Single-Pass Four-Throw Pupilloplasty Knot Mechanics

To the Editor:

Ashley[1] described "knot" as a term that comprises hitches, bends, splices, and true knots wherein a hitch fastens a rope to another object. The term knot is applied to stoppers at the end of a rope to keep that end from slipping. Knot tying is an important aspect of the Scout program and the timber hitch technique is used to attach a single length of rope to a log of wood or any cylindrical object (**Figures 1A-1D**). A mathematical theory of hitches has been proposed[2] that makes predictions that are correct when tested empirically. We present a brief overview of how the single-pass four-throw (SFT) pupilloplasty[3] knot stays in place.

The authors described SFT pupilloplasty[3] as a method wherein the suture forms a helical structure of thread that presses across itself and holds the iris tissue firmly. With clinical experience, we realized it was a self-locking and self-retaining method of performing pupilloplasty. Jack Holladay, MD (personal communication, November 18, 2018) was the first to suggest the resemblance of the helical loop of the SFT technique to the timber hitch and, on exploring this concept, we realized that it was indeed a timber hitch that had been adapted unknowingly (**Figures 1E-1F**). The Siepser[4] and modified Siepser[5] slipknot have been described and the authors developed the SFT as a modification of the modified Siepser slipknot wherein a second pass is not taken and there is no securing loop to form a true knot.[3] Ashley[1] explained various types of knot formation, including the slipknot and timber hitch. Minute differences are present and the knot formation changes with the addition or omission of a twist or a loop.

Various principles and models have been created that explain what causes a hitch to hold or loosen.[2] If T2 is the force exerted toward the center and T1 is the force that acts to pull the iris tissue toward the periphery, the SFT loop will hold if T2 > T1 (**Figure 1G**). With four throws, T2 > T1; hence the SFT loop holds and with fewer than four throws, the SFT loop loosens and opens up as T2 < T1. With the increase in throws, theoretically more friction is created and more energy is needed to approximate and slide the loop internally.[2] Four throws have been found to be optimal to prevent opening of the loop and create a self-locking system that accidentally correlates with the timber hitch method. Due to the turning and crossing of a hitch, a chain of inequalities is created that relates the tension in different sections of a hitch.[2]

To the best of our knowledge, opening of the SFT loop has not been reported in any case when optimal

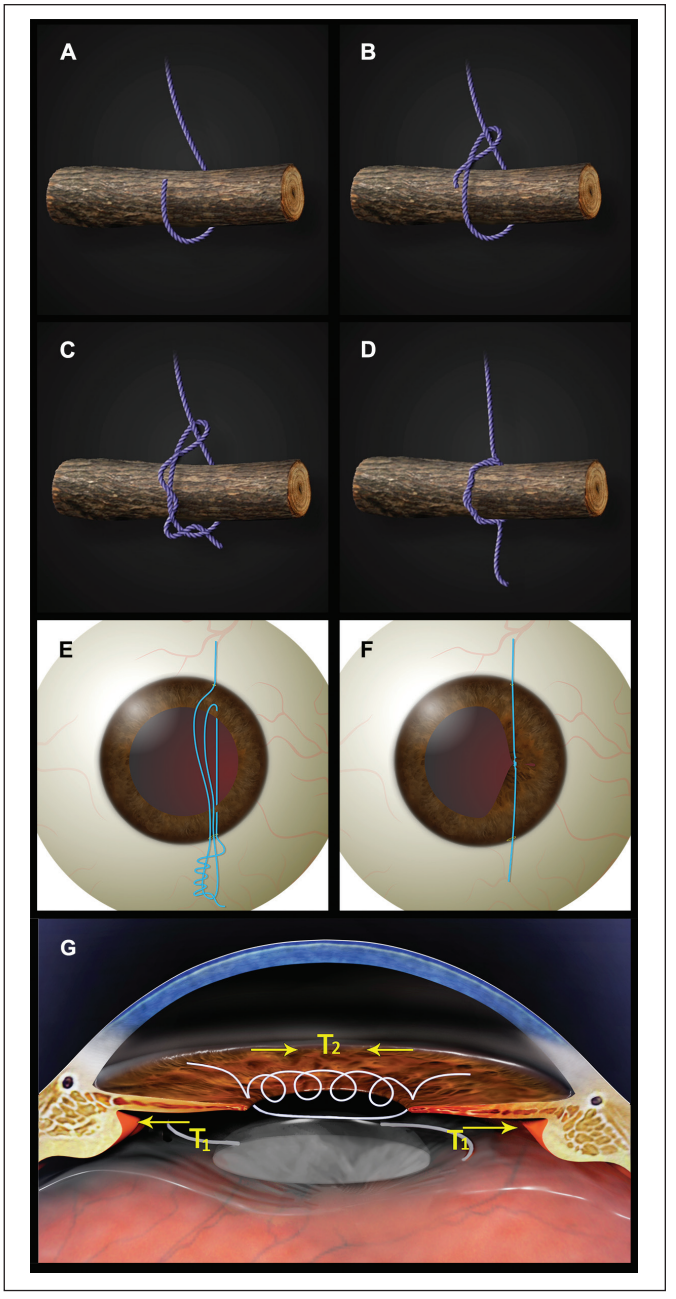

Figure 1. Animated description of timber hitch and single-pass four-throw (SFT) pupilloplasty depicting the loop formation on a log of wood along with the mechanics of SFT pupilloplasty. (A) A rope is passed around the log of wood. (B) One end of the rope is crossed over itself and a loop is created. (C) The rope is further tucked under itself and is looped around. (D) The rope end is pulled and the hitch engulfs the log circumference. (E) A loop of suture is withdrawn after approximation of the proximal and distal portion of the iris tissue. The suture end is passed through the loop. This is similar to the clinical stage depicted in Figures 1A, 1B, and 1C. (F) The suture ends are pulled and the loop slides inside, approximating and holding the iris tissue. This simulates **Figure 1D.** (G) Mechanics of SFT pupilloplasty. The image depicts the forces T2 and T1 exerted on the iris tissue. T2 is the frictional force that acts toward the center of the pupil and T1 is the force exerted by the peripheral iris tissue. With four throws, T2 > T1 (hence the SFT loop holds its position), whereas when T2 < T1 (< four throws), the SFT loop opens up.

four throws are taken in situ. The SFT technique is similar to the timber hitch, is easy to remember and tie, and can be adopted and emulated by surgeons with minimal effort.

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