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Biomechanical comparison of microvascular anastomoses prepared by various suturing techniques☆

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ABSTRACT

Introduction: The biomechanical properties of small vessels and microvascular anastomoses have not been studied completely yet. However, in case of vascular injury and various microsurgical reconstructive procedures a safe anastomosis is essential. Quick and reliable tests are needed to test various anastomoses in research and in teaching courses as well for quality control and proper feedback. We aimed to compare selected biomechanical properties of the simple interrupted, the continuous suture and the modified Lauritzen's sleeve-technique.

Materials and methods: Sixty femoral arteries from chicken thigh biopreparates and 12 abdominal aortas from rats were used in this study. In case of the pressure resistance test the groups were: the simple interrupted, the continuous suture and the modified Lauritzen's sleeve-technique. The tensile-strength, elongation and elasticity measurement groups were the simple interrupted and continuous sutures with 8 and 12 stitches. Furthermore the suture materials in various conditions (simple thread, knotted threads, stitch with intact and damaged threads) were also compared. The tensile-strength and the pressure probe devices were custom made in cooperation with the Faculty of Informatics.

Results: The average diameter of the chicken femoral arteries was 3.25±0.38 mm. The sleeve-technique showed the biggest pressure drop (56±16.41 mmHg), however, it was the fastest method. The tensile-strength of simple interrupted suture was 4.55±0.7 Newton (N), being lower than of the intact vessel (6.8 ± 1.4 N). The tensile-strength did not differ significantly between the 12-stitch simple interrupted and continuous sutures, however, the latter was stronger. The anastomoses made on thread model were significantly stronger than the ones on vessels.

Conclusion: The main variables were the number of stitches and the strength of the vessel. The pressure drop was not correlated with the stitch number. One incorrect stitch can dramatically increase the leakage. Although the sleeve-technique is quick to be performed, it cannot withstand high pressure. The suture material itself is far stronger then the vessel. The vessel tensile strength was decreased in the anastomoses. For the given vessel diameter more than 8 stitches should be used.

Introduction

Several techniques are known to join vessels for the anastomosis types (end-to-end, end-to-side, and side-to-side) [1]. The anastomoses itself can be done with different sutures like the simple interrupted the continuous or the sleeve-technique, which is said to be easier and faster than the previous types mostly in research [2]. During vessel injury the given situation can greatly affect the technique which can be used. The vessel could have segmental,

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or longitudinal damage, or spasm due to the blunt trauma [3], not talking about the standard microsurgical reconstructive procedures. The criteria of application can be the aim of the surgery, the anatomical situation, the geometry of the vessel and the available time, among other factors. To be able to decide which anastomosis is the most desired in the given situation the surgeon is required to have a thorough education and lots of experience [1]. If the wrong technique used several problems can occur, anastomosis rupture, tension, or narrowing of the vessel [4,5]. To help this decision the doctors should have information about the properties of each technique.

To describe an anastomoses there are several parameters that can be measured, for example: patency, blood flow, surgical difficulty, pressure resistance, and tensile-strength, among others. Each of which can significantly affect the properties of the finished anastomoses. The knot is self can have a great effect on the tensile strength [6,7], even microscopic differences in vessel structure can cause postoperative complications [8] The biomechanical parameters of an intact arteries in physiological, and pathophysiological circumstances are studied [9–12]. Even though the basic hemodynamic parameters of humans are well known, for a short period of time values can radically change out of range due to movement, or physical activity [8–15].

Several new anastomosis techniques have been made to improve microsurgical anastomoses techniques,[2,16–21] but a thorough comparison of biomechanical properties haven't been done between the old and newer techniques.

Despite of the significance of this issue, only few articles are known about the biomechanical properties of vessel anastomoses. Using the key words "arterial anastomosis" and "bursting test" on PubMed, only 11 articles were found, and using the key words "vessel anastomoses" and "tensile-strength" only 10 articles were published in the last ten years. This shows that this field is still under-examined.

There are different procedures to measure pressure resistance or burst pressure, but mainly they are used on intestinal anastomoses,[22,23] some measures microsurgical vessel anastomoses as well.[24,25] After the clamps are released the anastomoses can be still bleeding, at that time the burst pressure not as informative as pressure resistance. To further understand the biomechanics of vessel anastomoses a quick and easy test is required which can be conducted on non-living models as well, so during education courses anastomoses performed by the students can be tested as well. It could be beneficial because it can further elevate the quality of the teaching courses. Therefore, we aimed to compare the simple interrupted the continuous and the modified Lauritzen's sleeve-techniques by their biomechanical properties, using two new custom made measuring devices.

Materials and methods

Study design, biopreparates and animals

In the major part of the study 60 chicken thigh biopreparates (female, 6–7 weeks old) were used. In the additional study part measurements were carried out on 10 male WI:Crl rats (bodyweight: 349.7 ± 13.76 g) (permission registration Nr.: 25/2016/UD-CAW). The whole experiment focused on pressure tests and tensile-strength, elongation and elasticity analyses of the targeted vessels and the used suture materials. In all cases 8/0 polyamide thread (Silon) was used with serosa (taper) needle.

Study part I: pressure test

For this test 30 chicken thighs were used. The groups were the followings ($n = 10$/each): end-to-end anastomosis with simple interrupted, or with continuous, or using modified Lauritzen's sleeve-technique. An incision was made on the chicken thigh above the vessels. Then the femoral artery was gently dissected and all the side branches were ligated, and the distal end was clamped down. The proximal end of the artery was cannulated with a 20 G cannula. An infusion bag was connected to the cannula and the vessel was filled with a mixture of saline solution and Betadine. The pressure was initially set for 120 mmHg. If there was no leakage, the making of the anastomoses were started to be performed.

The simple interrupted suture was started with two corner stitches. The front and the back walls were connected with simple stitches. In case of the continuous suture technique, after placing the corner stitches the front and back walls were separately sutured together. For the sleeve-technique we had to modify the original Lauritzen's method because of the vessel diameter.[2] The original technique requires only two stitches in a 1-mm thick vessel. In case of a chicken femoral artery (diameter: 3.25±0.38 mm) we needed to use four stitches, and additional ones in case of leakage. Instead of corner stitches two pulling stitches were made 180º apart. The pulling stitches were placed in to the proximal end of the artery as far from the cut as wide the vessels were under pressure. These sutures were stitched through the edge of the distal end of the artery. By tying the pulling stitches, the distal end of the vessel was pulled into the lumen of the proximal end of the artery. Two additional sutures were placed between the pulling stitches on the front and the back wall. These were superficial stitches connecting only the adventitia of the two vessel ends.

The pressure measuring device consisted of a blood pressure monitor, an infusion bag and an infusion set. The measuring cuff was wrapped around the infusion bag to measure and control the pressure. The bag was filled with 1000 ml of saline solution mixed with 20 ml of Betadine. The Betadine was used to make the leakage in the anastomoses visible.

The measurement started by elevating the pressure in the infusion bag to 280 mmHg, and then the infusion tube was opened. The vessels were under water therefore the leakage was visible due to the Betadine content. The pressure drop was continuously measured for five minutes. The pressure resistance was calculated from the pressure drop that occurred during five minutes of observation.

Study part II: tensile strength, elongation, elasticity

The simple interrupted and continuous anastomoses were performed the same way as it was described in Study part I. The only difference was that the suture count was standardized. The following groups were established: simple interrupted suture, continuous suture, with 12 stitches, and an 8-stitch simple interrupted suture group was also added. The study part I clearly showed that the sleeve-technique, because of the highly different suture count, was not comparable with the other suture techniques, in this regard. We also included 10 rat abdominal aorta specimens (diameter: 2.21± 0.26 mm). End-to-end anastomoses were performed on the vessels with 8 stitches, using the same suture material. After the anastomoses were finished, the vessels were removed from the chicken thigh, and from the abdominal cavity of the rat, and placed into the tensile-strength testing device.

The suture material was also examined in different scenarios to better understand the biomechanics of anastomoses. We measured: single thread, a thread line with a knot in the middle, single stitch (Fig. 1, A), and stitch with a flattened (damaged) area in the middle (Fig. 1, B). Each knot was made out of three half knots. A thread model was also set, consisting of two 2/0 polyester braided thread loops (Tervalon) which were sutured together with the same techniques as mentioned before (Fig. 1, C). By this way the tissue variable was excluded, and only the suturing technique and the suture material could be investigated.

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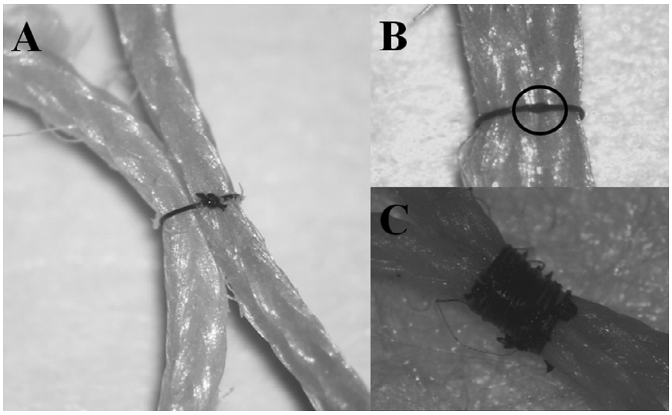

Fig. 1. The thread model. A: One stitch connecting the two thread loop; B: Flattened (damaged) area on the stitch; C: 12-stitch simple interrupted suture on the thread model.

The measuring device was custom made with the collaboration of the Department of Information Technology, Faculty of Informatics, and the Department of Operative Techniques and Surgical Research, Faculty of Medicine, University of Debrecen, Hungary. The device is consisted of a CNC servo motor, a torsion sensor, and an "Arduino" microcontroller [26]. The device measured the tensile-strength in Newton (N). Each second it made 11 steps, and each step equals 1.8º of rotation, which means 0.079 mm puling distance at each step. The equipment measured the puling force and draw a stress-strain curve. In this case, stress means the force, which acts upon the vessel and strain the distance which it has been pulled. Then the curves were analyzed. Each vessel was tested twice, the anastomosis itself and 1 cm proximally to test the intact vessel tensile strength as a control.

Statistical analysis

All the statistics were calculated with GraphPad Prism 8. The significance level was set to $p \leq 0.05$. Data distribution was checked for normality, and accordingly, Student *t*-test, or Wilcoxon, or Mann-Whitney non-parametric tests, as well as one-way ANOVA tests were used. The correlation between values was tested using Pearson correlation analysis. The elasticity was calculated using the Young's modulus on the high-strain region of the stress strain curves [27].

Results

Technical and general observations

During the pressure resistance measurements (Study part I), every test was recorded and later analyzed. We found that in all cases of the interrupted and continuous suture the leakage was originating from the puncture whole (Fig. 2, A, B). The most leakage was originating from individual incorrectly placed stitches (Fig. 2, C). The sleeve technique behaved differently, because the main source of leakage is from the space between the inner and outer arterial wall (Fig. 2, D). We also noticed that the artery has to be inserted as deep into the proximal end as thick the artery is under pressure.

Damaging the thread with the needle holder could cause suture failure, the flattened area weakened the stitch significantly. We found that the suture always broke where the flattened are was indicating the direct cause of failure (Fig. 3, A). The thread broke next to the knot every time, which suggest that the knot itself plays an important role in the structure of the anastomosis (Fig. 3, B). The 8-stitch anastomoses in the vessel behaved differently, instead of the tissue the stitches broke. The continuous suture separated in a characteristic ring shape, the simple interrupted anastomosis also broke in the same manner unless there was an unevenly placed stitch, in that case that stitch stayed on one side of the broken anastomosis, while the rest of the stitches remained on the other side, and the individual stitches remained intact (Fig. 3, C).

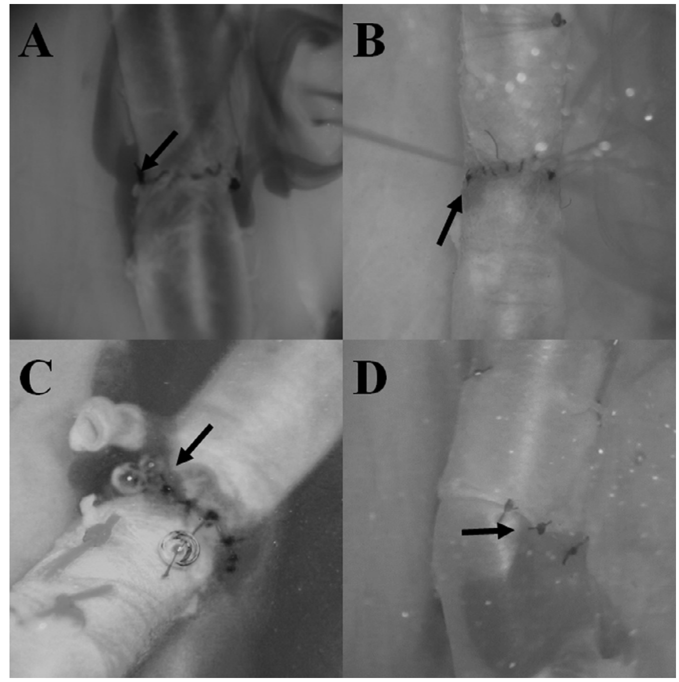

Fig. 2. Selected photos for technical observations in pressure drop study part. A: continuous suture leaking at the corner stitch, and distorting the vessel; B: leaking corner stitch in a continuous suture without deformation; C: leakage from simple interrupted suture; D: sleeve anastomosis leakage.

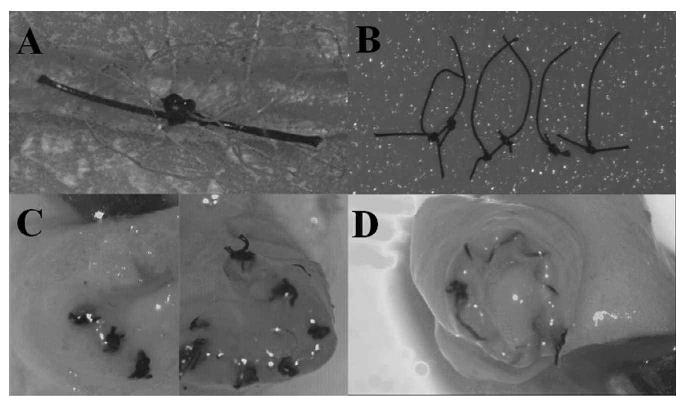

Fig. 3. Technical observations in tensile-strength study part. A: stitch that broke where the flattened are was; B: unaltered stitches broke adjacent to the knot; C: unevenly placed stitches after anastomosis failure; D: continuous suture characteristic ring-shaped rupture.

Pressure resistance

There were no significant differences between the groups in term of vessel diameter after completing the anastomoses. The sleeve-techniques leaked the most because, the pressure drop in case of the simple interrupted suture was 40.2 ± 12.8 mmHg; at the continuous suture it was 39.6 ± 9.8 mmHg; and the modified Lauritzen's method resulted in leakage at 56.0 ± 16.7 mmHg ($p = 0.029$ vs. interrupted, and $p = 0.016$ vs. continuous) (Table 1,

Table 1
Stitch count and pressure drop values of anastomoses using different techniques (simple interrupted suture, continuous suture, sleeve-technique).

Groups		Stitch count (n = 10) *Means*	*±SD*	*p value*	*vs.*	Pressure Drop [mmHg] (n = 10) *Means*	*±SD*	*p value*	*vs.*
A	**Simple interrupted**	13.1	2.4	*0.038*	B	40.2	13	0.9078	B
B	**Continuous**	15.1	1.4	*<0.0001*	C	39.6	9.9	*0.0155*	C
C	**Sleeve**	6.1	0.9	*<0.0001*	A	56	17	0.0289	A

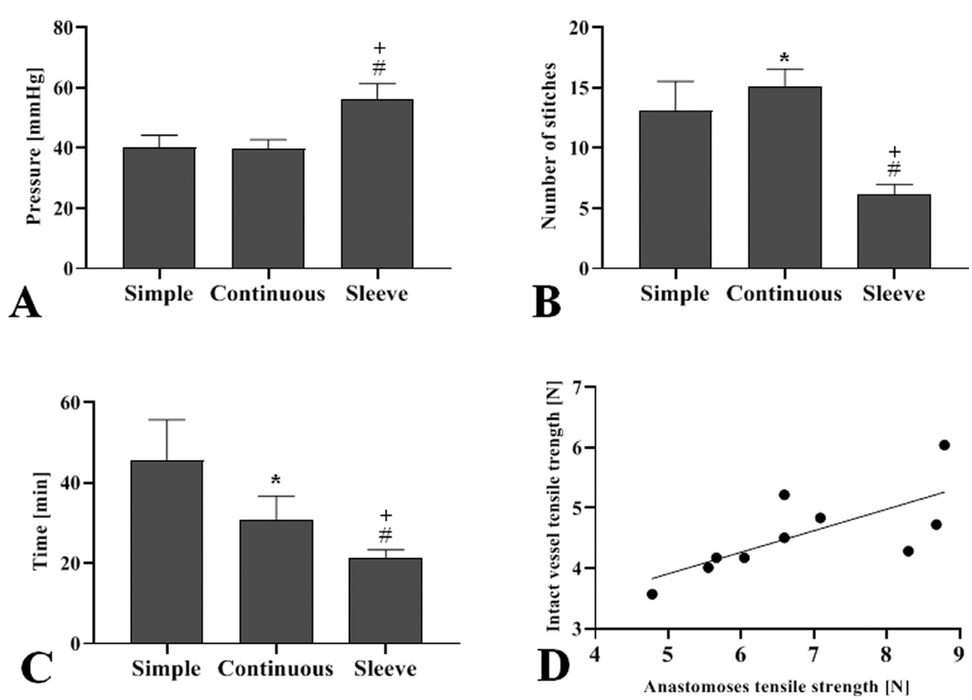

Fig. 4. Descriptive parameters for biopreparate anastomoses. A: pressure drop after 5 min; B: number of used stitches; C: required time to finish an anastomoses; D: correlation of the tensile strength between the intact vessel and the 12-stitch simple interrupted anastomosis. n = 10, means ±SEM; # $p < 0.05$ vs. Continuous; + $p < 0.05$ vs. Simple; * $p < 0.05$ vs. Continuous; .

Table 2
Correlation between the pressure drop and stitch number, and the tensile strength of the intact vessel and the anastomosis.

	Stitch number versus pressure drop values *Simple interrupted*	*Continuous*	*Sleeve*	Intact vessel tensile strength versus anastomosis tensile strength *12-stitch interrupted*	*12-stitch continuous*	*8-stitch interrupted*
P value	0.2955	0.3168	0.3130	*0.0211*	0.8314	0.1851
R value	0.3679	0.3532	0.3558	0.7111	0.07753	0.4562
Correlation	Medium	Medium	Medium	Large	Small	Medium

Fig. 4, A). The least amount of sutures were required by the sleeve suture as well. The suture count of the simple interrupted suture was 13.1 ± 2.4 stitches, and for the continuous suture 15.1 ± 1.4 stitches were used, the sleeve-technique needed 6.4 ± 1.1 sutures ($p < 0.0001$ vs. interrupted, and $p = 0.0001$ vs. continuous) (Table 1, Fig. 4, B). And the sleeve technique turned out to be the quickest (Fig. 4, C).

The correlation was calculated between the number of stitches used to the amount of pressure drop in each group. In each group the correlation coefficient wasn't notable, and there was no difference between the groups (Table 2).

Tensile strength

Testing of the tensile strength revealed that the shape of the stress-strain curve can give information about the technical mistakes that happen while the anastomosis was made (Fig. 5). If a stitch was incorrectly placed and it was holding more tissue than the other stitches, it broke first which could be seen on the curve (Fig. 5, B). In case of the continuous sometimes a notable indentation was visible in the curve that happened when one sides of the anastomosis broke separately due to the damage of the knot, or the thread (Fig. 5, C). A stair-like patter was visible when the sutures were unevenly placed and the anastomosis was torn apart stitch by stitch (Fig. 5, D).

The tensile strength of the vessels was significantly decreased after the anastomoses were performed in every group. There were no differences between the 12-stitch simple interrupted and the 12-stitch continuous suture, but the 8-stitch anastomoses were significantly weaker than the ones made with other two suturing techniques (12-stitch: 4.31±0.64 N; 8-stitch: vs. 3.47±0.32 N) (Table 3). The 12-stitch interrupted and the 12-stitch continuous suture tensile strength on the thread model was notably higher than the anastomoses or the intact vessels. Significant difference couldn't be found between the 8-stitch interrupted thread model anastomoses and the intact vessels (Fig. 6, A). Which suggests that this amount of stitches on a 3-mm vessel is not enough, because instead of the vessel, the thread itself was the weaker link. Ev-

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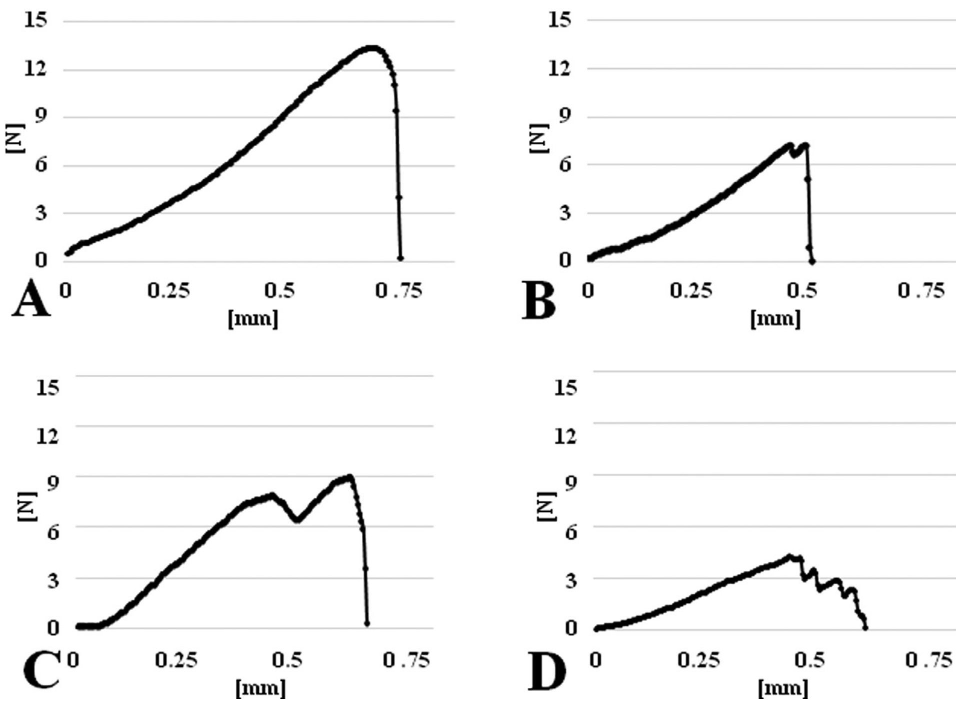

Fig. 5. Characteristic stress-strain curves; A: intact vessel; B: one unevenly placed stitch; C: damaged continuous suture; D: stair-like pattern after several unevenly placed sutures.

Table 3
Biomechanical parameters of the chicken thigh biopreparate anastomoses (A-F), the thread-model (G-I), and the rat abdominal aorta anastomosis (J,K): tensile strength, elongation and elasticity.

Groups		Tensile strength [N] ($n = 10$)				Elongation [mm] ($n = 10$)				Elasticity [Young' modulus] ($n = 10$)			
		Means	*±SD*	*p value*	*vs.*	*Means*	*±SD*	*p value*	*vs.*	*Means*	*±SD*	*p value*	*vs.*
A	**12-stitch interrupted**	4.55	0.70	*0.0003*	C	9.22	2.19	*0.0242*	C	0.75	0.21	0.7242	C
B	**12-stitch continuous**	4.31	0.64	*0.0016*	C	9.10	2.39	*0.0397*	C	0.71	0.16	0.4143	C
C	**8-stitch interrupted**	3.47	0.32	*0.0002*	F	6.82	2.03	*0.0215*	F	0.78	0.18	0.0637	F
D	**12-stitch interrupted *intact vessel***	6.80	1.39	*<0.0001*	A	7.79	1.78	0.0531	A	0.89	0.11	*0.0024*	A
E	**12-stitch continuous *intact vessel***	7.28	1.94	*0.0011*	B	8.28	1.95	*<0.0001*	B	0.86	0.30	*0.043*	B
F	**8-stitch interrupted *intact vessel***	8.13	2.37	0.8591	I	7.35	1.48	0.0732	I	1.13	0.33	*0.0114*	I
G	**12-stitch interrupted *thread-model***	10.28	1.33	*0.0079*	I	11.07	2.20	0.6905	I	1.95	0.28	*0.0159*	I
H	**12-stitch continuous *thread-model***	13.06	1.77	0.0317	G	12.87	3.55	0.6905	G	2.34	0.46	0.119	G
I	**8-stitch interrupted *thread-model***	8.17	0.78	0.0003	C	10.05	2.06	0.7767	C	1.63	0.22	0.0637	C
J	**8-stitch interrupted *rat model***	1.02	0.38	<0.0001	K	2.34	1.33	<0.0001	K	0.52	0.23	<0.0001	K
K	**Rat aorta *control***	4.36	1.45	<0.0001	D	6.72	2.07	0.0002	D	1.60	0.38	<0.0001	D

ery anastomoses were inspected after the test, and we found that in case of the 8-stitch anastomoses not the vessels were torn but the stitches were broken. The elongation of the vessels showed that the 8-stitch anastomoses on the vessel were the shortest 6.82±2.02 mm (Fig. 6, B). And all the intact vessel groups could elongate significantly more than the other anastomoses groups. The elongation of anastomosis performed on thread model didn't differ significantly from their matching anastomosis group.

The elasticity was calculated by the ratio of the elongation and the tensile strength on the high strain region of the strain/stress curve, higher values show that the material deforms less under tension, therefore the higher the value the stiffer the material. In case of the intact vessels the elasticity was significantly changed by the anastomoses in all groups. Each type of anastomoses technique made the vessels more elastic (Fig. 6, C). At the thread model each group showed drastically higher values which meant that the threads on their own, are much more rigid then the anastomoses performed on the vessels.

The rat aorta behaved the same as the chicken femoral arteries. The basic tensile strength was smaller because the vessels were significantly thinner (2.21±0.26 mm vs. 3.25±0.38 mm; rat vs. chicken; $p < 0.0001$). The main difference was that the decrease of elongation, tensile strength, and elasticity caused by the anastomosis was greater than what occurred at the chicken femoral artery groups. This enlarged reduction was significantly bigger in case of the elongation, and the elasticity parameter (Fig. 7).

When testing the threads themselves, they broke at 0.71±0 N which shows how well the suture material is made and how accurate the custom made device is. The knot decreased the tensile strength by an average of 0.23 N. One stitch could withstand no more than 1.29±0.03 N, but a flattened area weakened it to 1.06±0.06 N (Fig. 8, A). The elongation of the thread wasn't changed by the knot, and we got the same result at the flattened area group as well. The elasticity of the thread was decreased by the knot almost 30% (0.68±0.11 vs. 0.42±0.06; thread vs. knot on a thread; $p = 0.0006$), the flattened area also significantly decreased the elasticity values (3.00±0.49 vs. 2.1 ± 0.10; one stitch vs. one stitch with flattened area) (Table 4, Fig. 8, C). The correlation between the intact vessel tensile strength and the anastomosis tensile strength was also calculated. The continuous suture, and the 8-

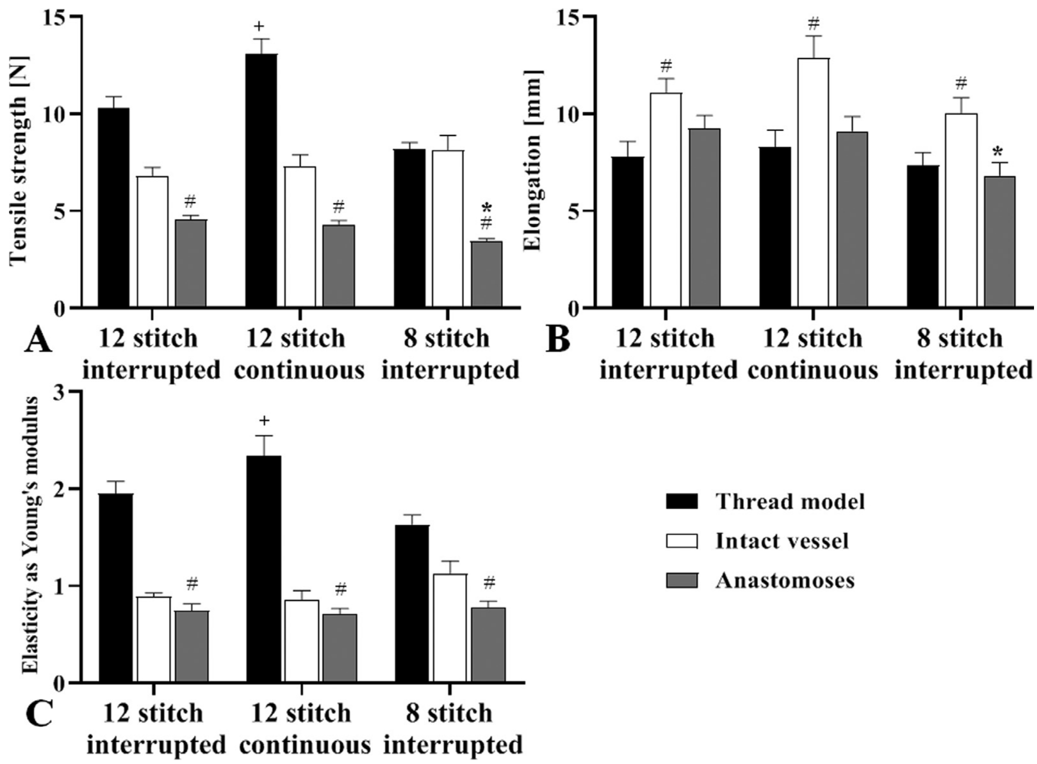

Fig. 6. Biomechanical parameters of biopreparate anastomoses. A: tensile-strength of the anastomoses intact vessels and the thread model anastomoses; B: elongation; C: elasticity o. $n = 10$; means±SEM; # $p < 0.05$ vs. All groups; + $p < 0.05$ vs. 8-stitch interrupted thread model; $* p < 0.05$ vs. 12-stitch simple or continuous sutured anastomoses.

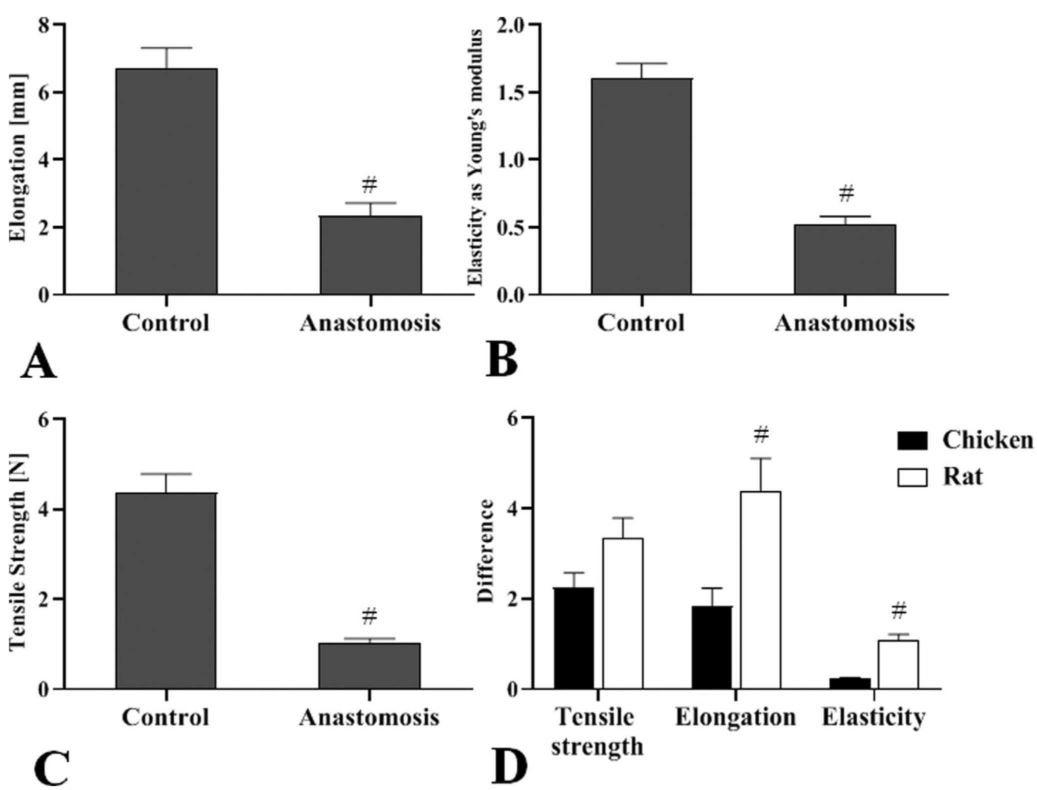

Fig. 7. Rat aorta biomechanical parameters. A: tensile strength of the anastomoses; B: elongation; C: elasticity; D: the amount of reduction that happened after the anastomoses was performed. $n = 10$; means±SEM; # $p < 0.05$ vs. control, vs. chicken biopreparate.

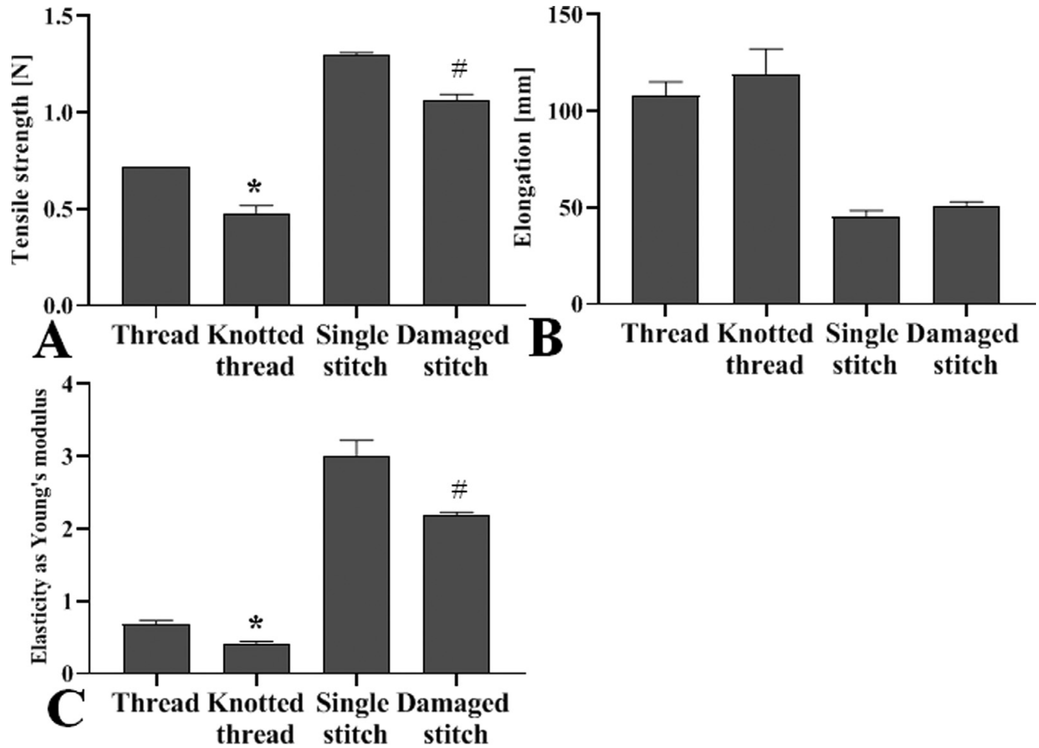

Fig. 8. Thread mechanical parameters; A: tensile strength of the threads; B: elongation; C: elasticity. $n = 5$; means ±SEM; # $p < 0.05$ vs. one stitch; ⋆ $p < 0.05$ vs. single thread.

Table 4
Biomechanical parameters of the suture material itself (single thread, knotted threads, single stitch, stitch with damaged thread): tensile strength, elongation, and elasticity.

		Tensile strength [N] ($n = 10$)				Elongation [mm] ($n = 10$)				Elasticity [Young' modulus] ($n = 10$)			
	Groups	*Means*	*±SD*	*p value*	*vs.*	*Means*	*±SD*	*p-value*	*vs.*	*Means*	*±SD*	*p value*	*vs.*
A	**Single thread**	0.71	0.00	*<0.0001*	B	108.0	18.71	0.8794	B	0.69	0.11	*0.0006*	B
B	**Knotted threads**	0.48	0.10	*0.0025*	D	119.1	34.67	*0.0025*	D	0.42	0.06	*0.0013*	D
C	**Single stitch**	1.30	0.03	*0.0005*	A	45.0	7.62	*0.0025*	A	3.00	0.49	*0.0025*	A
D	**Single stitch with damaged thread**	1.07	0.06	*0.0079*	C	50.4	5.41	0.1825	C	2.18	0.10	*0.0317*	C

stitch simple interrupted showed small p values, but the 12-stitch simple interrupted anastomosis p value showed a strong correlation (Table 2) (Fig. 4, D).

Discussion

Investigating various techniques for joining vessels, provided useful information and observations, being general surgical technical ones and objective, numerical ones. Concerning the technical observations, we also noticed in case of the sleeve technique that the artery has to be inserted as deep into the proximal end as thick the artery is under pressure, which increases tension on the vessel, this finding was also noted in the literature [28]. This gives the sleeve-technique a great disadvantage, because especially after a traumatic vessel injury the tension free anastomosis is a key factor. Tension can cause narrowing, intimal damage, and early postoperative complications such as occlusion [5,13,29]. Therefore, 'macro-surgical' applications of this kind of technique is questionable, because these problems increase with the size of the vessel. The continuous suture leaked only at the corner stitches, but it could easily narrow the vessel diameter which can also happen with the sleeve-anastomosis as well [30,31].

Although the sleeve-technique was the quickest method, it showed the highest pressure drop, and required the least amount of stitches. There was a low correlation between the number of stitches and the pressure drop in each group. This suggests that the leakage mostly caused by individual incorrectly placed stitches, thus the correct suturing technique is more dominant than the amount of stitches used. The original Lauritzen's sleeve-techniques couldn't be used, in the given vessel diameter. Therefore, the original technique had to be modified. Among the examined techniques the tension is the greatest in the sleeve anastomosis, because of the surgical invagination, which also causes narrowing of the lumen [30]. This means in case of a traumatic great vessel injury which can occur with great amount of tissue loss [3], this technique is not advisable, thus the sleeve technique is only suitable for microvascular applications.

All the anastomoses decreased the vessel tensile strength significantly along with the elongation and rigidity. The 8-stitch simple interrupted anastomosis was the weakest, and it could elongate the shortest. The amount of stitches used in an anastomoses can greatly affect the biomechanical properties of the anastomosis. Each suture is a new punctured hole, and each stitch can further narrow the diameter of the vessel. Therefore the optimal number of stitches is important. The increased suture number gave a stronger anastomosis, but the correlation was not linear.

The correlation between the intact vessel tensile strength and the anastomosis tensile strength was low in the simple interrupted and the 8 stitch simple interrupted groups. The 12 stitch simple interrupted show a high correlation, also narrowing never occurred during the formation of the anastomoses, thus in our study this anastomoses technique proved to be the most reliable. If time is not of the essence, the most physiological anastomoses with the least amount of tension is the 12 stitch simple interrupted out of the examined techniques.

Difference between the simple interrupted and continuous suture was only visible in case of the thread model where the continuous suture was less elastic but due to the small sample size the difference wasn't significant, therefore further research is required. The 8-stitch anastomoses on the thread model had the same tensile strength as the intact vessel, because instead of the vessel wall the stitches broke. This suggests that in the given vessel diameter more stitches are required. The knot and the flattened area on a thread caused significant decrease in the tensile strength and elasticity values. Therefore, the avoidance of the flattened area in a stitch is highly important for a secure anastomosis especially in case of continuous anastomoses where one suture defect can cause a total anastomosis failure. It is also known that even the twisting of the thread can decrease the tensile strength of the thread [7].

The custom made device [26] not only could accurately measure the biomechanical parameters but it could point out any incidental mistakes that could happened during the formation of the anastomosis. This can improve anastomosis techniques and help during teaching courses to give a better feedback, and show mistakes which couldn't be discovered using other techniques.

Conclusion

A pressure resistance test can give viable information of an anastomosis behavior at the first few minutes of operation, before the blood coagulation takes effect. The tensile strength of anastomoses can show how physiological the suture technique can perform. Answering these questions can help to identify the adequate suturing method for a given situation, which can vary drastically in case of traumatic injuries. Easily accessible measuring device not only can help to answer these questions but also can help to improve education during teaching courses, by giving a more detailed feedback, and point out mistakes that previously could not have been recognized.

Declaration of Competing Interest

The authors have no conflict of interest.

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