Mechanical suture–modern alternatives for suturing

DOI: 10.35530/IT.073.06.202289

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ABSTRACT – REZUMAT

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The increase in the incidence of gastric and colorectal cancer in developed or developing countries led to the need to improve oncological surgery. Oncological surgery of the digestive tract translates in most cases into resection and anastomosis. Using a mechanical suturing device is no longer considered something revolutionary. However, the technology behind new instruments that helps surgeons perform operations changed over time.
The main purpose of perfecting these devices is to execute a safer suture or anastomosis and shorten the intraoperative time. In this study, we made a short review of the principles behind intestinal and skin staplers, and the advantages and disadvantages of these tools as an alternative to manual suturing using textile materials. We also described the use of cyanoacrylate as an adhesive and sealant.

Keywords: *mechanical staplers, cyanoacrylate, intestinal anastomoses, skin staplers, technology, intracorporeal suturing device*

Sutura mecanică – alternative moderne pentru sutură

Creșterea incidenței cancerului gastric și colorectal în țările dezvoltate sau în curs de dezvoltare a condus la necesitatea îmbunătățirii chirurgiei oncologice. Chirurgia oncologică a tractului digestiv se traduce în majoritatea cazurilor prin rezecție și anastomoză. Folosirea unui dispozitiv mecanic de sutură nu mai este considerată ceva revoluționar. Cu toate acestea, tehnologia din spatele noilor instrumente, care ajută chirurgii la efectuarea intervențiilor s-a schimbat în timp.
Scopul principal al perfecționării acestor aparate este executarea unei suturi sau anastomoze mai sigure și scurtarea timpului intraoperator. În acest studiu, s-a realizat o scurtă trecere în revistă a principiilor din spatele staplerelor intestinale și cutanate, a avantajelor și dezavantajelor acestor instrumente ca alternativă la sutura manuală cu materiale textile. Am descris, de asemenea, utilizarea cianoacrilatului ca adeziv și sigilant al plăgilor.

Cuvinte cheie: *staplere mecanice, cianoacrilat, anastomoze intestinale, staplere cutanate, tehnologie, dispozitiv de sutură intracorporeală*

INTRODUCTION

This article aims to present an overview of modern suturing methods. For this purpose, PubMed, ResearchGate and public search engines were searched for representative articles. Search terms were “skin stapler”, “cyanoacrylate”, “intestinal anastomoses”, and “intracorporeal stitching”. The period covered was between 1980 and August 2022.

Intestinal staplers

Surgical staplers work by compressing tissue, connecting two pieces of tissue with staggered rows of B-shaped surgical staples and, in some models, cutting away excess tissue to create a clean closure of the surgical wound. Common materials for surgical staples include stainless steel and titanium [1].
The technique of surgical stapling was pioneered by Hungarian surgeon Humer Hultl. Hultl's prototype stapler of 1908 required two hours to assemble and load. The technology was refined in the 1950s in the Soviet Union, allowing for the first commercially produced reusable stapling devices for the creation of bowel and vascular anastomoses to be developed. In 1977 Johnson and Johnson's Ethicon brand entered the market and today they are widely used, along with competitors from the Far East. USSC was bought by Tyco Healthcare in 1998, which became Covidien on June 29, 2007. Since its introduction, the surgical stapler has provided a means to efficiently create safe and effective visceral and vascular anastomoses. The surgical stapler design continues to evolve while still maintaining the basic principles that were implemented in the original design [2]. Of course, there can be a sum of malfunctions when using intestinal staplers, part of which interest the staple formation. The presence of unacceptable

forms can compromise the integrity and strength of the staple line resulting in an increased rate of leaks and bleeding (figure 1) [3].

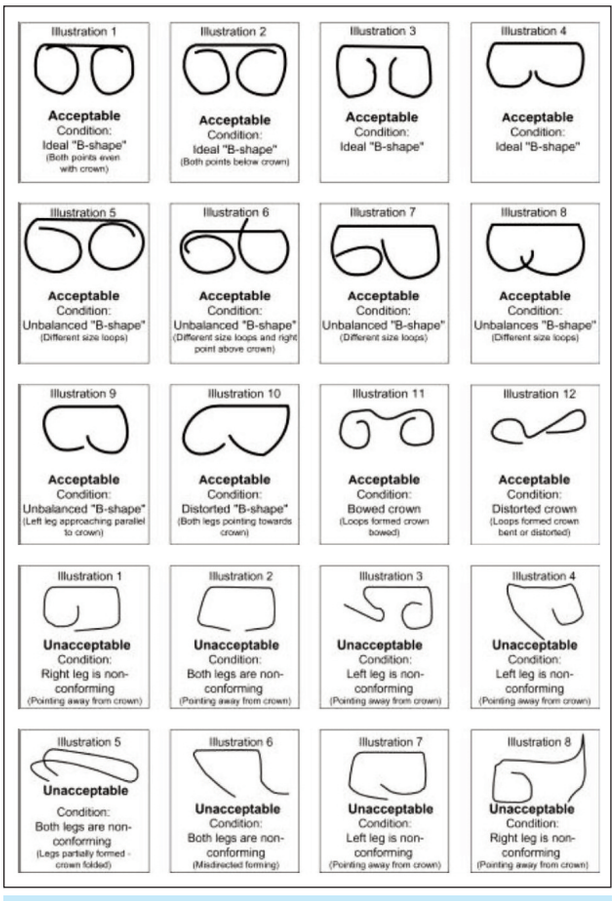

Fig. 1. Acceptable and unacceptable forms of the staple line [3]

Principles of intestinal staplers

There are various designs for different types of surgeries, with most categorized as either linear or circular. Most modern staplers bend each staple into a B-shape staple form, which helps to secure the tissue in place. However, malformed staples can occur because staple leg bending depends on several tissue/stapler characteristics including tissue thickness, tissue viscosity, staple height, and other staple properties (thickness, bending characteristics, type of metal, etc.). Staples are designed to form consistently unlike manual suture with textile materials which rely heavily on surgeon's experience, so staples that are not forming as intended should be investigated [4].

Staples in surgical staplers are made available in various sizes and heights so that the surgeon can choose the one that provides appropriate hemostasis/tissue apposition without significant ischemia or tissue destruction [5].

If the closed staple height is too low, then it may inadequately appose the tissues and result in leakage, bleeding, and/or dehiscence. Conversely, if the staple height selected is to high, then ischemia, serosal shearing, or "cheese wiring" may result, potentially leading to leakage or frank necrosis [4].

The unique properties of the different types of tissues in the body have a major impact on the choice of a stapler and staple height. Different tissues in the body vary in thickness, and dimensions may change based on sex, age, organ/system/anatomical structure, location within an organ, preoperative therapies, intraoperative medications, and disease state [4].

Optimal stapling of any tissue requires an adequate tissue compression time (to decrease the fluid amount within he tissue) to allow elongation of the tissue being compressed, the smooth firing of the instrument, and consistent staple line formation; this need must be balanced against the risk of increased tissue tearing and excessive tensile strength [5].

Most of both linear and circular classical surgical staplers used for better timing during the interventions have an automatic variant. One of the criteria for safe anastomosis is to wait some seconds between closing the stapler on the tissue and shooting the cartridge for the water from the tissue to disperse and to reduce the edema under compression. Automatic staplers are adapted to the tissue thickness, hydration level and consistency to adjust firing speed based on force feedback when clamped and during firing.

Advantages, disadvantages and indications of intestinal stapler

Using surgical staplers reduces operating times by increasing the speed by which the anastomosis is completed. The tissue is less traumatized because it is manipulated less. Another advantage is that anastomoses can be performed, safely and reliably, in difficult-to-reach areas (e.g., low anterior rectal resection). Tissue heals just as well as in the case of a sutured anastomosis with textile materials. The learning curve for performing stapled anastomoses is low. Staplers that are equipped with their blade reduce the risk of contaminating the peritoneal cavity with gut bacteria, by cutting between the stapled ends of the bowls.

The primary disadvantage is represented by the higher cost of the surgery. Some staplers or cartridges do not come equipped with a knife, thus necessitating the use of a scalpel, increasing the risk of injury. The stapler or cartridge can malfunction resulting in the firing mechanism not activating the knife, requiring the use of a scalpel; the staples did not bite enough tissue or were not placed at all, increasing the risk of bowl contents spilling into the peritoneal cavity when the stapler is fired. Another disadvantage is represented by the risk of the stapler's jaws becoming locked together, traumatizing the tissue in the effort to unlock them.

Most commonly performed anastomoses using staplers are represented by side-to-side gastrojejunal anastomosis, end-to-end esojejunal anastomosis, side-to-side entero-entero anastomosis, end-to-side or side-to-side ileocolic anastomosis, side-to-side colocolic anastomosis, side-to-end or end-to-end colorectal anastomosis [6].

Skin staplers

Skin stapling is an alternative to conventional suture with textile materials. Any scalpel wounds or excisional wounds can be closed with the sterile disposable instruments now available. The main advantage is speed. Wound closure with the stapler can be performed in one-fifth to one-half the time required for conventional suturing using textile strings. The stapler is ideal for closing wounds in areas with thick skin and high tissue tension [7].

A study showed that closing the skin with staples in laparoscopic cholecystectomy is three times faster. Furthermore, the anaesthetic time was reduced, thus increasing the efficacy of anesthetic gases [8].

Principles and technique of skin staplers. Comparison with classical sutures with textile materials

Depending on the type of surgery that is performed, the length and the anatomical site of the wound, the closure of the skin is made using different methods and materials.

Sutures using textile materials are most commonly used for skin closure of surgical wounds. The material from which the suture can be either natural or synthetic, absorbable or non-absorbable, single filament or braided. Sutures are flexible, have strength, and are non-toxic and these characteristics offer them a great advantage. Although the sutures are used most often, they can cause ischemia of the tissues and in this way hinder regular and rapid healing [9]. One of the advantages is having a low inflammatory reaction in the tissues. Staples have great results in the fixation, the rapidity of the application and better cosmetic look [10].

For the healing to occur in good conditions, the skill and technique of the surgeon are also important, as well as the closure materials.

Stapling is associated with lower tissue reaction and a lower risk of infection when compared to textile stitches. This produces a higher resistance to infection in contaminated wounds, given the non-introduction of exogenous material, and consequent impairment of local immune response [11]. Also, the staples reduce the local inflammatory response, width of the wound, time to wound closure, and residual cross marks. Although the sutures are the most common technique of closure, they can increase the risk of wound infection.

Complications of surgical wounds that can occur are dehiscence or infection and have a considerable impact on the recovery of the patient [12]. Both methods for skin closure, staples or sutures hold the skin edges together while healing is occurring. Staples are considered to be superior in this case because they are quicker and easier to place than sutures with textile materials, but they can create an increased tension along the incision, so they have a higher dehiscence rate than sutures [13].

Regarding the duration of the two types of procedures, staples have a way more rapid speed of closure. In skin closure, the staplers used are disposable and loaded with 5–35 staples, depending on the manufacturer. They are lightweight and have handles that are easy to grip and control [14].

Cyanoacrylate

Cyanoacrylate has been used in several fields of different surgical specialities as an adhesive or a sealant. It can be used for the closure of mucous and cutaneous lacerations. One of its advantages is that it has an excellent immunological response. Regarding aesthetic concerns, cyanoacrylate has been applied with satisfactory results, when compared with common sutures with textile materials. It presents better coaptation of edges of cutaneous and mucosal lesions, smaller residual scars, and biocompatibility. However, it is limited to areas of little tissue tension [15].

Some of the most frequent indications for the use of cyanoacrylate include esophageal fistula, myocardial surgery, bilateral mammoplasty, skin wound closure, bone and cartilage grafting, corneal surgeries, varicose vein occlusion, and embolization of arteriovenous malformations [16–18].

There are several in vivo studies that compare the effects of cyanoacrylate versus sutures. Cooper and Paige a study involving 18 adult and pediatric patients with cleft lips and reported excellent results with no allergic or infectious reactions and no dehiscence using cyanoacrylate [19]. Vastani and Maria compared the use of cyanoacrylate and textile sutures in alveoloplasty in 30 patients and found that inflammation after suturing was greater than after cyanoacrylate [20].

There are multiple types of surgical adhesives and sealants, of which we can take note cyanoacrylates, albumin and glutaraldehyde, poly(ethylene glycol) (PEG), polyurethane, and fibrin [21].

Cyanoacrylates were first used in a surgical setting in 1959 and since then many composites have been studied and used. Cyanoacrylates are part of a class of monomers made up of alkyl esters of 2-cyanoacrylic acid; most studied composites are methyl, ethyl, n-butyl, isobutyl, isohexyl and octyl cyanoacrylates. However, only n-butyl and octyl composites are actually used at present. There are advantages and disadvantages regarding the length of the alkyl chains: while shorter chains (n-butyl) provide a stronger bond, longer chains (octyl) provide more flexibility and thus, a higher breaking point. Longer chain-cyanoacrylates are preferred lately due to their superior bursting strength [21]. For example, a study conducted by Charles et al. showed a bursting strength of incisional wounds about 3 times greater in patients who benefited from closure with Dermabond (an octyl-2-cyanoacrylate) compared to the ones treated with Histoacryl (n-butyl-cyanoacrylate) [22].

Cyanoacrylates are mostly used nowadays in skin closure after surgery or traumatic lesions, providing a good tissue approximation and sealing postoperative wounds from the environment, some of them acting like a microbial barrier. To succeed in approximating

the tissue edges, these must be priorly brought together by sutures in the subcutaneous plane. Compared to the common textile suture closing of the skin, at 3–4 weeks and 3 months follow-ups there have not been reported differences between the two techniques as far as wound complications or the cosmetic result are concerned. However, patient satisfaction was greater in patients who benefited from adhesive-closed wounds [21].
Regarding the future uses of cyanoacrylates composites, possibilities are open because of the strong development of new composites with even better results on the outer tissues of the human body. In addition, there are some who strive to develop compounds that can be used inside the human body and aid or even totally replace microsurgery involved in some urological, vascular, gynecological, and general surgical procedures. However, even though this method is already used successfully in experimental animals, the surgical community is still mostly reluctant to use these compounds in humans [23].

Intracorporeal suturing devices (definition, main components compatible threads)

As laparoscopic surgery and minimally invasive approaches were described for increasingly complex pathologies, the need intracorporeal suturing and knotting grew. At first, surgeons tried performing sutures and knots the same way they did while using an open approach [24] but the need for a faster, easier method led the surgical community to a breakthrough comparable to that of the emergence of the sewing machine for the clothing industry.
Intracorporeal suturing devices, such as SewRight 5 SR (LSI Solutions), DuraKnot (Ethicon), Overstitch (Apollo Endosurgery Inc.), EndoSew (Karl Storz Endoscopes) and Endostitch (Covidien) revolutionised minimally invasive surgery, giving surgeons the opportunity to positively affect pacient health in a less aggressive manner [25].
Intracorporeal stitching devices are instruments used in laparoscopic surgery for the approximation of tissue and placement of interrupted or running stitches in soft tissues. It passes a single or double-pointed needle with a textile thread firmly attached back and forth between two needle holders to avoid the need for manually grasping and otherwise manipulating the needle. The device generally includes a body portion defining a suture tray and a loading unit portion attached to the body portion.
The Endo Stitch (Covidien, Mansfield, MA) is a 10-mm single-use suturing device that allows the placement of multiple suture types during laparoscopic surgery and simplifies the process of laparoscopic knot tying. The SILS Stitch (Covidien, Mansfield, MA) is based on the same technology as the Endo Stitch with the added advantage of articulation up to 75 degrees and rotation up to 360 degrees [26].
The suture compatible with these devices come in the form of loading units, containing one or more strands of sutures attached to a needle, including Surgidac™, Polysorb™, Bralon™, and Softsilk™ – available in two suture thread lengths – 7" for intracorporeal knot tying and 48" for extracorporeal knot tying.
Automatic suturing devices have simplified the intracorporeal suturing process and allow even less-experienced surgeons to efficiently perform laparoscopic suturing and knot tying [26]. Reconstructive laparoscopic procedures requiring multiple suture placement may be completed in a shorter period using this instrument [27].
These devices enable surgeons to operate in tight spaces during advanced laparoscopic procedures, and to reach tissues in their natural anatomical position rather than pulling or manipulating tissue into the suturing device [26].

DISCUSSION AND FURTHER PERSPECTIVES

Every technique has its limitations, but hand-sutured anastomoses with textile materials occupy the first place due to the necessity of large incision to access organs and the prolonged time for completing an anastomosis [28]. Another important aspect is the shorter time taken for a stapled anastomosis compared to a manual suture [29]. Of course, the surgeon's need to be in control of his gestures at every moment can cause some reluctance to use mechanical devices, but we believe that the widespread use of staplers is just the beginning of the paradigm shift related to mechanical anastomoses and sutures.
As mechanical suturing devices are being developed for decades worldwide, in the past few years, biomedical companies are struggling to bring out to market ultimate intracorporeal suturing devices to support surgeons in one of the most challenging steps of minimally invasive surgery. In this way, a novel device (Su2ura Approximation) used to insert anchors threaded with textile stitches to allow a single action placement of a suture has been in a comparative experimental study with Endo-stitch for safety measurements and performances [30].
A retrospective case series on dogs showed similar results regarding the technique approach in 2017 between an endoscopic needle driver (END) vs a SILS Stitch articulated endoscopic suturing device (AESD) [31]. Further studies on humans are expected.
To facilitate intracorporeal anastomosis in all cases of laparoscopic colectomy, not only those in which the colon is exteriorized, a device by which purse-string suturing can be performed intracorporeally was invented in 2017 by a Japanese team. The 6 cm device can be introduced through a 12 mm trocar inside the peritoneal cavity [32].

CONCLUSION

As recent years have shown, a medical system must work quickly, accurately and safely. These conditions apply to all specialities, including surgery. Part of the merits of medical evolution is attributed to technological development. There is still a relatively important percentage of surgeons who are skeptical or critical of the use of mechanical suture devices, but the

results in the literature are comparable both for staplers and for classic suture techniques using textile materials. Future generations of surgeons will probably use more precise, sophisticated and safer devices to replace hand-sewing and maybe even the instruments that are consider now “modern”.

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