was then visualized and measured at a magnification of 4x.

$$L_c = \frac{D_c}{\sin(180 - \theta)}$$

The tissue holding capacity of the sutures was tested using an *in vitro* mechanical tester to determine the force required to induce a 2 mm gap orthogonal to a wound which had been closed as follows. The incision, 1 cm long, was created in a skin simulant (Darra chamois), and closed with (i) a barbed suture using a modified running stitch (Figure 3), and

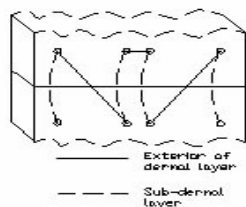


Figure 3. Modified Running Stitch Technique

(ii) a commercial 4-0 monofilament polydioxanone suture (PDS II) with three simple interrupted stitches as the knotted control. (Because of the smaller effective diameter of a barbed 20 suture, its straight pull strength is equivalent to the knot pull strength of a size 4-0 regular

suture<sup>4</sup>.) Both suturing techniques had six crosses along the wound. Ten sutured tissue specimens of each suture type were tested on a tensile tester (Sintech) with a 250 lb. load cell, a 5 cm gauge length, and a crosshead speed of 5 cm/min. Each test continued until a 2 mm gap occurred at any point along the incision line. The test was filmed using a Sony® Hi8 video camera so that the time and force required to produce the 2 mm gap could be precisely measured after each test with the aid of an image analysis system.

**Results and Discussion:** The means and standard deviations of the barb geometries for the knotless sutures with low (A), medium (B) and high (C) cut angles are shown in Table 1:

Parameters	A	B	C
Cut Angle, $\theta$	155.9 $\pm$ 2.0	159.9 $\pm$ 2.1	163.3 $\pm$ 2.1
Cut Depth, $D_c$ (mm)	0.14 $\pm$ 0.02	0.15 $\pm$ 0.03	0.15 $\pm$ 0.03
Cut Length, $L_c$ (mm)	0.34 $\pm$ 0.06	0.44 $\pm$ 0.06	0.52 $\pm$ 0.07
Distance b/w Cuts (mm)	0.94 $\pm$ 0.08	0.94 $\pm$ 0.10	0.95 $\pm$ 0.08

Table 1 Barb Geometry Measurements

The means and standard deviations of the forces required to induce a 2 mm gap are shown in Table 2:

Samples	Tissue Holding Capacity (kgf)
A	2.57 $\pm$ 0.75
B	2.83 $\pm$ 0.85
C	2.32 $\pm$ 0.63
Control	1.56 $\pm$ 0.43

Table 2. Tissue Holding Capacity

Statistical analysis using two way ANOVA and t-tests ( $p < 0.05$ ), found that there was a significant difference between the barbed and knotted sutures, but not between the three designs of barbed sutures. These results support the claim that barbed sutures spread out the holding force evenly along the length of the suture, whereas localized tension and pressure are associated with knotted sutures.

**Conclusions:** The *in vitro* model has demonstrated that (i) the tissue holding capacity of the three bi-directional barbed sutures was superior to that of the conventionally knotted sutures. (ii) Based on the current selection of geometrical parameters a higher biomechanical performance is suggested with a medium cut angle for the barbed sutures. Further studies are required to model the micro-biomechanical performance of the barbs of knotless sutures in different tissues. This will facilitate the design of knotless sutures with optimum tissue holding capacity for various clinical applications.

### References:

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