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Original Research Article

Evolution of Suture Material - A Systemic Review

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Abstract: Reviewing the development and history of sutures used in surgery is the goal of the study. Based on a review of the literature, we identified pertinent papers and surgical textbooks regarding suture for wound closure using computerised and manual database searches. The essay explores those earliest known applications of suture by Edwin Smith surgical papyrus and after that the name suture comes from Latin term was first used by Hippocrates in 400 BC. He used linen as suture material. The development of sutures made of natural materials is traced chronologically up to the present, when synthetic sutures are used in an increasing number of daily surgeries. In this millennium, long history of sutures, the early work of Edwin smith, Hippocrates, Sushruta, Galen, Albucasis, Avicenna Celsus, Paré, and Lister is recognised. Because the science and history of sutures are not well-known to the majority of surgeons. Suture needs a holistic review to understand current research and progress on this widely used product.

Keywords: Suture, monofilament, PRISMA.

INTRODUCTION

Various methods can be chosen to close wound in different parts of body. In general, clean and non-contaminated wound with healthy local tissue conditions are best closed by primary permanent closure. Permanent closure can be achieved with suturing [1]. The word suture is derived from the Latin sutura, “a sewn seam.” Materials including linen, cotton, horse hair, animal tendons and intestines, and wire from precious metals have been used to approximate wounds and act as ligatures. Many adaptations over time have led to the highly sophisticated products we use in our practice today [2].

METHODS

During performing this systemic review, we followed the standard of the Cochrane handbook of systemic review. As well as we followed the PRISMA Guidelines (preferred reporting items for systemic review and meta-analysis).

Literature Search Strategy

We searched the following electronic database: PubMed, Scopus, Embase, and Web of science, central. Further survey for suture materials was also carried out from related books from various libraries.

Eligibility Criteria and Study Selection

We included all original studies that reported the evolution of suture material. We excluded conference abstract, animal studies, and studies that were not reliable for selection due to any reasons other than the reasons mentioned earlier.

Information Sources

We included all data base of authentic website of PubMed and books of history of medicine.

Selection Process

Published papers, articles, books that met the inclusion criteria were included in the study.

Data Collection

Each type of dataset was extracted independently by two authors at least. The extracted data was reviewed by other authors.

Risk of Bias Assessment

We used the Cochrane risk of bias (ROB) assessment tool, adequately described in chapter 7 of Cochrane handbook of systemic review of intervention to assess ROB.

Synthesis Methods

We tabulated the data according to the Prisma guidelines.

RESULT AND OBSERVATION

Study Selection and Characteristics

Initially database search retrieved 529 citation that were abstracted to 224 after removal of duplicates, using Zotero software. Additional records 280 were excluded during abstract screening and the full text article of remaining 25 abstracts were retrieved for further evaluation.

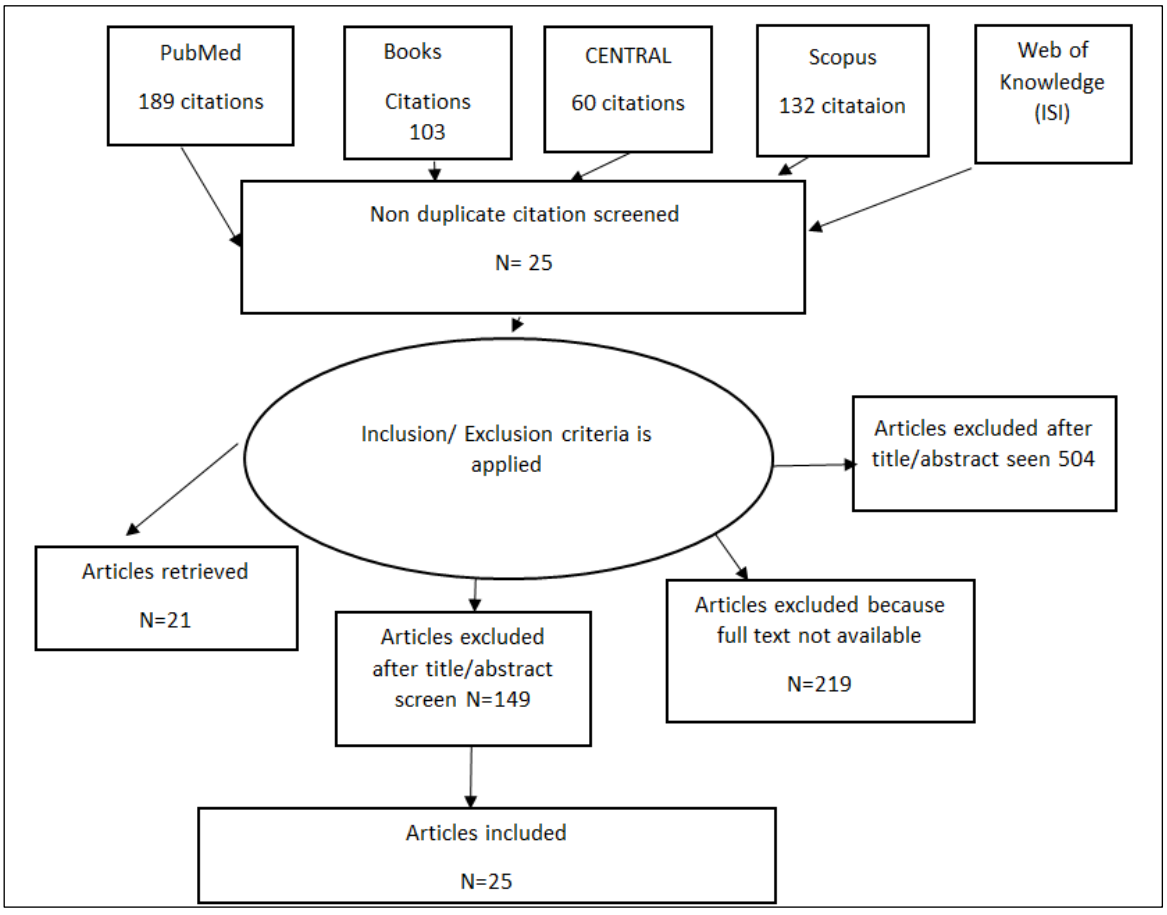

Fig. 1: A flow diagram of search strategy and study selection proces

Mesopotamia Civilisation (4000 B.C)

Mesopotamia land between the Tigris and Euphrates River, was the arena of the growth and decay of many civilisations including those known as Sumerian, chakdean, Assyrian and Babylonian. Eight of the fifteen Mesopotamian's prescriptions were devoted to how to apply plasters for the treatment of wounds and sores. Other records outlined specific postoperative instructions, for instance, the dressing of operation sites with oil-soaked linen

bandages. In addition, there are descriptions of the stitching of wounds using different materials including fine threads performed in ancient Mesopotamia [2].

Egyptian Civilisation (3100 B.C)

Edwin Smith Surgical Papyrus which was discovered as a piece of a course book in ancient Egypt is recorded as the oldest surgical document. In 1862 Edwin smith (1822-1906), a pioneer purchased a papyrus found in a grave near Luxor. The 48 cases preserved in the Edwin smith papyrus were arranged systemically from head to foot in order of severity. That document mentioned methods to close the wounds with sutures and preventing the infection for the sutured wound. The oldest and well-preserved suture on the human body was found on a mummy of the 21st Egyptian Dynasty (around 1100 BC). The sutures were on the belly, knee and elbow of the mummy. Societies from different cultures in the ancient period used such as horse hair, dry tendon, gold and silver wires as suture material [2].

Chinese Medicine (2900 B.C)

Fu Hsi, who is said to have reigned about 2000 B.C, is the legendary founder of China first dynasty his most important invention includes yan and Ying concepts. The most famous Chinese surgeon Hua T' o was credit for invention of anaesthetic drugs, medicinal baths, hydrotherapy and suturing [2].

Indian Medicine (2500 B.C)

The sushruta is lived about 600 BC its emphasis on the art of surgery. The sushruta describes many difficult operations such as cataract, lithotomy, opening the chest and drain the pus, various kinds of threads and needles were used for closing the wound but when intestine was torn large black ant's were recommended as wound clips. Large black ants should be applied to the margins of the wound so ants firmly beaten the part with their jaw. Sushruta, also used cotton, drawn copper, horse hair as ligatures [3].

***Hippocrates* (460-377 BC) – (Father of Modern Medicine)**

Hippocrates was born in Kos, a Greek island of the south eastern. He was the son of Herak lides and belonged to a family of physicians their ancestry of Asclepius, Hippocrates worked mainly in Kos and the nearby coast of Asia Minor (corresponding to present-day Turkey) [4]. He mentioned ivory and bone needle for stitching wound. The name suture for natural or synthetic materials comes from Latin word *sutura* and this term was first used by Hippocrates in 400 BC. Linen as suture material, used by Hippocrates in fistula operation [5-7].

***Galen* (129-200 AD)**

Galen was born in Pergamum on the Ionic coast of Asia Minor in 129A.D. under Roman jurisdiction. In 400 B.C. *Galen*, physician to the Roman gladiators, recommended the use of silk and hemp sutures for hemostasis [5] Galen of Pergamon 150 A.D., gained a reputation by treating and sometimes suturing the severed tendons of gladiators, presumably he was referring to linen or Celtic thread [4]. He continues, in many places under Roman rule 160 The Scottish Society of the History of Medicine can obtain silk, especially in large cities where there are many wealthy women. If there is no such opportunity, choose from the material where you are living, the least putrescible, such as thin catgut which quickly falls from the vessel. This is the first reference to catgut although Galen makes it plain in other passages that it was known to the ancients [7]. Wool used in the operation on the eyelid [8].

Aurelius Cornelius Celsus

Roman teacher *Aurelius Cornelius celsus* (25 BC- 50 BC). Celsus placing a suture ligature for haemostasis. Celsus was first to mentioned a double ligature on blood vessels. Ligature the larger vessels but as for the small ones we catch them with hooks and twist them many times thus closing their mouths [2]. Celsus tells us that sutures were of ancient origin and should be 'soft, and not over twisted, so that they may be easier on the part. Whether he was referring to linen or wool is uncertain. He also described fibulae or small metal clips similar to the Michel clips of today [8].

Zakariya Razi or Rhazes (850-923AD)

Rhazes (835-925 A.D.) as known to the Europeans is Abu Bakr Mohammad ibn Zakaria AI-Razi, born in the city of AI-Rayy (few miles south of Tehran, Persia). Rhazes wrote his most important medical encyclopaedia "Continents" (AI- Hawi) which greatly affected the human civilisation specially in Europe. Rhazes (850–923) in Baghdad, propagated catgut lute strings for abdominal wall repair. He also utilized horse hair suture [7].

Ali Ibn Sina, or Abu ali Hasan Ibn Abdullah ibn sina Avicenna (980AD–1037AD) was "prince of physicians," and first scholar to create a complete philosophical system in the Arabic language. Avicenna's great medical treatise, the canon, was written for general practitioners. Because the information in the canon was essential for medical practice, Avicenna suggested that doctors should memorise the entire book [2]. Avicenna also expected the physician to master surgical technique for treating wide variety of wound and injuries. After the operation, warm water, vinegar or wine was sponged over the site of surgical wound. He noticed rapid dissolution of sutures in the presence of infection and

described a natural monofilament suture, pig's bristles [6]. Avicenna's contribution to suture development was his realization that traditional materials such as linen thread, when used in the presence of gross infection as in the repair of anal fistula, tended to break down rapidly. In search of more suitable material, he turned to pigs' bristles and so invented the first monofilament suture. He also described a double suture, a technique still used today [8].

Ismail Jorjani

Ismail Jorjani, one of the famous Iranian physicians in the history of Islamic medicine, was born in Gorgan in 434, A.H (1042, A.D.) and died in Marve in 531, A.H (1136, A.D) during Kharazmshahi dynasty. He was claimed to belong to the second generation of physicians like Avicenna. Zakhireye Kharazmshahi is one of the most complete, significant and comprehensive Persian medical texts that truly must be recognized as an integrated medical encyclopaedia which covers all aspects of medical subjects In Zakhire, he elaborated on different methods of surgery and the related tools in a way that is quite expressive of the dexterity and the depth of his experience. He also wrote about the needed medications and the types of medical care before and after surgery in the best possible way. It can be claimed that Zakhire is the best surgical document of the time after Zahravi's Al-Tasrif and Razi's Al-Havi here we point to some of the surgeries which had been recommended by Jorjani for stopping severe haemorrhage of wounds. He suggested using plaster casts several centuries before European scientists. In case of the polyp existence, Jorjani explained how to use a thin sharp semi-circular knife for cutting and paring and a curved needle made of metal with a piece of silk string or the hair of horse for stitching and repairing the wound [9].

Abul Qasim Zahrawi Albucasis (936AD -1036AD)

A more specialised guide to Arab surgery was provided by *'albucasis'*, an extremely ascetic man who devoted much of his time to working among the poor. He belongs to medieval Europe distorted the name of the Arab surgeon Abu '1-Qasim Khalaf ibn 'Abbas al-Zahrawi. Surprisingly little is positively known about him. The last element of his name indicates his birthplace as al-Zahri', the royal city five miles west of Cordova, founded 936 A.D. by the Caliph 'Abd al-Ral, the eighth Umayyad ruler of Spain [8].

Ants' nipper is not a classical method but used by Albucasis for bringing skin edges together. Some men of experience have said that when a wound occurs in the intestine and it is small, it should be sutured in this manner, namely ants with large heads are taken then the edges of the wound are brought together and one of these ants is applied by its open jaws to the two edges of the wound, and when it seizes it and closes its jaws then the head is cut off, and it will stick and will not loosen. Then another ant is applied near the first; and you proceed after this manner with a number of ants according to the size of the wound. Then reduce the intestine and sew up the wound for the heads will remain sticking to the intestine until it is healed up and no harm will come to the patient [8].

According to *albucasis* gut material was originally used for violin strings and obtained at musical instrument shops that provided "kits", thus the term kitgut or catgut [4]. The kit being an early form of musical instrument. The process for creating bow strings for musical instruments was called 'kitgat' meaning fiddle string. A 'kit' means a three-stringed violin and from this word came 'catgut' [1, 4, 5]. The intestine may also be sewn up with the fine suture which is extracted from an animal's gut and sticks to it after being threaded in a needle. The method is that the end is taken of this suture made of gut, well scraped; and to this end is fixed a fine linen thread, twisted, and then that thread is passed through the needle affixed to the suture of animal's gut, with which the intestine is sewn and then replaced in the abdominal cavity [8].

Hair ox is used in the treatment of pterygium. Wire, either gold or silver, is use for wiring in the teeth. These might be the patient's own, when knocked out or loosened by a blow; or they might be artificial ones made of ox-bone [8, 10].

Ambroise Paré (1509–1590), often called the Father of Modern Surgery, was a French barber surgeon. As a military surgeon he saw the evolution of guns and ammunition. Recognizing that haemostasis by bathing the freshly amputated stump in hot oil caused unnecessary pain and damage to tissues that ultimately would have to heal. Battlefield surgery often included to amputation of arms or legs, an operation that could lead to death and haemorrhage many patients died after amputation because cauterisation destroyed the flap of skin needed to cover the amputation site and increased the danger of infection [10, 11]. Paré used ligatures to tie off individual vessels. He was advocate of gentle handling of tissues. He developed the Bec de Corbin (crow's beak), a clamp designed to grasp a bleeding vessel [2].

By the end of the nineteenth century, many surgeons had joined microbiologists using improved method of sterilisation's goals of antisepsis is to kill the germs in and around a wound by means of germicidal agents. The goals of sepsis are to prevent the introduction of germs into the surgical site. Joseph Lister (1827-1912) was a British surgeon, experimental pathologist, a pioneer of surgical sterile techniques and father of modern surgery. Before Lister, surgery was very dangerous and the high death rate (46%) made many people suggest it should be stopped. The statement 'the

operation was successful but the patient died' was quite common. Although asepsis and sterile technique have replaced antisepsis as the primary principle in combating infection. Intra-abdominal sepsis is one of the most challenging situations in surgery. Colorectal surgery is associated with a high sepsis rate because the colon has the highest micro-organism's burden (1012 organisms/ gram of luminal content) [12, 13]. On 1 September 1960, in a medical history series entitled 'They Made History', the BBC broadcast a re-enactment (it would now be called a docudrama) of an operation that Joseph Lister performed at King's College Hospital on 26 October 1877. The patient was Francis Smith, who had fractured his patella (kneecap) a fortnight earlier and had reluctantly agreed to allow Lister to wire together the separated fragments of bone. The programme was based on case notes held at King's College and an address that Lister gave to the Medical Society of London in 1883 [11, 12]. Lister was the first to make a connection between the presence of germs, which he termed 'the evil influences of the impure atmosphere', and infection. Before this time suture was left long with 'the ends left projecting from the wound'. Lister speculated that if the bacteria in the interstices of suture material could be eliminated, the material could be safely left in situ with the ends cut short. In his first human experiment on 12 December 1867 with his new suture technique he noted, 'Healing took place without any suppuration, and with remarkable absence of swelling or tenderness'. Lister used carbolic acid to clean suture material, instruments, dressing materials, and wounds. He also initiated a fundamental change in the preparation of suture materials when he steeped catgut in a solution of carbolic acid in five parts of olive oil with a very small quantity of water diffused through it. Unhappy about the handling qualities of catgut, he developed chromic catgut in 1881 [2, 13-15].

DISCUSSION

Origin of suture material was started from Mesopotamia civilisation they used fine thread. The oldest and well-preserved sutures on the human body were found on a mummy of the 21st Egyptian Dynasty (around 1100 BC) [2]. Sushruta, also used cotton, horse hair as ligatures [3] Hippocrates in 400 BC used linen as suture material [5]. Celsus was first to mentioned a double ligature on blood vessels [2], the first monofilament was invented by Avicenna by pigs' bristles suture [8]. Zahrawi (Albucasis) used ants with large heads and put on the edges of the wound are brought together and one of these ants is applied by its open jaws to the two edges of the wound, and when it seizes it and closes its jaws then the head is cut off. The process for creating bow strings for musical instruments was called 'kitgat' meaning fiddle string. A 'kit' means a three-stringed violin and from this word came 'catgut'. The intestine may also be sewn up with the fine suture which is extracted from an animal's gut and sticks to it after being threaded in a needle [8]. Lister used carbolic acid to clean suture material, instruments, dressing materials, and wounds [12, 14]. The ideal suture material could be utilized for any purpose and would be characterized by good handling characteristics, have good knot security and tensile strength, would be sterile, nonelectrolytic, nonferromagnetic, noncapillary, nonallergenic, and noncarcinogenic, and would not provide a medium for bacterial growth. It should be resistant to shrinkage and absorbed with minimal tissue reaction, easy to sterilize without alterations to its properties and be economical to use. Surgical stapler has changed the practice of surgery, in a profound way. Several different devices available for stapling are skin stapler, ligating and dividing stapler, gastrointestinal anastomosis (GIA) stapler, thoracoabdominal (TA) stapler, end to end anastomosis stapler, surgical adhesive such as fibrin seal adhesive Currently available tissue adhesives include octyl cyanoacrylate (Dermabond), butyl cyanoacrylate (LiquiBand), and N-butyl-2-cyanoacrylate (GluSeal) [16] present suturing material like silk, prolene, chromic catgut contains many disadvantages like High coefficient of friction, poor knot security, expensive, low tensile strength and high tissue reactivity. So Polyglactin 910 (Vicryl), Polyglycolic (Dexon), Polyglyconate (Maxon), Polydioxanone (PDS) and Poliglecaprone 25 (Monocryl) come into the market and have good knot security, High tensile strength, Low tissue reactivity and High knot security [17].

CONCLUSION

Origin of suture material by Greek roman and Arabic philosopher. His works were claimed by European surgeons that came after him. Many Muslim scholars should have more researches on them. With that, Islamic Medicine History will gain more appreciation. An understanding of the origins of suture improves the gratitude for the use of modern sutures. Key contributions include Celsus inventing the use of suture ligatures for haemostasis, Albucasis was founder of catgut, re-popularization of suture over cautery by Paré, and sterilization of suture by Lister. The last 80 years have noted improvements on natural materials with the development of synthetic sutures that are custom-made for a particular anatomic structure and function.

Contribution of Authors

1. Prof. Saiyad Shah Alam: conceptualized the study and reviewed final draft.
2. Dr Aeliya Rukhsar: Collection of the material and relevant literature and prepared the draft of the article.
3. Prof. Ghulamuddin Sofi: Reviewed the draft and checked for technical details. Critical appraisal and correction of the draft.

Declaration of Conflict of Interest

There is no conflict of interest to declare.

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