Prevention of knot slippage with the use of cyanoacrylate glue: a mechanical study

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ABSTRACT

Purpose. To assess the effect of cyanoacrylate glue on knot slippage and strength in vitro.

Methods. Ethibond 3/0 was tested using a tensile tester. A single drop of cyanoacrylate glue was applied to the knots. Seven knot configurations (10 samples each) were tested: (1) a surgeon’s knot (S) plus 4 square throws (+4) without glue (control group), (2) S plus one square throw (+1) without glue, (3) S+1 with glue, (4) S with glue, (5) S+1 wet post-tie without glue, (6) S+1 wet pre-tie without glue, and (7) S+1 wet pre-tie with glue. Wet sutures were immersed in normal saline for 24 hours prior to knot tying. Wet pre- and post-tie sutures were immersed for one minute prior to knot tying and tensile testing, respectively. Outcome measures were the mode of failure (knot slippage or suture snapping) and the ultimate tensile strength.

Results. All knots without glue failed owing to knot slippage, except for the controls, whereas all knots with glue failed owing to suture snapping. The ultimate tensile strength was significantly higher in knots with glue and controls than in knots without glue. The ultimate tensile strength did not differ significantly between S+4 without glue and S with glue (p=0.48), indicating that glue could reinforce knots and reduce the number of throws needed. Wet suture is protective against failure (p<0.01).

Conclusion. Cyanoacrylate glue may have clinical applications for flexor tendon repairs for which a reduced knot size is advantageous.

Key words: cyanoacrylates; sutures; tensile strength

INTRODUCTION

Knot slippage at a suture end may cause suture failure owing to untying. In addition, the suture itself stretches under load; different suture materials have different properties pertaining to knot slippage and material stretching. Particularly in flexor tendon repairs, suture lengthening and knot slippage may result in gapping at the repair site. A critical gap of 4 mm can cause failure of the construct.1 For flexor
tendon repairs, especially in zone II, a smooth glide in the flexor sheath is important; the optimal suture material should be strong, resistant to creep, not prone to slippage (even with a minimal amount of throws), and not bulky (as to hamper movement). However, there is no material that fulfills all these criteria.

In our hospitals, a synthetic polyfilament—Ethibond 3/0 (Johnson and Johnson, UK)—is commonly used for flexor tendon repairs. It requires multiple knot throws (usually 4) to avoid slippage and to secure a surgeon’s knot (a double forward throw with a reversed single throw). Despite being stable, this knot is quite bulky and can impede motion. We therefore assessed the effect of cyanoacrylate glue on knot slippage and strength in vitro (in both dry and wet situations) to determine whether a reduced knot size (fewer throws) with cyanoacrylate could maintain the knots without increasing the risk of failure (knot slippage or suture snapping).

MATERIALS AND METHODS

Ethibond 3/0 was tested using a Zwick Roell Tensile Tester (Zwick Testing Machines, Leominster, Hereford, UK). A single drop of cyanoacrylate glue (Loctite Superglue, Henkel Corporation, Connecticut, US) was applied to the knots. Seven knot configurations (10 samples each) were tested: (1) a surgeon’s knot (S) plus 4 square throws (+4) without glue (control group), (2) S plus one square throw (+1) without glue, (3) S+1 with glue, (4) S with glue, (5) S+1 wet post-tie without glue, (6) S+1 wet pre-tie without glue, and (7) S+1 wet pre-tie with glue. Wet sutures were immersed in normal saline for 24 hours prior to knot tying. Wet pre- and post-tie sutures were immersed for one minute prior to knot tying and tensile testing, respectively.

To avoid inter- and intra-investigator variability, reproducible knots were made by the tensile tester by tying each throw around a metal cylinder at a predetermined rate (0.5 inches/min) at 80% of ultimate knot break tension (33.1 N). Suture ears were cut to 3 mm. The rate of load application was set at 5 inches/min. Outcome measures were the mode of failure (knot slippage or suture snapping) and the ultimate tensile strength. Groups were compared using Student’s t test.

RESULTS

All knots without glue failed owing to knot slippage, except for the controls, whereas all knots with glue failed owing to suture snapping (Table). The ultimate tensile strength was significantly higher in knots with glue and controls than in knots without glue. The ultimate tensile strength did not differ significantly between S+4 without glue (control) and S with glue (41.4±0.6 vs. 41.2±2.3 N, p=0.48, Student’s t test), indicating that glue could reinforce knots and reduce the number of throws needed. Wet suture (both pre- and post-tie) is protective against failure (21.8±2.3 and 17.5±2.3 vs. 5.7±0.8 N, p<0.01, Student’s t test).

DISCUSSION

Cyanoacrylate (C5H8NO2) is a monomer that rapidly undergoes exothermic polymerisation on contact with air. The double bonds present in the monomer become single bonds, causing them to link together in enormous chains, changing the liquid to a hard brittle acrylic plastic. Complications associated with cyanoacrylate injection are mainly thrombotic (cerebral stroke, pulmonary embolisation, portal vein embolisation, splenic infarction and coronary emboli). These are unlikely to occur with careful application on sutures for tendon repairs. Cyanoacrylate has been widely used by plastic surgeons for skin closure. Nonetheless, according to the International Programme on Chemical Safety, the

<table>
<thead>
<tr>
<th>Knot configuration</th>
<th>Mean±SEM ultimate tensile strength (N)</th>
<th>Failure mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgeon’s knot (S) plus 4 square throws (+4) without glue (control)</td>
<td>41.4±0.6</td>
<td>Suture snapping</td>
</tr>
<tr>
<td>S plus one square throw (+1) without glue</td>
<td>5.7±0.8</td>
<td>Knot slippage</td>
</tr>
<tr>
<td>S+1 with glue</td>
<td>33.0±1.9</td>
<td>Suture snapping</td>
</tr>
<tr>
<td>S with glue</td>
<td>41.2±2.3</td>
<td>Suture snapping</td>
</tr>
<tr>
<td>S+1 wet post-tie without glue</td>
<td>17.5±2.3</td>
<td>Knot slippage</td>
</tr>
<tr>
<td>S+1 wet pre-tie without glue</td>
<td>21.8±2.3</td>
<td>Knot slippage</td>
</tr>
<tr>
<td>S+1 wet with glue</td>
<td>40.8±1.6</td>
<td>Suture snapping</td>
</tr>
</tbody>
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the toxicological database for cyanoacrylate is limited. It was not practical to assess its implications for human health in terms of carcinogenicity, genotoxicity, and reproductive toxicity.

Knot slippage depends on the type of knot, the length of cut 'ears', the moisture content, and the friction of the suture material. Cyanoacrylate glue has beneficial effects on suture knot properties (for polydioxanone). Knot slippage is associated with its moisture content. To simulate physiological conditions, suture properties immersed in saline have been assessed. The goal of flexor tendon repair is to achieve a strong repair that can withstand the forces of postoperative mobilisation, thus decreasing extrinsic adhesion formation and increasing intrinsic healing capability. A strong repair relies on a robust knot entailing multiple throws. For Ethibond 3/0 sutures, the use of cyanoacrylate glue to reduce the number of throws and hence the knot size without adversely affecting tensile strength or likelihood of failure has clinical applications for flexor tendon repairs, in which a reduced knot size is advantageous. Further research is needed prior to its clinical use, particular with respect to the effect of cyanoacrylate-reinforced knots on tendon glide within a flexor sheath model.

Limitations of our study were its in vitro pilot study nature and the problem of knot heterogeneity. Inter- and intra-investigator variability affects knot performance. To minimise this variation, reproducible knots were tied mechanically around a metal cylinder using the Tensile Tester. The same suture was used, assuming that all Ethibond suture packs have the same friction coefficient. However, the atmospheric moisture content was not controlled.

DISCLOSURE

No conflicts of interest were declared by the authors.

REFERENCES