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Intracorporal knot tying techniques – which is the right one?

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ABSTRACT

Introduction: Intracorporal knot tying (ICKT) and suturing in minimal invasive surgery (MIS) represent a key skill for advanced procedures such as Nissen fundoplication. Suture placement under tension is particularly challenging during MIS. The aim of this study was to compare ICKT of the common surgical square knot and the slipping knot on a simulated suture placement under tension. Furthermore, we objectively assessed the surgical skill of ICKT following 3 hours of hands-on training.
Methods: A box trainer was used for laparoscopic knot tying with predefined openings. A 12 cm suture was placed in central view. We used a standardized silicon suture pad with a defined wound dehiscence of 0.5 cm and marked needle entrance and exit targets next to the incision. Twenty participants were divided among three groups in this study. The first group ($n = 5$) consisted of senior physicians. The second group ($n = 5$) was made up of surgical residents in the first to fourth year of residency training. The third group ($n = 10$) contained medical students between their third and sixth year of study without any prior experience in laparoscopic surgery. Residents and students received a 3-hour hands-on training in surgical square and slipping knot tying. Each participant tied two of each knot types before and after the hands-on training. Knot quality, performance, total time and suture placement accuracy were the parameters for assessment in this study.
Results: The knot quality was greater for the slipping knot compared with the square knot in all groups. There were no significant intragroup differences in knot tying performance, task time and accuracy of both suture methods. Students and residents improved in all categories for both ICKT techniques after training.
Discussion: We compared ICKT of the surgical square knot with the slipping knot on a simulated suture placement under tension during a standardized training program for medical students and surgical residents. In our study, the average quality of the slipping knot was significantly superior to the square knot in all participants. The knot tying performance, task time, and accuracy of students and residents after hands-on training were not significantly different between both suture methods. This suggests that the two ICKT techniques have similar properties except the quality advantages of the slipping knot. Although students and residents improved in all categories for both ICKT techniques after training, they did not achieve expert level for task times and accuracy.
Conclusions: In this pilot trail, the quality of the slipping knot was superior to the surgical square knot during intracorporal suturing under tension. Our 3-hour sequential training program improved laparoscopic suturing and knot tying skills in all participants. Our findings suggest that training centers for MIS using validated training programs should be a continuous and integral part of surgical education.
Level of evidence: USPSTF Level III: monocentric, prospective, pilot Trial.

Intracorporal knot tying (ICKT) and suturing in minimal invasive surgery (MIS) represent a key skill for advanced procedures such as Nissen fundoplication [1]. Suture placement under tension is particularly challenging during MIS. Different intracorporal knot types with varying properties and training modalities have been developed, including virtual reality simulators and box trainers. In addition, trainee surgeons can develop their skills safely and effectively outside the operating room using live animals [2–4]. For optimal ICKT results, it is important to use the right knot tying technique. But which is the right one? The aim of this study was to compare ICKT of the common surgical square knot and the slipping knot on a simulated suture placement under tension. Furthermore, we objectively assessed the surgical skill of ICKT following 3 hours of hands-on training.

1. Methods

1.1. Materials

A box trainer (Karl Storz GmbH, Tuttlingen, Germany) was used for laparoscopic knot tying with predefined openings. Two working ports

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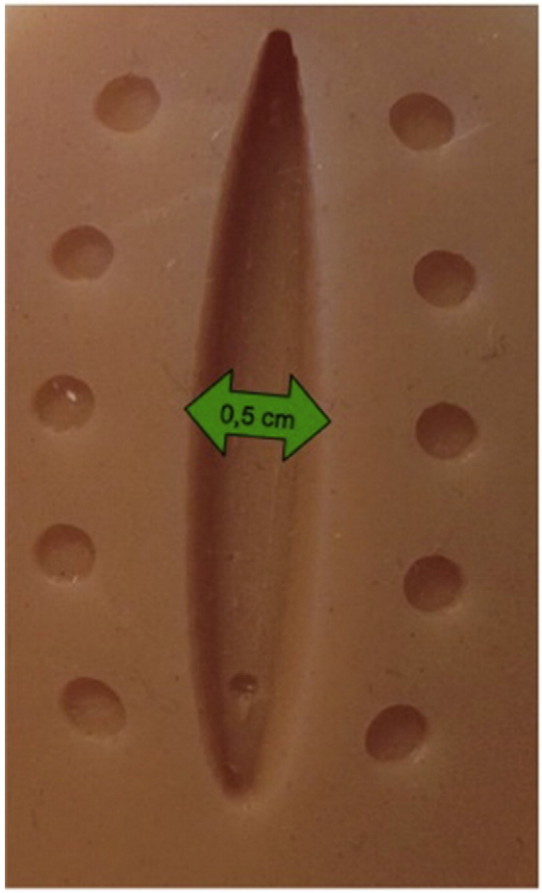

Fig. 1. Silicon suture pad (iSurgicalPad, iSurgicals, England).

were placed through these openings at 30° angles either side of a midline-positioned 10-mm-diameter laparoscope with 30° optics (Karl Storz GmbH, Tuttlingen, Germany). Two lockable laparoscopic needle holders (Karl Storz GmbH, Tuttlingen, Germany) were inserted into the lateral ports. The laparoscope was fixed with a clamp at a set angle and focal length that allowed the participant to work independently. The laparoscope was connected to a camera box (Telecam Pal; Karl Storz, GmbH & Co. KG, Tuttlingen, Germany) and a Xenon 300 light source (Karl Storz GmbH, Tuttlingen, Germany). The image was visualized on a 14-inch monitor (Sony Trinitron, Tokyo, Japan) placed at a defined height directly in front of the proband. A video-recording device was connected to the camera box to record the laparoscopic procedure for later assessment. A 12 cm suture (Ethibond 3/0, Excel, RB 1, 17 mm, 1/2c, Ethicon, Johnson and Johnson, Somerville, NJ) was placed in central view. We used a standardized silicon suture pad with a defined wound dehiscence of 0.5 cm (iSurgicalPad, iSurgicals, England) and marked needle entrance and exit targets next to the incision (Fig. 1) [1]. The suture pad was fixed with double-sided adhesive tape onto the bottom of the box trainer.

1.2. Participants

Twenty participants were divided between three groups in this study. The first group ($n = 5$) consisted of senior physicians with previous experience of >100 laparoscopic interventions and >20 laparoscopic sutures. The second group ($n = 5$) was made up of surgical residents in the first four years of residency training. These participants had previously performed >10 laparoscopic interventions and <20 laparoscopic sutures. The third group ($n = 10$) contained medical students between their third and sixth year of study without any prior experience in laparoscopic surgery.

1.3. Study design and setting

This was a monocentric, prospective, pilot trial in the MIS training center of the Department of General, Visceral, and Transplantation Surgery at Heidelberg University. To compare both ICKT methods, we used a standardized surgeon's square knot and the slipping knot.

Surgeon's square knot: The needle was driven through the tissue then a left-hand needle holder was used to pass the needle to the right hand. A C-loop was made (Fig. 2a) and tied first with a counterclockwise double-wrap throw using the left-hand and starting above the positioned C-loop. Suture ends were pulled apart. The needle was then passed to the left-hand needle holder to make an inverse C-loop. A second clockwise single-wrap throw was made using the right-hand from above the positioned inverse C-loop (Fig. 2b). The third counterclockwise single-wrap throw was made in the same way as the first throw.

Slipping knot: The first and second throws were performed in a similar way as the surgeon's square knot, except for an initial single-wrap throw. Suture ends were pulled apart but left loose to allow slipping (Fig. 3a). This knot was converted to the slipping position by pulling the needle-side suture with the left-hand (Fig. 3b). The needle-side suture was held under tension and the knot was slipped down to the base using the tip of the right-hand needle holder. The suture ends were pulled apart to re-tighten the knot, re-converting it to a non-sliding knot. The third counterclockwise single-wrap throw was performed in the same way as the first throw. Residents and students received a 3-

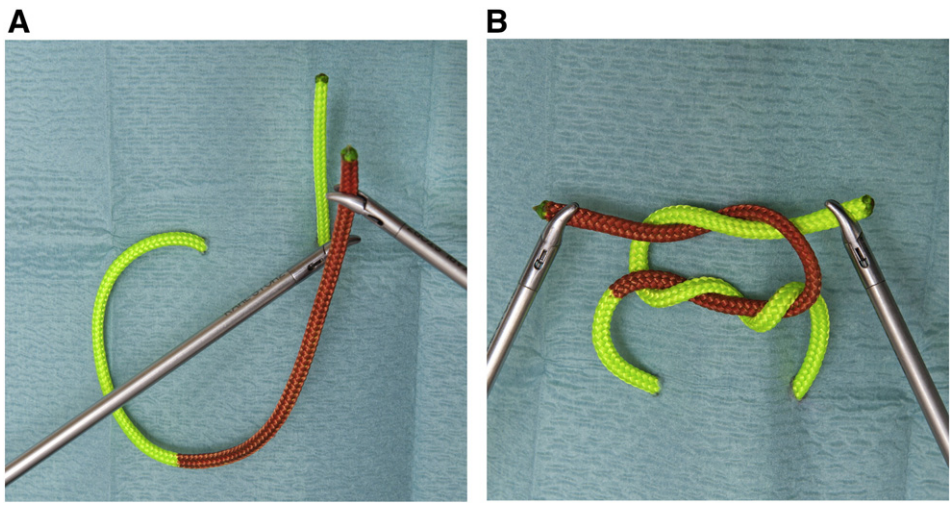

Fig. 2. a. Surgeon's square knot using the "C-loop" technique. b. First double-wrap throw followed by the second single-wrap throw.