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Original Article / *Özgün Makale*

An *in vitro* evaluation of tensile strength of synthetic sutures used in nasal surgery

Nazal cerrahide kullanılan sentetik sütürlerin gerilme dayanımının in vitro değerlendirilmesi

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ABSTRACT

Objectives: This study aims to evaluate the tensile strength of surgical synthetic absorbable (polyglactin [PG] suture [Vicryl®]) and non-absorbable (polypropylene [PP] suture [Prolene®]) sutures in simulated interstitial tissue over a period of 10 days.

Materials and Methods: Two suture materials, PG suture (Vicryl®) and PP suture (Prolene®), were used in 4-0 gauges. The tensile strengths of both suture materials were measured as knotless and knotted without any processing. Suture materials were subjected to knotted and knotless tensile testing using an Instron 3369 Universal tester. The materials were then kept in plasma for 10 days to simulate an *in vitro* environment and tensile strength was measured as both knotted and unknotted.

Results: Polypropylene sutures were found to be stronger than PG sutures ($p<0.01$). This result was similar in both knotted and unknotted measurements. There was no statistically significant difference between knotted and unknotted values before and after immersion ($p>0.05$).

Conclusion: Unknotted and knotted PG sutures have lower tensile strength than PP sutures. This characteristic was unchanged after plasma immersion to simulate tissue. Absorbable sutures have relatively less suture-related complications compared to non-absorbable sutures. Because of all of these characteristics, we believe that PP sutures can be safely used in cartilage shaping and cases requiring stabilization in nasal surgery.

Keywords: Breaking strength, nasal cavity, polyglactin, polypropylene.

ÖZ

Amaç: Bu çalışmada cerrahi sentetik emilebilen [poliglaktin (PG) sütür (Vicryl®)] ve emilmeyen [polipropilen (PP) sütür (Prolene®)] sütürlerin gerilme dayanımı simüle edilmiş interstisyel dokuda 10 günlük bir süre boyunca değerlendirildi.

Gereç ve Yöntemler: İki sütür malzemesi, PG sütür (Vicryl®) ve PP sütür (Prolene®), 4-0 ölçüsünde kullanıldı. Her iki sütür malzemesinin gerilme dayanımları herhangi bir işlem olmaksızın düğümsüz ve düğümlü olarak ölçüldü. Sütür malzemeleri Instron 3369 Universal test cihazı kullanılarak düğümlü ve düğümsüz gerilme testine tabi tutuldu. Malzemeler daha sonra *in vitro* bir ortamı simüle etmek için 10 gün boyunca plazmada tutuldu ve gerilme dayanımı düğümlü ve düğümsüz olarak ölçüldü.

Bulgular: Polipropilen sütürlerin PG sütürlerden daha dayanıklı olduğu bulundu ($p<0.01$). Bu sonuç hem düğümlü hem düğümsüz ölçümlerde benzerdi. İmmersiyon öncesi ve sonrasında düğümlü ve düğümsüz değerler arasında istatistiksel olarak anlamlı farklılık yoktu ($p>0.05$).

Sonuç: Düğümsüz ve düğümlü PG sütürlerin gerilme dayanımı PP sütürlerden daha düşüktür. Bu özellik dokuyu simüle etmek için plazma immersiyonundan sonra değişmedi. Sütüre bağlı komplikasyonlar emilebilen sütürlerde emilmeyen sütürlere göre göreceli olarak daha azdır. Tüm bu özellikler nedeniyle PP sütürlerin nazal cerrahide kıkırdak şekillendirmesinde ve stabilizasyon gerektiren olgularda güvenle kullanılabileceğini düşünüyoruz.

Anahtar sözcükler: Kopma dayanımı, nazal kavite, poliglaktin, polipropilen.

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Sutures have been used since ancient Egypt mainly for the purpose of closing wound edges, but also to reduce dead space, bring tissues closer together, and shape tissues. Sutures can be classified according to their structure as natural (such as intestinal), synthetic absorbable, and synthetic non-absorbable.[1,2]

Tensile strength graphs obtained after evaluating the mechanical properties of the sutures provide objective information that best demonstrates the properties of suture materials. Starting with mechanical properties such as elasticity, fragility, and tensile strength, sutures should be selected depending on the properties of the tissues they are to be applied to and the process to be carried out.[3]

In otorhinolaryngology, tension sutures are frequently used in otoplasty, rhinoplasty, and tissue repair and shaping procedures of head and neck surgery. Absorbable and non-absorbable sutures used in nasal surgeries can be used in different fields according to the biological properties of the material. There are different views on the use and reliability of sutures used in nasal surgery. Non-absorbable polypropylene (PP) has high knot reliability and durability. For this reason, it can be used in dome suture and alar flaring suture applications where the cartilage should be shaped, as well as being highly preferred in septum-nasal spine and septocolumellar suture applications where long-term stabilization is required.[4] In contrast, polyglactin (PG) sutures are used as an alternative in these regions due to its absorbable properties.[5]

In this study, we aimed to evaluate the tensile strength of surgical synthetic absorbable (PG suture [Vicryl®]) and non-absorbable (PP suture [Prolene®]) sutures in simulated interstitial tissue over a period of 10 days.

MATERIALS AND METHODS

This study was conducted between October 2018 and May 2019. The study evaluated surgical synthetic absorbable PG (Vicryl® 4/0; Ethicon Inc., Cornelia, GA, USA) and non-absorbable PP (Prolene® 4/0; Ethicon Inc., Cincinnati, OH, USA) suture materials. Size and sample of each material were selected based on their usage in nasal surgery. The study protocol was approved by the Bakırköy Dr. Sadi Konuk Training and Research Hospital Ethics Committee (2018/281). A written informed consent was obtained from the volunteer who received the plasma. The study was conducted in accordance with the principles of the Declaration of Helsinki, applicable regulatory requirements, and Good Clinical Practices.

Tensile strength measurements of the corresponding sutures in our study were performed with the same standards in all samples. The samples were subjected to tensile testing using an Instron® 3369 Universal tester (8500/8800 system, Instron Ltd., High Wycombe, Buckinghamshire, UK). Force was continued to be applied until the sample broke and the breaking strength was recorded as test data. Tensile strength measurements were measured as newtons (N) (Figure 1).

Two gauges of each type were used in 11 samples. The four knots were primarily discarded at knotted sutures. A total of 11 non-absorbable sutures (PP) were evaluated without immersion and knotting (group PrePPU), 11 non-absorbable sutures without immersion but with knotting (group PrePPK), 11 absorbable sutures (PG) without immersion or knotting (group PrePGU), and 11 absorbable sutures without immersion but with knotting (group PrePGK). Eleven unknotted non-absorbable sutures (group PostPPU), 11 unknotted absorbable sutures (group PostPGU), and 11 knotted absorbable sutures (group PostPGK) were all evaluated 10 days after immersion.

The plasma required for plasma immersion was obtained from the senior author in accordance with international blood product preparation criteria.[6] A biologic simulation of the interstitial tissue was created *in vitro* by mixing 9 mL of human plasma in a 1:1 ratio. Samples were incubated for 10 days at 37°C in an incubator (Memmert incubator, GmbH + Co. KG. Schwabach, Germany) in the prepared plasma solution. After 10 days, the tensile strength measurements of the samples were recorded (groups PostPPU, PostPPK, PostPGU, PostPGK).

Statistical analysis

The IBM SPSS Statistics version 24.0 for Windows package program (IBM Corp., Armonk, NY, USA) was used for statistical analysis. Quantitative data were summarized as mean and standard deviation. Normal distribution conformity was analyzed with the Shapiro-Wilk test. The significance of each intergroup difference was analyzed using Student's t-test, and the significance of any difference in median values was assessed by the Mann-Whitney U test or chi-square test. Quantitative data were analyzed using the Wilcoxon test. A value of $p<0.05$ was considered statistically significant.

RESULTS

Tensile strength of 88 sutures was measured. The results for all sutures are provided in Table 1 and Figure 2. While the average score of group PrePPU was 18.10 N without subjection to immersion, the average score of group PrePGU was 15.11 N. The difference

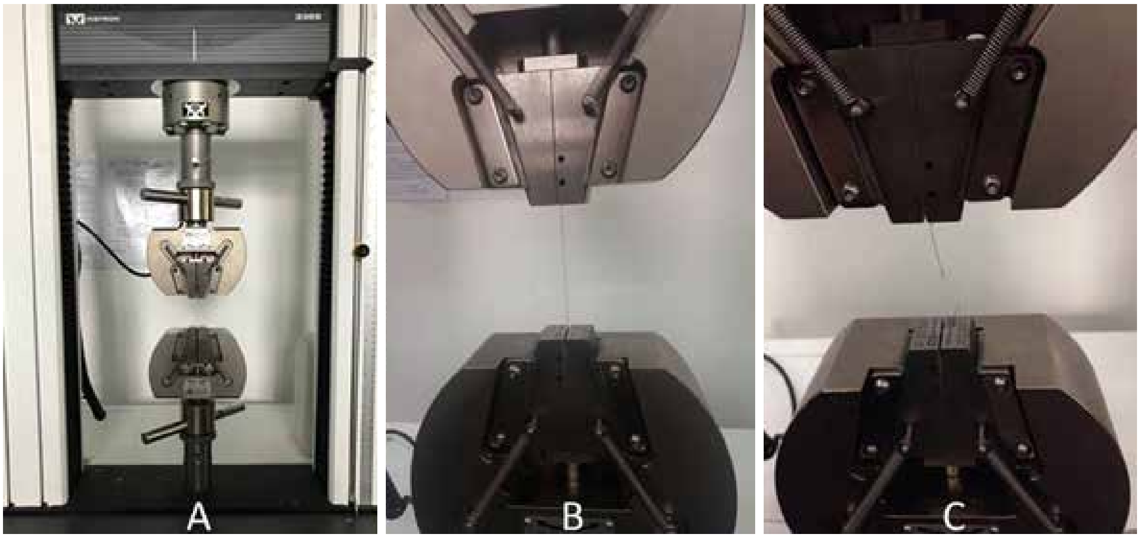

Figure 1. (a) Intron 3369 Universal test machine. **(b, c)** Tension and stress testing.

between these groups was statistically significant (p=0.0001). While the average score of group PrePPK was 15.23 N, the average score of group PrePGK was 10.88 N which was also statistically significant (p=0.0001). After 10 days of plasma immersion, the average score of group PostPPU was 17.65, while that of group PostPGU was 14.40 N which was statistically significant (p=0.0001). When the measurements were performed after knotting, the average score of group PostPPK was 14.35 N, while the average score of group PostPGK was measured as 10.36 N which was also statistically significant (p=0.0001).

The difference between group PrePPU and group PostPPU values was not statistically significant (p=0.61). The difference between group PrePPK and group PostPPK values was not statistically significant (p=0.057). The difference between group PrePGK and group PostPGK values was not statistically significant (p=0.63). That is to say, subjection to immersion did not make any change in the strength of the sutures.

DISCUSSION

In the present study, we performed an *in vitro* evaluation of tensile strength of PG and PP sutures. We also evaluated the effects of immersion on the tensile strength of both sutures. In our study, we used plasma for the immersion environment. The samples were tested as unknotted and knotted before incubation, and the same groups were retested after 10 days of plasma incubation. We did not find any statistically significant difference between the groups before and after immersion in our study. The tensile strengths of the knotted groups were significantly different from the unknotted groups. All values of absorbable groups were statistically more resistant than all values of non-absorbable groups.

The characteristics of the suture materials and application techniques are important in avoiding the complications that may arise in the postoperative period.[7] Sutures can be classified as absorbable and

Table 1
Tensile strength measurements of groups

	Non-absorbable		Absorbable			
	PPU	PPK	PGU	PGK	p^*	p^{**}
Preimmersion	18.1±1.1	15.2±0.6	15.1±0.4	10.9±0.6	0.0001†	0.0001†
Postimmersion	17.7±1.1	14.4±1.6	14.4±1.2	10.4±0.8	0.0001†	0.0001†
p	0.061‡	0.057‡	0.063‡	0.094‡		

PPU: Polypropylene sutures without knotting; PPK: Polypropylene sutures with knotting; PGU: Polyglactin sutures without knotting; PGK: Polyglactin sutures with knotting; * Statistical analysis between PPU and PGU; ** Statistical analysis between PPK and PGK; † Wilcoxon test; ‡ Mann-Whitney U test; Units are provided in newtons.

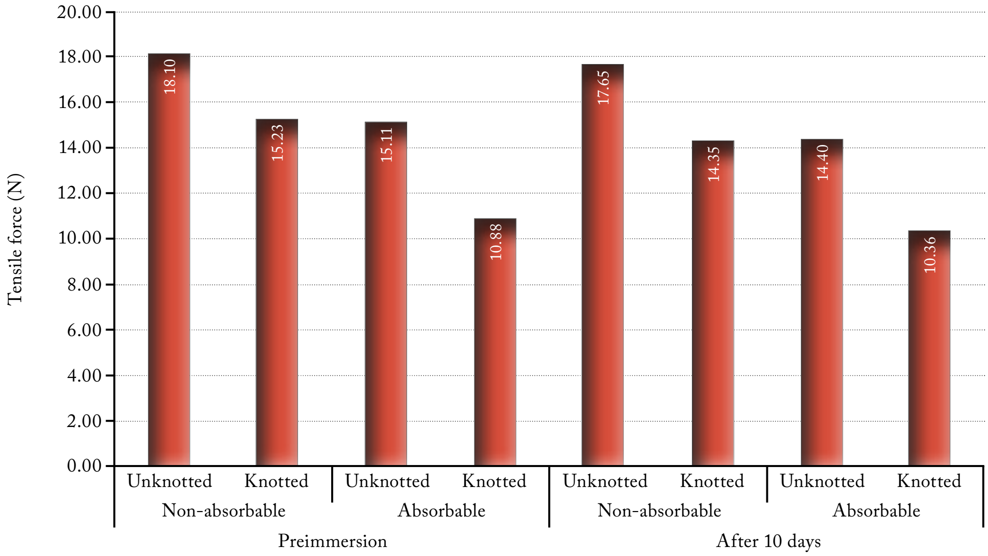

Figure 2. Tensile strength graph of groups.
N: Newton.

non-absorbable. The mechanical properties of these materials differ according to their composition. In particular, the strength of absorbable sutures after immersion is significantly reduced. While knotting procedures differ depending on the applied technique, they generally reduce the mechanical strength of the suture materials.[8] The combined suture technique has a stronger tension force than a simple and horizontal mattress suture.[7] In the present study, we took primarily four knots on each suture.

The tensile strength as well as the absorption period of the suture is very important in the selection of suture in nasal surgery. Tension sutures are widely used in otorhinolaryngology and particularly in nasal surgery. Cardenas et al.[9] reported using 5/0 PP in nasal type surgery. Neu[10] recommended the use of 5/0 nylon suture in ensuring nasal type cartilage concavity. Sutures are critical in the shaping of cartilage in the first preoperative two-three months and support the cartilage fixation of soft tissue molding of the scar tissue formed around the cartilage during this period.[11,12] After this period, the effect of the presence of sutures on the reshaping of cartilage diminishes. Severe reactions due to non-absorbable PP and late-absorbing polydioxanone (PDS) (mean 180 days) used in septorhinoplasty cases are few but can occur.[13] The high rate of unwanted complications such as tissue reactions, fibrosis, and rejection associated with non-absorbable sutures leads rhinologists towards absorbable materials.[5,9] Gruber[14] reported that using 4/0 PDS with nasal typing provided better results. Polyglactin sutures, which are absorbed in four-six weeks on average, provide adequate stabilization and are used as an alternative to non-absorbable materials. This could eliminate the difficulty of using non-absorbable suture materials in the reshaping of cartilage.[15]

Liao et al.[16] reported that the clinical efficacy of non-absorbable and absorbable suture anchor fixation techniques is similar to that of arthroscopic tibial eminence fractures. Kocaoglu et al.[17] reported that the use of absorbable sutures in the treatment of Achilles tendon repair compared to non-absorbable sutures resulted in satisfactory results in terms of functional outcomes while providing low suture reactions rates. Monteiro et al.[18] reported that the absorbable or non-absorbable feature of the suture used in successful arthroscopic shoulder joint loosening was not a significant factor. Moreover, Justan[19] developed an *in vitro* experimental flexor tendon model and reported that with regard to its elasticity and favorable standard deviation tensile strength measurements, polyester multifilament non-absorbable uncoated material was considered to be the most suitable.

Polyglactin sutures generally retain their tensile strength at standard pH values, while rapidly losing these properties in acidic and alkaline environments.[3] On the contrary, hyperplasia and inflammation of the intima are seen at a lower rate and shorter period in these sutures compared to PP sutures.[4,15] Among the sutures, multifilament compared to monofilament, and natural compared to synthetic caused higher rates of tissue reactions.[20] All suture materials cause more or less inflammation in the region they are applied. While this reaction is short-lived and limited in absorbable sutures, not only it is longer in non-absorbable sutures, but it may also cause the development of small granulomas in some patients.[15,16] Kama et al.[21] performed a similar assessment in an experimental study of PP mesh. Polypropylene has been shown to develop a significant inflammatory reaction to fibrosis formation, but limited foreign body reaction. Parara et al.[22] conducted a study on objective erythema caused by five different materials based on digital photography. The most ideal suture material used for skin closure was absorbable, monofilament, and one that retains its original strength until removed in postoperative 10 days. In a similar study, open technique rhinoplasty suturing inverted-V transcolumellar incisions with rapid resorbable sutures resulted in significantly less discomfort and no difference in scarring compared to non-resorbable sutures.[23]

Alkan et al.[24] evaluated the biomechanical characteristics of septal and costal cartilage with samples from fresh cadavers and found no statistically significant difference between the elastic forces of both tissues, which was below 18 N. In particular, costal cartilage was considered more flexible than septal cartilage.

Experimental studies of mechanical evaluations of sutures in different environments have used different setups. The tensile strength values of synthetic multifilament non-absorbable materials used in experimental flexor tendon models were found to be adequate.[19] In an *in vitro* study on suture materials, measurements of seven different suture materials kept in room temperature and average humidity for 24 hours were performed with an Instron® Tensometer Table Model, which resulted in different flexibility and tensile values.[3] In another study evaluating oral synthetic absorbable sutures, artificial saliva was used to stimulate oral conditions. The samples were kept in immersion for 14 days.[25,26] In an *in vitro* veterinary study where elasticity and breaking strength of synthetic suture materials were evaluated, horse body fluids were used for immersion. Absorbable suture materials were incubated at 37°C for 7, 14 or 28 days in phosphate-buffered saline, equine serum, equine urine, and equine peritoneal fluid from an animal with peritonitis. Each suture material type was tested for failure in a material testing machine for each time point and incubation medium. Yield strength, strain, and Young's modulus were calculated, analyzed, and reported.[27]

In conclusion, the tensile strength measurements were significantly higher in the non-absorbable group in our *in vitro* study. There was no statistically significant difference within both groups before and after immersion. Due to the results of the present study, we believe that PP sutures can be safely used in cartilage shaping in nasal surgery and in cases that require stabilization compared to PG sutures.

Declaration of conflicting interests

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