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Bursting strength evaluation after different types of mesh fixation in laparoscopic herniorrhaphy

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Abstract
Background: In laparoscopic inguinal herniorrhaphy, meshes commonly have been fixed with a stapler. Recently, a new mode of fixation using a helical fastener has been introduced. The purpose of this experimental study was to compare the stability achieved by various types of mesh fixation.
Methods: In 20 human cadavers, polypropylene meshes 10 × 15 cm in size were fixed in both groins by using either a helical fastener or a hernia stapler (4.8 mm). The mesh was fixed with 2, 4, and 8 elements and stressed with a dynamometer until the prosthesis ruptured. A paired and two-sided Student's *t*-test was used for statistical evaluation.
Results: With the helical fastener, the mesh could be fixed always at the desired site. However, with the stapler, it was not possible to fix the mesh in the pubic bone or, at times, in the Cooper's ligament. When two fixation elements were used, the mesh fixed by the helical fastener was able to withstand a median load of 34 N (range 23–53 N), and that fixed by the stapler 7.5 N (range 3–12 N; $p < 0.001$). When four fixation elements were used, the mesh fixed by the helical fastener was able to withstand 70.5 N (range 53–80 N) and that fixed by the stapler 17.5 N (range 4–25 N; $p < 0.001$). With the use of eight elements, the mesh fixed by the helical fastener withstood 127 N (range 84–156 N) and that fixed by the stapler 32.5 N (range 15–59 N; $p < 0.001$). Thus, in all cases the helical fastener was significantly more stress resistant. The main reason for detachment of the mesh was tissue disruption or deformation of the fixation elements. Only when a stress of more than 130 N was applied did the mesh tear in two cases.
Conclusions: The stress-bearing capacity (shear force resistance) of a mesh fixed by a helical fastener is up to four times that of a mesh fixed by a stapler. Therefore, the helical fastener provides significantly more stable fixation and will be able to protect the patient better from recurrent hernias caused by mesh migration.

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Key words: Helical fastener — Laparoscopic herniorrhaphy — Mesh fixation — Shear forces — Statics

Since the use of large prostheses in laparoscopic herniorrhaphy began, the incidence of recurrent hernia has been on the decrease. This is because the synthetic material covers all weak sites of the groin [7]. In addition, the most commonly used prostheses are able to withstand much more than the expected maximum load on the site [6, 13]. Therefore, the only cause of recurrent hernia is mesh migration [4, 10]. The transabdominal preperitoneal (TAPP) technique was devised to overcome this problem. In this technique, the mesh is fixed in the tissue with endoclips. A further recent development involves the use of titanium coils. In this study these two modes of fixation were evaluated regarding their ability to withstand shear forces (Fig. 1). Furthermore, the ideal fixation sites were determined in terms of anatomy [15] and statics. Because the strength of fixation also depends on the number of fixation elements [3], an increasing number of elements were used in this experimental study.

Methods

In 20 human cadavers (ages 45 to 85 years; 5–24 hours postmortem), in which there had been no previous surgery in the groin and whose records mentioned no history of inguinal hernia, a median laparotomy was performed, and both groins were prepared. After incision of the peritoneum, the following structures were exposed: the symphysis, pubic tubercle, ramus superior of the pubis, Cooper's ligament, inguinal ligament, epigastric vessels, spermatic cord, and testicular vessels.

In one groin, a Prolene mesh measuring 10 × 15 cm (Ethicon, European Logistics Centre, 66, rue de la Fusée, B-1130 Brussels, Belgium, MP 1510) was fixed with the helical fastener (Auto Suture Company, United States Surgical Corporation, Norwalk, Connecticut 06856, USA, Pro Tack 5 mm). On the contralateral side, the mesh was fixed with the stapler (Auto Suture, Endo Universal 65° 12 mm). The fixation points were determined in a previous series of experiments.

For each method of fixation, only those anatomic locations that permitted secure fixation in at least 75% of the experiments were taken into consideration, because it was known from clinical experience that fixation

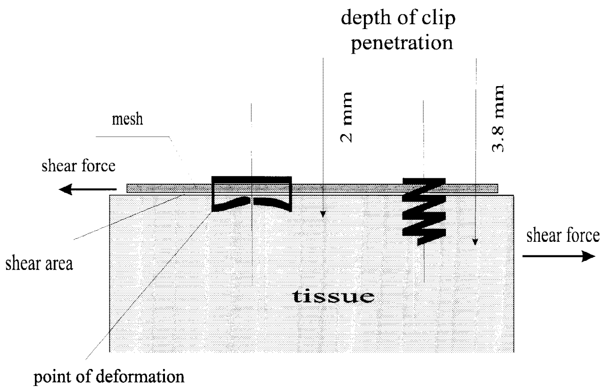

Fig. 1. Comparison of endoclip and coil fixation of the mesh.

elements not firmly adherent in tissue are difficult to remove. In some cases, they cannot be removed without tissue damage.

The same number of fixation elements were used on the medial and lateral sides. The polypropylene mesh was fixed with an increasing number of elements (2, 4, and 8). Alternate groins were used for each fixation method. After the mesh was fixed, it was stressed by using a dynamometer (accuracy 0.5 N), in the direction of maximum load (from the upper margin of the mesh in cranial direction), and the capacity of the mesh to withstand shear force was assessed.

In addition to determining the level of load, the mode of detachment also was documented. A paired and two-sided Student's *t*-test was used for statistical calculation. Finally the technical function of both applicators was compared.

Results

Even the preliminary experiments revealed differences between the modes of fixation. The helical fastener was able to penetrate all proposed fixation sites without difficulty. Therefore, the mesh could be fixed at all sites considered suitable in terms of anatomy and statics (Fig. 2). Furthermore, the functional performance of fixation by the helical fastener was superior.

In 320 fixations (together with the preliminary experiments), a technical problem was encountered in only two cases (0.6%). With the stapler, however, the mesh could not be fixed securely to the bone in all cases. The same was true for fixation in tendon. The clips had to be detached and refixed in 29 cases (9.1%) to achieve an optimal experimental setting. With the exception of the pubic bone, the fixation points used in both methods were identical (Fig. 2).

Using two elements, mesh fixation with the helical fastener resulted in a stability of 34 N (range 23–53 N), whereas that with the stapler was 7.5 N (range 3–12 N). With four elements, the stability achieved with the helical fastener was 70.5 N (range 53–80 N), whereas that with the stapler was 17.5 N (range 4–25 N). With eight elements, the helical fastener produced a stability of 127 N (range 84–156 N) and the stapler, 32.5 N (range 15–59 N). Statistical evaluation showed that in each of the three experimental series, the helical fastener was significantly superior to the stapler ($p < 0.001$) (Fig. 3).

The main reason for disruption of the prosthesis was tissue tear or deformation of the fixation elements (Fig. 4). A tear in the polypropylene mesh at the site of the fixation element was registered in only two cases (0.4%), at shear forces greater than 130 N.

Discussion

In laparoscopic herniorrhaphy, preperitoneal mesh placement as a "new first line of defence" significantly enhances the strength of the abdominal wall. Synthetic prostheses are stable enough to withstand physiologic load without disruption [6, 13]. Therefore, recurrent hernias can occur only when excessively small prostheses are used [10, 11], or in the event of mesh migration [10]. Migration is caused by shear forces. To counter this problem in the total extraperitoneal (TEP) technique, often the fixation of the prosthesis is based solely on intra-abdominal pressure.

In our recent study of static calculations, we showed that in the TEP technique, hernia openings with a diameter smaller than 4 cm can be treated without recurrence risk only by a sufficient mesh overlap [5]. In hernias larger than 4 cm, the fixation should be supplemented by additional elements (stapler or helical fastener) to avert migration of the prosthesis [5].

By way of contrast, in the TAPP technique the prosthesis is fixed with a varying number of different fixation elements [2]. The stability of the prosthesis increases strongly in direct proportion to the ingrowth of connective tissue [3]. Therefore, especially in the immediate postoperative period, the prosthesis is exposed to the risk of migration.

For fixation, in addition to the stapler, which has been in use a long time, a helical fastener is now available. These two instruments differ both in diameter and in their respective mechanism of fixation. With the helical fastener, elements 4 mm in diameter are screwed into the tissue at a depth of 3.8 mm to fix the mesh. Therefore, the instrument used to introduce the elements must have an external diameter of 5 mm. In contrast, the hernia stapler requires an incision of 12 mm, with the additional risk that trocar incisions of this size may cause trocar hernias [9]. The staples of the stapler are longitudinal and 7 mm in size, and their depth of penetration is 2 mm. When the staple is embedded in the tissue, its inclination is altered by 90°.

The aim of the current study was to compare the stability achieved by these two methods of mesh fixation in the critical postoperative period. This was efficiently evaluated in an experimental setting on human cadavers studied a few hours postmortem. The reason for using recently deceased cadavers was as follows. As in patients who recently have undergone surgery, the stability of the prosthesis in the tissue of such cadavers depends solely on the adhesive force of the fixation. The fixation sites used in both procedures were identical, except for the pubic bone. Here, the mesh could be fixed by the helical fastener, but not by the stapler. With the stapler, the mesh was fixed in Cooper's ligament or the falciform ligament instead of the pubic bone.

In both groups, the stability increased in direct proportion to the number of fixation elements. The results show that the stability achieved by the helical fastener was four times that achieved with the stapler. The cause of detachment was tissue disruption in 52.7% of cases and deformation of the fixation element in 46.9% of cases. The mesh was sufficiently strong. Only at a high unphysiologic load of more than 130 N did the prosthesis tear in two cases (0.4%).

A separate analysis of the detachments in the lower load range (<50 N) showed that when the stapler was used, the connection was disrupted by 94%, with nearly equal rates of

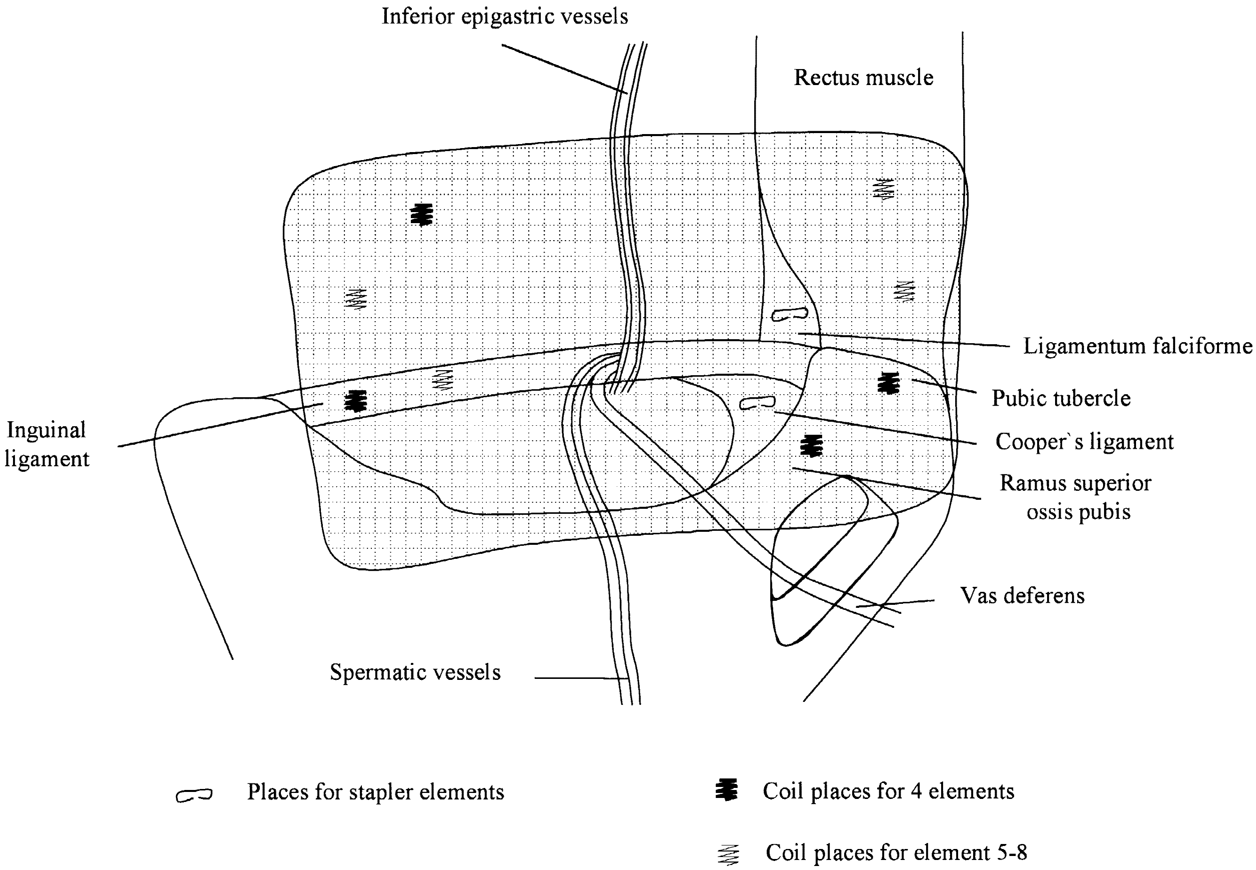

Fig. 2. Fixation points for the helical fastener and stapler.

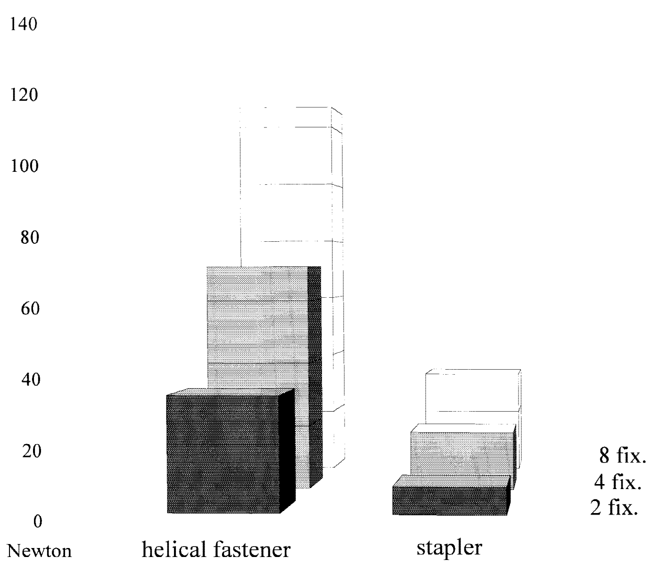

Fig. 3. Graphic comparison of the stability of the prosthesis after helical fastener fixation and after stapler fixation.

tissue disruption (47%) and deformation of the clip (53%). The disruption of tissue at a relatively low level of stress after stapler fixation can be explained, on the one hand, by the superficial depth of fixation (2 mm) (Fig. 1) and, on the other hand, by contusion of tissue. Deformation of the clip occurs at the point where it is bent by 90°. Under pressure, the angle of the clip opens (Fig. 1) and the fixation to tissue is broken. At stresses higher than 50 N, elements fixed by the helical fastener became detached because of structural changes in 40.1% of the cases: The coiled form was altered or the coil was extended. In 59.1% of the cases, the tissue gave way especially in the nonbony fixation points.

The markedly higher stress-bearing capacity of the helical fastener has several causes; (a) The helical fastener penetrates bony tissue without difficulty and adheres securely to the bone. (b) The depth of penetration is twofold higher than that of the stapler, leading to better fixation in the tissue. (c) In terms of statics, the adhesive force of screw fixation is superior to that of clip fixation [1].

Because of the high stability reached with the helical fastener (23–53 N with two elements), the number of fixation elements can be reduced. According to our static calculations for the TEP technique [5], we know that with the TAPP technique, hernia defects with common sizes need only a medial and a lateral fixation element to avert mesh migration. To prevent recurrences caused by mesh folding, mesh twisting, or mesh lifting secondary to hematoma [10], further fixations should be performed caudally on the Ramus superior ossis pubis and cranially for the medial and lateral mesh region. For oversize hernias, we need to increase the number of fixation elements in accordance with the size of the hernia opening. In consequence of the enormous spread of stability afforded by use of the stapler (e.g., with four elements 4–25 N), no recommendation for minimum number of needed fixation elements can be given. However, also for the stapler, a direct proportion exists

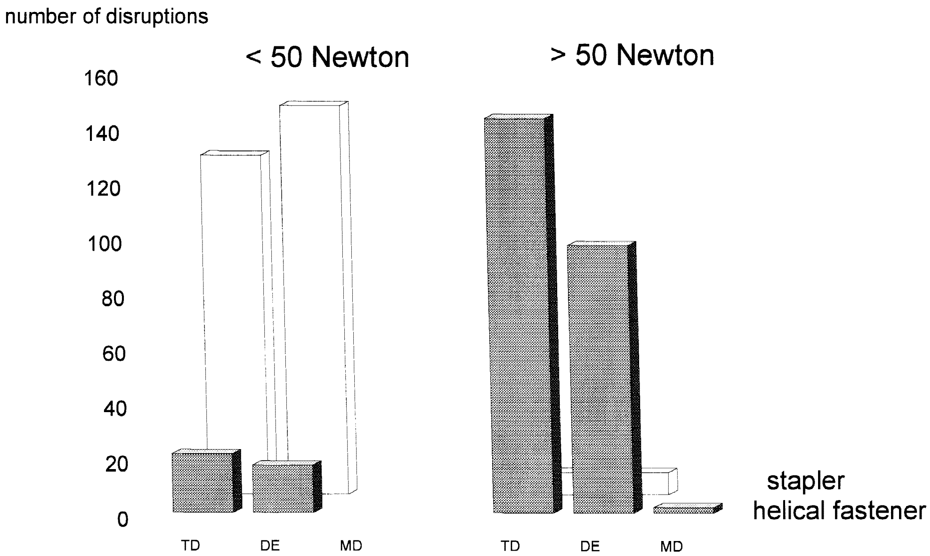

Fig. 4. Reasons for mesh disruption. Divided according to low (<50 N) and high load (>50 N). TD = tissue disruption, DE = deformation of element, MD = mesh disruption.

between the size of hernia defects and the needed number of staples.

In addition to greater stability, the coil-like screwing movement of the helical fastener is more protective to tissue than the clip. When the clip makes a 90° twist in the tissue, the tissue is compressed during fixation, and contusion occurs. This may cause painful nerve lesions [14, 12] requiring laborious therapeutic measures including surgical repair [8]. In contrast, the helical fastener method causes no squeeze of tissue, and if necessary, the removal of the fixation elements can be performed very easily.

In terms of technical stability, the following was observed. The helical fastener "jammed" on two occasions (0.6%). Therefore, the rate of error when the fixation elements were fired from the instrument was relatively low. These errors occurred when more than 20 fixation elements were fired from one fastener. However, such a large number of elements are not used in the patient, even if hernias are present on both sides. With the stapler, the fixation of clips was insufficient in 29 cases (9%). The most frequent reason for the staple not penetrating the tissue was incomplete bending of the staple.

A major advantage of the stapler is that it permits safe and swift closure of the peritoneum. With the helical fastener, it is not certain whether the tip of the coil will sink definitely into the tissue. Therefore, peritoneal closure should be performed with sutures. Initially, this may increase operating time, but should pose no problems for the practiced surgeon.

Conclusions

The helical fastener produces a fourfold stronger fixation, which means that less fixation elements are needed to produce greater stability. The trocar size required for this instrument is 5 mm, in contrast to 12 mm for the stapler. Similarly, technical dysfunction occurs much more rarely with the helical fastener. Finally, because it averts tissue contusion, the new helical fastener should be given preference for mesh fixation in laparoscopic herniorrhaphy.

References

1. Böhm A, Fritsch R (1993) Statik. Manz-Verlag, Vienna
2. Dion YM, Charara J, Guidoin R (1994) Bursting strength evaluation: comparison of 0-Prolene sutures and endoscopic staples in an experimental prosthetic patch repair of abdominal wall defect. Surg Endosc 8: 812–816
3. Dion YM, Laplante R, Charara J, Marios M (1994) The influence of the number of endoclips and of mesh incorporation on the strength of an experimental hernia patch repair. Surg Endosc 8: 1324–1328
4. Felix EL, Michas CA, Gonzalez MH Jr (1997) Laparoscopic hernioplasty: why does it work? Surg Endosc 11: 36–41
5. Hollinsky C, Hollinsky KH (1999) Static calculations for mesh fixation by intraabdominal pressure in laparoscopic extraperitoneal herniorrhaphy. Surg Laparosc Endosc 9: 106–109
6. Horgan LF, Shelton JC, O'Riodan DC, Moore DP, Winslet MC, Davidson BR (1996) Strengths and weaknesses of laparoscopic and open mesh inguinal hernia repair: a randomized controlled experimental study. Br J Surg 83: 1463–1467
7. Korman JE, Hiatt JR, Feldmar D, Phillips EH (1997) Mesh configurations in laparoscopic extraperitoneal herniorrhaphy: a comparison of techniques. Surg Endosc 11: 1102–1105
8. Krähenbühl L, Stiffeler H, Baer HU, Büchler MW (1997) Retroperitoneal endoscopic neurectomy for nerve entrapment after hernia repair. Br J Surg 84: 216–219
9. Lajer H, Widecrantz S, Heisterberg L (1997) Hernias in trocar ports following abdominal laparoscopy. Acta Obstet Gynecol Scand 76: 389–393
10. Lowham AS, Filipi CJ, Fitzgibbons RJ Jr, Stoppa R, Wantz GE, Felix EL, Crafton WB (1997) Mechanisms of hernia recurrence after preperitoneal mesh repair: traditional and laparoscopic. Ann Surg 225: 422–431
11. Sandbichler P, Draxl H, Gstir H, Fuchs H, Furtschegger A, Egender G, Steiner E (1996) Laparoscopic repair of recurrent inguinal hernias. Am J Surg 171: 366–368
12. Seid AS, Amos E (1994) Entrapment neuropathy in laparoscopic herniorrhaphy. Surg Endosc 8: 1050–1053
13. Soares BM, King MW, Marois Y, Guidoin RG, Laroche G, Charara J, Girard JF (1996) *In vitro* characterization of a fluoropassivated gelatin-impregnated polyester mesh for hernia repair. J Biomed Mat Res 32: 259–270
14. Tetik C, Arregui ME, Dulucq JL, Fitzibbons RJ, Franklin ME, McKernan JB, Rosin RD, Schulz LS, Toy FK (1994) Complications and recurrences associated with laparoscopic repair of groin hernias. Surg Endosc 8: 1316–1323
15. van Mameren H, Go PM (1994) Surgical anatomy of the interior inguinal region: consequences for laparoscopic hernia repair. Surg Endosc 8: 1212–1215