Tensile strength study of the abdominal wall following laparotomy synthesis using three types of surgical wires in Wistar rats[1]

Estudo da resistência tênsil da parede abdominal após síntese de laparotomia usando três tipos de fios cirúrgicos em ratos Wistar

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ABSTRACT
PURPOSE: To study the tensile strength of the abdominal wall following laparotomy synthesis utilizing three types of surgical wires. **METHODS**: Thirty Wistar rats were randomized into three groups of ten rats each. Each group underwent a 3cm-laparotomy which was closed with 3-0 polyglactin 910, polyglecrapone and catgut wires. After 63 days, euthanasia was performed and part of the abdominal wall was removed with which a strip was produced measuring 2.0 cm in length by 6.0 cm in width comprising the abdominal muscles with the implanted mesh. The sample was fixed in a mechanical test machine in which constant force was applied contrary to the tissue strips. Maximum force was considered, expressed in Newton, until full rupture of the tissue occurred. The non-parametrical Kruskal - Wallis test was used for the statistical analysis, admitting $p \leq 0.05$.
RESULTS: The average strength of the catgut group was slightly lower (33.50 N) than that of the polyglactin group (34.23 N), the difference not being statistically significant (p=0.733). The polyglecaprone group was the one which presented the lowest strength value of all three wires analyzed (29.86 N). No statistical difference was obtained when comparing the strength values of the polyglecaprone group and the catgut group (p=0.06). However, when the polyglecaprone group was compared to the polyglactin 910 group no statistical difference was obtained (p=0.029). **CONCLUSION:** The polyglactin wire presented the highest tensile strength among the three wires analyzed, such value being statistically significant when polyglactin was compared to the polyglecaprone wire.
Key words: Surgery. Tensile strength. Rats.

RESUMO
Objetivo: Estudar a resistência tênsil da parede abdominal após síntese de laparotomia utilizando três tipos de fios cirúrgicos. **Métodos:** Trinta ratos da linhagem Wistar randomizados em três grupos de dez exemplares cada um. Em cada grupo fez-se uma laparotomia de dois centímetros que foi fechada com fios 3-0 de poliglactina 910, poliglecaprone e categute. Após 63 dias, foi feita a eutanásia e retirou-se uma área da parede abdominal com a qual fez-se uma tira medindo 2,0 cm de comprimento por 6,0 cm de largura englobando os músculos abdominais com a tela implantada. A amostra foi fixada em máquina de ensaios mecânicos na qual se aplicou força constante contrária às tiras de tecido. Foi considerada a força máxima expressa em Newton até ocorrer a ruptura total da amostra. Para a análise estatística, utilizou-se teste não paramétrico de Kruskal - Wallis admitindo-se $p \leq 0{,}05$. **Resultados**: A média de resistência do grupo categute foi ligeiramente menor (33.50 N) ao da poliglactina (34.23 N), sendo essa diferença não estatisticamente significativa (p=0,733). O grupo poliglecaprone foi o que apresentou menor resistência entre os três fios analisados (29.86 N). Comparando as resistências do grupo poliglecaprone ao grupo categute não se obteve significância estatística (p=0,06). Entretanto quando o grupo poliglecaprone foi comparado à poliglactina 910 houve significância estatística (p=0,029). **Conclusão:** O fio de poliglactina apresentou a maior resistência tênsil dentre os três fios analisados, sendo esta estatisticamente significativa quando comparado ao fio de poliglecaprone.
Descritores: Cirurgia. Resistência à tração. Ratos.

1. Research performed at the School of Medicine, Laboratory of Anesthesiology, São Paulo State University (UNESP), Botucatu, São Paulo, Brazil.

Introduction

The most common method for the reapproximation of surgical wound edges is suture[1], since closure of the surgical incision restores tissue form and function. Therefore, this becomes the basic principle following the operatory procedure and one which must be conducted in the best possible manner since morbidity may not be negligible in the event of complications.[2]

It is true that no suture wire has all the characteristics that will classify it as being optimal[1], which leads surgeons to continue to search for a suture material that will be close to optimal.[1,3] The incision must be closed in such a way that the healing process can take place with no delay and the suture can be maintained until the intrinsic tensile strength of the scar is efficient. In recent years, better surgical materials have become available. However, we are not yet close to solving the problem of abdominal rupture as this becomes more and more frequent.[4] As a matter of fact, several specimens have been utilized throughout this century in search of the ideal suture for abdominal wall synthesis and, in spite of all the technological progress, the discussion around the synthesis of the abdominal wall remains constant. All these studies which address techniques and suture materials are aimed to establish the best usage options, though there is not yet an ideal definition about the issue.[5]

The search for the ideal suture material leads to trials about the physical-chemical characteristics of different wires. The tensile strength of suture wires is one more aspect to be taken into account in the difficult decision about which suture wire to use in the synthesis. Furthermore, the study of tensile forces is important for the understanding of the healing process and will always comprise an important experimental tool to be explored in a continuous manner. [6]

This line of research, aiming at the tensile strength of surgical materials, has been widely published in the literature in recent years. This trial is a consequence of the development of this line of research and employs a methodology that has been previously described in the literature. In order to contribute to this discussion, it provides an analysis of the tensile strength of three different absorbable wires used in daily surgical practice: plain catgut, polyglactin 910 and polyglecaprone 25.

Methods

The present trial has met all the criteria, technical standards and international research animal rights adopted by the Brazilian College of Animal Experimentation (COBEA) and are in full agreement with the Federal Law no. 6638 of the Federative Republic of Brazil. It has also been approved by the Research Ethics Committee of the University of Southern Santa Catarina (UNISUL).

The animals were submitted to pre-operatory 12-hour fasting and remained throughout the study in the UNISUL Operatory Technique and Experimental Surgery Laboratory under room temperature, continuous airflow, absence of noise and stress, obeying the natural day and night cycles. They were kept in individual cages placed on shelves equally distant from the light source, with feed and water *ad libitum*.

Thirty Wistar rats (*Rattus norvegicus albinus*), male, weighing between 200 and 300 grams, apparently healthy, 90 days old, coming from the UNISUL Central Biotery, were distributed in three groups of 10 rats each, identified by individual numbers in the cages and classified as follows:

- CG Group (n=10): catgut 3-0 wire (monofilament absorbable)
- PG910 Group (n=10): polyglactin 910 3-0 wire (multifilament absorbable)
- PGP Group (n=10): polyglecaprone 3-0 wire (monofilament absorbable)

Anesthetic induction was done with ether inhalation followed by an injection of a 2% ketamine chloridrate and xilazine chloridrate solution in 1:1 dilution administered intramuscularly (0.2 ml/100g) on the inside portion of the right leg.

Then, the animals were placed horizontally on their backs on a hard board and fastened with adhesive tape. Epilation and antissepsy was done with a polyvynilpyrrolidone-iodine solution on the anterior abdominal wall, followed by a median 4-cm incision on the skin and median 2-cm laparotomy.

The laparotomy synthesis was done using the aforementioned wires with separate stitches 0.5 cm apart from each other and 0.5 cm from the edge of the incision. The stitches were done on a single plane and tied with 4 semi-knots. Skin synthesis was done with nylon 3-0 utilizing a continuous locking suture.

FIGURE 1 – Tissue sample of the anterior abdominal wall with 1cm thickness. The area to be submitted to tensile strength assessment can be visualized in the detail. Polyglecaprone group.

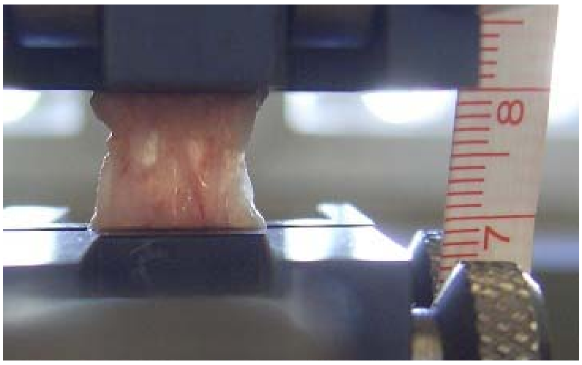

FIGURE 2 – Specimen fixed on the test machine. Catgut group

After 63 days of follow-up the animals were submitted to euthanasia according to resolution no. 714 of the Federal Board of Veterinary Medicine, epilation was done once again followed by an inverted-U incision with the full resection of the anterior abdominal wall. With this sample a strip was created, measuring 0.5 cm in length by 6.0 cm in width, transversal to the surgical scar area of the abdominal wall and which was later used for the mechanical analysis (FIGURE 1).

The strip ends were fixed on tabs with an irregular surface for optimal specimen attachment. The specimens were placed in a universal mechanical test machine EMIC® model DL – 2000 (Equipment and Testing Systems Ltda Curitiba, PR, Brazil) at a distance of 1.0 cm from each side of the laparotomy scar, leaving a free area of 1.0 cm on the spot where the synthesis had been conducted using the suture wires under study (FIGURE 2).

Constant traction was applied at a speed of 20 mm/second, perpendicular to the suture line and contrary to the tissue strips, with a maximum force being applied and considered upon rupture of the sample. We used a load cell which bears tests in the range of 1 to 50 N with a reading resolution of 0.01 N. The moving speed of the machine chuck jaws was pre-set to 20 mm/minute and the test results were obtained in the physical magnitude of Newton. The statistical analysis was done using a Kruskal-Wallis non-parametrical test. The statistical significance level with a p value of $p<0.05$ was admitted.

Results

During follow-up the animals remained in the Operatory Technique and Experimental Surgery Laboratory at UNISUL and no death occurred in the 63-day period.

The physical magnitude analyzed in this paper was force and the unit utilized to measure force in the International System of Units is Newton. The relationship to transform 1N into other measuring units of other systems is $1N = 10^5$ d = 1 kgf = 9.80665 N. The tensile strength test result is demonstrated in TABLE 1.

TABLE 1 –Abdominal wall tensile strength following laparotomy. Result of traction tests of the catgut, polyglactin and polyglecaprone groups. Force value in Newton.

ANIMAL Nº	CG GROUP	PG910 GROUP	PGP GROUP
1	38.53	30.62	30.37
2	29.11	35.50	32.14
3	37.36	27.09	31.47
4	39.71	36.85	33.82
5	31.13	36.18	29.45
6	28.10	29.45	26.59
7	32.64	30.62	28.77
8	36.85	34.16	27.09
9	26.25	40.05	23.56
10	35.34	41.80	35.34
Average	33.50	34.23	29.86

The average strength of the catgut group was 33.50 N, being slightly lower when compared to the polyglactin group which presented 34.23 N. The analysis between the catgut and the polyglactin group showed that there is no statistical significance (p=0.733). The polyglecaprone group was the one which presented the lowest strength among the three wires analyzed, with an average strength of 29.85 N. No statistical significance was obtained when comparing the strength of the polyglecaprone group to that of the catgut group (p=0.06). Nevertheless, when the polyglecaprone group was compared to the polyglactin 910 group, the difference was statistically significant (p=0.029).

Catgut Group X Polyglactin Group
0.733

Catgut Group X Polyglecaprone Group
0.06

Polyglactin Group X Polyglecaprone Group
0.029*

* statistically significant difference

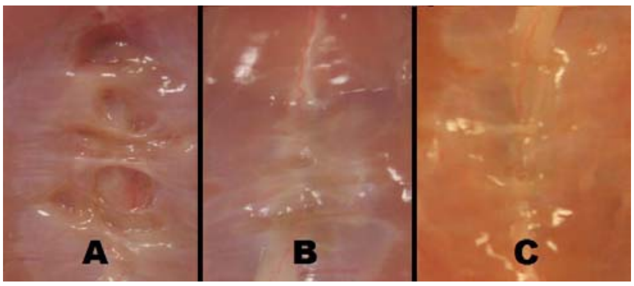

FIGURE 3 – Visibilization of the anterior abdominal wall. In **A** one can notice the formation of herniary sacs.
A – CATGUT **B** – POLYGLACTIN
C –- POLYGLECAPRONE

Discussion

The purpose of any suture is to create opposition of the wound edges until the scar is strong enough to withstand the forces which are imposed upon it.[7]

Basically, synthetic absorbable sutures can be classified as monofilament or multifilament. The concern about tissue drag of multifilament wires such as polyglycolic acid and polyglactin 910 has led to the development of wires which generate less tissue trauma at the time of suture.

Wires made of polydioxone, polyglyconate and polyglecaprone, which are synthetic monofilament absorbable compounds, have been incorporated to daily surgical practice due to the fact that they produce less tissue drag when compared to multifilament wires. [8]

Thus the opportunity came up to conduct an experiment with monofilament wires, here represented by catgut and polyglecaprone 25, and a multifilament wire, in this case polyglactin 910.

The experiment was done exclusively with absorbable wires, as it was not considered reasonable to use, in the same tests, wires that have too distinct characteristics such as the unabsorbable ones. A trial which uses both absorbable and unabsorbable wires may have its methodological standard jeopardized with the biases involved in the data collection.

Among the many available wires it is important to know their features and interactions with the tissues so as to apply them properly.[9] Thus, this study provides one more characteristic of surgical wires, the tensile strength, thus we can gain more knowledge as to which is more adequate for a certain type of synthesis.

The efficiency of a suture is related to the tensile strength of the material employed[10], and the strength of the scar can make a difference with regards to whether or not the procedure is a success or a failure.[7]

If tensile strength is directly related to the efficiency of the suture, one can conclude that quantifying tensile strength is a basic step towards finding the physical characteristics of wires. Mechanical tests conducted among the three wires analyzed demonstrated that the polyglactin 910 wire presented the highest tensile strength, such difference being statistically significant when polyglactin 910 was compared to polyglecaprone 25. Polyglactin has been used in surgical practice for approximately 30 years with optimal results, presenting high tensile strength when used in laparotomy syntheses *in vivo*. It is considered to be the material of choice in the closure of the abdominal cavity. [3]

Trials assessing tensile strength in experimental surgery have been increasingly published in the literature. The rupture force analysis in a mechanical test machine is an adequate technique that provides accurate and quick results, which can undoubtedly be developed in experimental surgery trials. The methodology applied in the conduction of mechanical tests has been developed based on studies and the utilization of the mechanical test machine is an adequate technique for this type of trial.[11]

As to the abdominal wall closure method, separate stitches were used as the synthesis technique and it was then possible to isolate the application of force during the mechanical tests, which would not be possible if a continuous suture had been used.

The isolation of the force to be applied is an essential requirement for the achievement of truly reliable results. As a matter of fact, both the continuous technique as well as the one with separate stitches have been widely accepted and utilized in the abdominal wall synthesis.[5]

The appearance of the abdominal wall can be visualized at the time of euthanasia (FIGURE 3). It is possible to notice that when the abdominal wall suture was done using catgut wire (A) the latter was not able to maintain proper strength to ensure a good healing process, hence the formation of herniary sacs. In the polyglactin (B) and polyglecaprone (C) groups, the healing of the abdominal wall occurred in a homogeneous fashion, without the formation of herniary sacs. The healing process is known to be dynamic, thus it becomes necessary to maintain the tensile strength of the suture for a certain period of time. The exudative phase lasts 1 to 4 days, during which period there is no safety with regards to the tensile strength of the suture. Next is the proliferative phase, which lasts 5 to 20 days, during which epithelization, contraction and fibroplasia take place. At this stage the tissue recovers 14 to 30% of its original tensile strength. Most rapidly-absorbed sutures are degraded in this phase, increasing the probability of incisional hernia.[12]

The polyglactin and the polyglecaprone wires did not cause hernia formation. Since the absorption time is longer, an average of 50 to 100 days respectively, they maintain the tensile strength necessary during the healing process. In FIGURE 3 it is also possible to notice that the polyglecaprone wire remains visible in the suture after 63 days. On the other hand, the catgut wire is absorbed in less than a week, during which time it loses half of its original strength.[1] This explains the healing defects found in the group submitted to synthesis with a catgut wire and illustrates why it must be avoided in slow-healing sutures which are submitted to constant stress and strain.[1] Due to its physical-chemical characteristics, the catgut wire should not be used in tissues which require a coaptation time of more than a week.

When comparing the polyglactin 910 wire to the polypropylene and mononylon wires, the polyglactin wire was the one which presented the lowest tensile strength.[13] This is predictable, since the comparison was made among unabsorbable wires which maintain suture strength for an indefinite period of time. In the present trial, the tensile strength of the polyglactin 910 group was 34.23 N, the highest among all the wires analyzed.

Industrial surgical wires are advertised based on experimental and clinical trials. It is up to the surgeon to make a choice as to which wire to use. The purpose of this trial is to provide more subsidies that will lead to the best possible choice. The knowledge of biological phenomena, experience and common sense are all part of the decision–making process. Nevertheless, the financial cost many times becomes the main determining factor in the choice of a surgical wire.[10] The polyglecaprone 25 wire is the one that presents the highest cost when compared to the polyglactin

910 and the catgut wires, which in many cases may limit its regular use. Besides, it is not recommended for *in vivo* laparotomy synthesis.

Another characteristic about which we can make some comments is with regards to wire handling. The ease of handling and the pliability property are subjective concepts which are dependent on the attrition coefficient of the material, as well as on its memory. [10] During wire manipulation it was verified that the polyglecaprone wire has the lowest attrition coefficient, which allows for greater malleability when compared to the other materials used in this trial. The polyglecaprone wire has a high handling capability and a minimum tissue drag.[8] Finally, we agree that the polyglactin wire is an excellent surgical wire which has the extra advantage of having good tensile strength, as has been presented here.

Conclusion

In the experimental conditions described above, the polyglactin wire presented the highest tensile strength when compared to the catgut and the polyglecaprone wires.

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