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Evaluation of Tensile Strength of Sutures Used in Dentistry

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ABSTRACT
Aim: The aim of this study was to compare the mechanical properties of sutures used in dentistry according to different materials in vitro.
Material and Methods: Eight 3-0 different absorbable and non-absorbable suture materials with 3-0 gauge (Polytetraflouroethylene, polypropylene, polyester, polyglactin 910, polyglycolic acid, poliglecaprone 25, polydioxanone, and silk) were compared in terms of mechanical strength. All sutures were tied with a simple suture technique. Each material contained 10 samples per group, with a total sample size of 80 specimens. Failure load was measured in N while elongation was measured in µm using a microtensile testing device. A one-way analysis of variance (ANOVA) was used to analyze the difference in failure loads and elongation values.
Results: Polydioxanone was significantly more resistant to tensile forces among all tested materials ($p<0.001$) which was followed by poliglecaprone 25, whereas polyglactin 910 presented the lowest failure load values. Although there was no direct relationship between tensile strength and elongation values of the materials, polydioxanone demonstrated increased elongation before failure. Additionally, polyglactin 910 indicated a significantly lower elongation capacity among all tested materials.
Conclusion: Failure load and elongation were dependent on the suture material type. Where high tensile strength is required, polydioxanone is an advantageous material due to its high resistance to loads and better elongation characteristics.
Keywords: Tensile strength; sutures; mechanical tests.

Diş Hekimliğinde Kullanılan Dikiş Materyallerinin Çekme Direncinin Değerlendirilmesi

ÖZ
Amaç: Bu çalışmanın amacı, diş hekimliğinde kullanılan dikiş materyallerinin mekanik özelliklerinin farklı materyallere göre in vitro olarak karşılaştırılmasıdır.
Gereç ve Yöntemler: Sekiz adet abzorbe olabilen ve abzorbe olamayan 3-0 gauge kalınlığında (Politetrafloroetilen, polipropilen, polyester, poliglaktin 910, poliglikolik asit, poliglekapron 25, polidioksanon ve ipek) dikiş materyali mekanik özellikleri açısından karşılaştırılmıştır. Bütün dikiş materyalleri basit sütür tekniği ile bağlanmıştır. Her materyal için grup başına 10 örnek olacak şekilde, toplamda 80 örnek olarak dikişler hazırlanmıştır. N cinsinden gerilme mukavemeti ve µm cinsinden uzama dahil olmak üzere mekanik özellikler, bir mikro gerilme test cihazı kullanılarak ölçülmüştür. Gruplar arasındaki uzama ve mukavemet direnci değerleri ANOVA kullanılarak istatistiksel olarak karşılaştırılmıştır.
Bulgular: Polidioksanon, test edilen tüm malzemeler arasında çekme kuvvetlerine karşı önemli ölçüde daha dirençli bulunmuştur ($p<0,001$), bunu poliglekapron 25 takip ederken, poliglaktin 910 en düşük kırılma yükü değerlerini göstermiştir. Malzemelerin çekme mukavemeti ile uzama değerleri arasında doğrudan bir ilişki olmamasına rağmen, polidioksanon kırılmadan önce artan uzama göstermiştir. Ek olarak, poliglaktin 910, test edilen tüm malzemeler arasında önemli ölçüde daha düşük bir uzama kapasitesi göstermiştir.
Sonuç: Başarısızlık yükü ve uzamanın, dikiş materyalinin cinsine bağlı olduğu saptanmıştır. Yüksek çekme mukavemetinin gerekli olduğu durumlarda, polidioksanon, yüklere karşı yüksek direnci ve daha iyi uzama özellikleri nedeniyle avantajlı bir malzeme olarak görülmüştür.
Anahtar Kelimeler: Çekme direnci; dikiş; mekanik testler.

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INTRODUCTION

Suture materials are used in medicine and dentistry for the purpose of proper wound stabilization and closing in surgical procedures. In oral tissues, factors such as the oral flora, constant mechanical forces due to mastication, speech, swallowing, patient habits including oral hygiene and smoking, affect wound healing. Suturing is of critical importance where mechanical integrity of the flaps is required. Hence, it is essential for a suture material to have sufficient tensile strength, high knot security and minimal inflammatory tissue reaction for optimum healing in the postoperative period (1).

In an ideal suture material, behaviour of the suture against stress-strain needs to match the sutured tissue. This behaviour is highly dependent on the physical properties of the material, which can be classified as monofilament and multifilament types (2). Multifilament sutures are produced of several filaments braided or twisted together whereas monofilament sutures include only a single strand of the filament. The physical structure of a braided suture provides increased tensile strength and flexibility, thus providing an easy handling in clinical applications which offer an advantage against monofilament sutures. However, multifilament sutures can cause a higher inflammatory reaction due to bacterial retention or food debris (3). Monofilament sutures show less resistance to the tissues when passing and harbour less bacteria, but they must be handled carefully as they can weaken or break when crushed by instruments (4).

Various factors are taken into consideration when a suture material is preferred. The suture materials can be evaluated based on different aspects, which can be classified as tissue reactions, physical and handling characteristics. The physical properties of a suture are determined by its structure, diameter, elasticity and knot strength which can affect the tensile strength of the material (2). Suture materials tend to lose their initial strength by 70 to 80% following their implementation (5). Therefore, initial tensile strength is critically important as insufficient resistance of the suture material can lead to an early suture rupture which may cause the separation of wound edges or flaps, hence resulting in a poorer healing. A comprehensive understanding of the suture material is essential in dental applications, as the success of any surgical intervention also depends on the wound closure. There is no ideal suture material that can compensate all the clinical requirements. In addition, due to differences in testing methodologies, it is not possible to compare available results in a complete manner. Therefore, the aim of the present study is to evaluate the mechanical properties of eight suture materials used in dentistry under a specific testing condition to allow an easy comparison.

MATERIAL AND METHODS

This study evaluated eight different absorbable and non-absorbable suture materials with 3-0 gauge, commonly used in dental surgical interventions: polytetrafluoroethylene (PTFE, Cytoplast, Osteogenics Biomaterials, Lubbock, USA), polypropylene (PP, Propilen, Dogsan Inc, Trabzon, Turkey), polyester (PE, Politer, Dogsan Inc, Trabzon, Turkey), silk (S, Silk, Dogsan Inc, Trabzon, Turkey), polyglactin 910 (PG, Vicryl rapid, Ethicon Inc, Somerville, USA), polyglycolic acid (PGA, Pegesorb rapid, Dogsan Inc, Trabzon, Turkey), poliglecaprone 25 (PGC, Monocryl, Ethicon Inc, Somerville, USA) and polydioxanone (PDO, Pedesente, Dogsan Inc, Trabzon, Turkey). Properties of the materials are given in Table 1.

Table 1. Eight suture materials and their properties

Suture material	Codification	Structure	Composition	Degredation
Polytetraflouroethylene	PTFE	Monofilament	Synthetic	Nonabsorbable
Polypropylene	PP	Monofilament	Synthetic	Nonabsorbable
Polyester	PE	Multifilament	Synthetic	Nonabsorbable
Polyglactin 910	PG	Multifilament	Synthetic	Absorbable
Polyglycolic acid	PGA	Multifilament	Synthetic	Absorbable
Poliglecaprone 25	PGC	Monofilament	Synthetic	Absorbable
Polydioxanone	PDO	Monofilament	Synthetic	Absorbable
Silk	S	Multifilament	Natural	Nonabsorbable

Sample Preparation

The sample size was calculated as 9 with G* Power software (version 3.1; University of Dusseldorf, Germany), with an effect size (d) of 1.5, α of 0.05, and 1-β (power) of 0.80, and sample preparation is described according to previously published study (6). Briefly, an experimental platform consisting of two square plates with a hole to tie the suture material was prepared for each sample using a three-dimensional printer (Creality Ender-3 Pro; Shenzhen Creality 3D Technology Co LT, Shenzhen, China). The experimental setup is demonstrated in Figure 1. All plates were tied with a simple suture technique for all tested materials by one experienced surgeon (AET) using a Mathieu needle holder. Surgeon's knot, which is constructed by an initial double-wrap throws, plus 3 additional throws followed by one reverse and one forward direction were used in all materials. An additional suture was added to each group in case of loss during testing. Ten samples were used for each suture material group with a total sample size of 80 specimens.

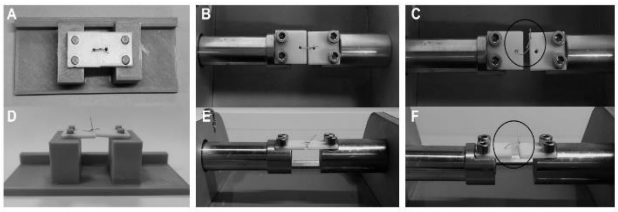

Figure 1. A-D) Experimental setup from above; B-E) Sutured plates are inserted into the testing machine; C-F) Suture rupture after the application of tensile forces. Suture is marked with a circle

Mechanical Test

Mechanical properties including failure load and elongation were measured using a microtensile test machine (MOD Dental, Esetron Smart Robotechnologies, Ankara, Turkey). An increasing stretching force with the speed of 5 mm/min was applied gradually. Failure load was measured as the maximum strength the suture material could endure without rupturing in Newton. Elongation was determined as the total displacement shown by the suture material before tearing under gradually delivered forces and it was measured in μm.

Statistical Analysis

The data were analyzed using the Kolmogorov-Smirnov and Shapiro-Wilk tests to ensure a normal distribution. Descriptive statistics were presented as means and standard deviations. A one-way analysis of variance (ANOVA) was used to analyze the difference in failure loads and elongation values. Pairwise analyses were performed using the Tukey HSD test. Analysis was conducted using a statistical software (SPSS version 20.0; IBM SPSS Statistics Inc., Chicago, IL, USA) at a significance level of 5%.

RESULTS

Statistical evaluation of the results indicated that the failure load highly depended on the type of material (Figure 2). Among the tested suture materials, the highest resistance to forces was found in PDO group with a failure load at 60 ± 3 N. This material indicated significantly higher resistance compared to other groups ($p=0.004$), which was followed by PGC ($p=0.0043$). The lowest failure load, with a statistically significant difference compared to other materials, was noted in PG and PTFE groups, which failed at 18 ± 1 N and 15 ± 3 N, respectively ($p<0.001$). The other suture materials PE, PGA, S and PP showed similar values ranging between 42 and 33 N.

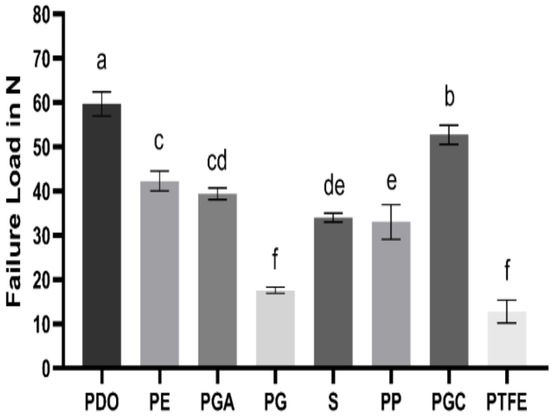

Figure 2. Failure load values (in N) of the tested suture materials (PDO, polydioxanone; PE, polyester; PGA, polyglycolic acid; PG, polyglactin 910; S, silk; PP, polypropylene; PGC, poliglecaprone 25; PTFE, polytetrafluoroethylene). Similar superscript lowercase letters (over the bars) imply no significant difference according to Tukey's pairwise comparisons $p>0.05$.

There were no knot failures with all eight suture materials. Elongation values varied according to the tested suture material. The greatest value for elongation at failure was obtained with PDO (7316 ± 275 µm) whereas PG (1221 ± 136 µm) showed the lowest value, indicating a statistically significant difference as compared to other suture materials ($p<0.001$). PGA and PP indicated a similar elongation pattern as well as S with PTFE, the prior group with higher elongation in µm than the latter (Figure 3).

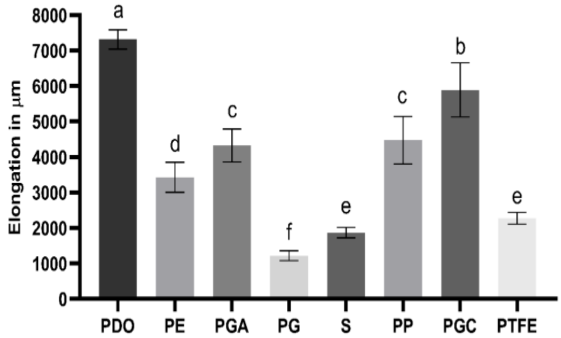

Figure 3. Elongation values (in µm) of the tested suture materials (PDO, polydioxanone; PE, polyester; PGA, polyglycolic acid; PG, polyglactin 910; S, silk; PP, polypropylene; PGC, poliglecaprone 25; PTFE, polytetrafluoroethylene). Similar superscript lowercase letters (over the bars) imply no significant difference according to Tukey's pairwise comparisons $p>0.05$.

DISCUSSION

The present in vitro study was designed to determine the tensile properties of 8 suture materials used in dentistry with a simple suture technique. A single experienced surgeon carried out suturing procedures to limit variability. Materials included in the current study were made of natural or synthetic fibers, in multifilament or monofilament structures which were both absorbable or nonabsorbable to have a various range of suture materials to be compared.

A simple suture technique was used as it is the most commonly used suturing technique in oral surgical interventions, such as periodontal or implant placement surgeries, which can be performed easily by specialists as well as general dental practitioners. The simple suture can be preferred in diverse applications including closing elevated flaps and stabilization of soft tissues in oral region. A survey among periodontists indicated that simple interrupted suture was chosen by the majority of the participants for periodontal surgical procedures (7). Therefore, this technique was chosen in the current study for clinical relevance to most circumstances. In addition, suture length was ended at 3 mm in accordance with similar studies (8,9) which enabled sufficient suture length to prevent any possible knot slippage.

Multifilament braided sutures have greater tensile strength with higher resistance to forces, more flexibility and increased knot security as compared to monofilament sutures (10,11). However, various results are reported in terms of tensile resistance of suture materials based on physical structure. When compared with Silk and PTFE; PGA and polyamide showed higher values for failure load, which were both monofilament and multifilament, indicating the structure is not a sole factor for better performance (9). In the present study, PG, a multifilament structured suture, demonstrated the lowest values in failure load, indicating lower tensile performance. In a similar study, among the suture materials PGA, PG and PGC, before immersion, tensile strength of PGA was reported to be greater than other groups, although there was not much difference between the three materials (12). In the present study, there was a significant difference between these three materials, PGC having the highest values followed by PGA while PG had the least resistance. The discrepancies between these materials can be due to different suture sizes or brands of the materials used. Although suture sizes in gauges give an average diameter, suture diameters are not measured exactly in most of the studies including the present one.

The highest tensile strength was found for PDO material in the present study. Another study reported that among 3-0 gauge tested sutures, PGC was stronger with a breaking load of 71.6 N, compared to PDO suture materials with two different brands, 50.7 N and 48.7 N respectively (13). However, it was also found that PDO gained strength over time when incubated in PBS. As the present study compared the tensile strength at one point, aiming to determine the initial highest tensile strength performance of sutures, and without any immersion period, the results must be evaluated with caution. In addition, tensile strength is shown to vary among the same suture materials with different brands possibly due to variations in manufacturing (13, 14, 15) which can also explain the disparities between the tensile strength of suture materials in different publications.

On the other hand, knot configuration can play a role in the resistance of the suture material. Abellan et al. (9) reported that the resistance pattern of knots varies significantly according to the suture material type, suggesting different protocols to be used in each suture type for more clinical efficiency. A single knot configuration was used in the present study for standardization. Additional studies can be conducted to determine the ideal configuration for each suture material for clinical practice.

Mechanical forces on a suture material can cause irreversible elongation, meaning it can keep its initial length even though sutured tissues experience volume changes such as swelling. When swelling ceases, sutures can cause deformation to adjacent tissues or some plastic sutures can be deformed by themselves with little destruction to the tissues during swelling while getting too wide to completely approximate the wound edges (16). Hence, a high elongation capacity of a suture can pose both an advantage or a disadvantage depending on the used circumstances. Suture materials with high elongation can stretch and compensate edema, whereas sutures with high tensile failure loads are necessary in tissues under high tension (17). Therefore, both elongation and tensile strength need to be considered of a material on suture selection as both of these qualities may not correlate. The maximum elongation was found for PDO in the present study. It was reported that PDO shows a high percentage of elongation, up to 144% prior to breakage, and can lose tensile strength by 20 weeks (18). Another study demonstrated that 3-0 gauge PDO sutures with two different brands have maximum extension values of 7930 μm and 8070 μm, similar to the average elongation value found for PDO, 7315 μm, in the present study. The results indicate that PDO can show greater deformation before breaking and can resist higher forces, rendering it a suitable material to be used in oral tissues.

Suture materials can further be categorized due to their ability to lose tensile strength within a time period affected by biological activities of host tissues, as either absorbable or nonabsorbable (19). Absorbable sutures either go under a hydrolysis process when made of synthetic materials or natural suture materials are digested by body enzymes. When used in wound closure, an absorbable suture shows a gradual decrease in tensile strength over the initial weeks. Addition of infection to this process can also increase loss of tensile strength in a shorter period of time (4). Some studies indicated that absorbable suture materials show higher tensile resistance compared to nonabsorbable sutures (3, 9, 20). Differing reported results suggest that not only the degradation property of suture material is a determinant in its tensile strength, but suturing techniques, knot configuration and filament structure are also effective. In the present study, both absorbable and nonabsorbable suture materials were tested, with an absorbable suture material, PDO, showing superior tensile properties among all groups, whereas another absorbable suture, PG, presented the lowest failure load values. A limitation of the present study is the lack of comparison of these materials in terms of degradation, which was not applicable to the present study design as immersion in saliva was not performed. Therefore, an evaluation of the effect of absorption profile and pH changes on the suture tensile strength was not possible. Further clinical considerations when using a suture material include their resorption rate and inflammatory response. Although PDO demonstrated superior mechanical behaviour among the tested materials, it is reported to be a difficult suture material for handling with poor knot security and can be considered as a slowly absorbable suture with complete hydrolysis extending to 6-7 months (21). The presence of a remnant suture for lengthy periods may contribute to prolonged inflammation in the surgical area, but a minimal inflammatory response was reported for PDO in comparison to nylon and PG (22), rendering this material a valid option for its use in the oral region.

Additionally, another limitation of the study is the use of a single size suture for the mechanical testing. According to FDA, in order to demonstrate consistent tensile strength retention of a suture, it is necessary to test at least the smallest and largest suture sizes for a suture type (23). Sutures of 3-0 gauge were chosen for the present study as it is commonly used in oral surgery. However, sutures of 4-0, 5-0 and 6-0 gauge are also used in mucogingival microsurgery, hence it may be beneficial in the following studies to explore if the tested sutures can show a similar mechanical performance with smaller diameters.

CONCLUSION

In conclusion, the tensile properties of sutures vary depending on the material type. The results of the present study indicated that PDO is advantageous due to its tensile strength and higher elongation to failure with a simple suture technique in vitro, thus making it a valuable choice for circumstances in which high tissue retention is essential. Mostly used in cardiovascular, general and orthopaedic surgery, there is a lack of studies on the use of PDO in the oral region. Although in vitro studies present valuable information about physical properties, more clinical studies would shed light on the benefits or disadvantages of the use of PDO in oral tissues.

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REFERENCES

1. Burkhardt R, Lang NP. Influence of suturing on wound healing. Periodontology. 2000 2015; 68(1): 270-81. https://doi.org/10.1111/prd.12078.
2. Karaca E, Hockenberger AS, Yildiz H. Investigating changes in mechanical properties and tissue reaction of silk, polyester, polyamide, and polypropylene sutures in vivo. Textile Research Journal. 2005; 75(4): 297-303. https://doi.org/10.1177/0040517505054734.
3. Kim JC, Lee YK, Lim BS, Rhee SH, Yang HC. Comparison of tensile and knot security properties of surgical sutures. Journal of Materials Science Materials Medicine. 2007; 18: 2363-9. https://doi.org/10.1007/s10856-007-3114-6.
4. Bryne M, Aly A. The surgical suture. Aesthetic Surgery Journal. 2009; 39(Suppl_2):67–72. https://doi.org/10.1093/asj/sjz036.
5. Arce J, Palacios A, Alvitez-Temoche D, Mendoza-Azpur G, Romero-Tapia P, Mayta-Tovalino F. Tensile strength of novel nonabsorbable PTFE (Teflon®) versus other suture materials: an in vitro study. International Journal of Dentistry. 2019; ID7419709. https://doi.org/10.1155/2019/7419708.
6. Taysi AE, Ercal P, Sismanoglu S. Comparison between tensile characteristics of various suture materials with two suture techniques: an in vitro study. Clinical Oral Investigations 2021; 25(11): 6393-401. https://doi.org/10.1007/s00784-021-03943-3
7. Griffin TJ, Hur Y, Bu J. Basic suture techniques for oral mucosa. Clinical Advances in Periodontics. 2011; 1(3): 221-32. https://doi.org/10.1902/cap.2011.110053.
8. Muffly TM, Cook C, Distasio J, Bonham AJ, Blandon ER. Suture end length as a function of knot integrity. Journal of Surgical Education. 2009; 66(5): 276-80. https://doi.org/ 10.1016/j.jsurg.2009.10.003.
9. Abellán D, Nart J, Pascual A, Cohen RE, Sanz-Moliner JD. Physical and mechanical evaluation of five suture materials on three knot configurations: An in vitro study. Polymers (Basel). 2016; 8(4): 147. https://doi.org/10.3390/polym8040147.
10. Rawal A, Kumar R, Saraswat H. Tensile mechanics of braided sutures. Textile Research Journal. 2012; 82: 1703-10. https://doi.org/10.1177/0040517512445340.
11. Chellamani KP, Veerasubramanian D, Balaji RSV. Surgical sutures: An overview. Journal of Academia and Industrial Research. 2013; 1(12): 778-82.
12. Khiste SV, Ranganath V, Nichani AS. Evaluation of tensile strength of surgical synthetic absorbable suture materials: an in vitro study. Journal of Periodontal & Implant Science. 2013; 43(3): 130-5. https://doi.org/10.5051/jpis.2013.43.3.130.
13. Tobias KM, Kidd CE, Mulon PY, Zhu X. Tensile properties of synthetic, absorbable monofilament suture materials before and after incubation in phosphate-buffered saline. Veterinary Surgery. 2020; 49(3): 550-60. https://doi.org/10.1111/vsu.13326.
14. De la Puerta B, Parsons KJ, Draper ER, Moores AL, Moores AP. In vitro comparison of mechanical and degradation properties of equivalent absorbable suture materials from two different manufacturers. Veterinary Surgery. 2011; 40(2): 223-27. https://doi.org/10.1111/j.1532-950X.2010.00768.x.
15. Kreszinger M, Toholj B, Acanski A, Balos S. Tensile strength retention of resorptive suture materials applied in the stomach wall-an in vitro study. Veterinarski Arhiv. 2018; 88(2): 235-24. https://doi.org/10.24099/vet.arhiv.170130.
16. Holmlund DE. Knot properties of surgical suture materials. A model study. Acta Chirurgica Scandinavica . 1974; 140(5): 355-62.
17. Naleway WE, Lear W, Kruzic JJ, Maughan CB. Mechanical properties of suture materials in general and cutaneous surgery. Journal of Biomedical Materials Research B. 2015; 103(4): 735-42. https://doi.org/10.1002/jbm.b.33171.
18. Mäkelä P, Pohjonen T, Törmälä P, Waris T, Ashammakhi N. Strength retention properties of self-reinforced poly L-lactide (SR-PLLA) sutures compared with polyglyconate (Maxon) and polydioxanone (PDS) sutures. An in vitro study. Biomaterials. 2002; 23(12): 2587-92. https://doi.org/10.1016/s0142-9612(01)00396-9
19. Lober CW, Fenske NA. Suture materials for closing the skin and subcutaneous tissues. Aesthetic Plastic Surgery. 1986; 10(4): 245-7.
20. Moser JB, Lautenschlager EP, Horbal BJ. Mechanical properties of polyglycolic acid sutures in oral surgery. Journal of Dental Research. 1974; 53(4): 804-8.
21. Dart AJ, Dart CM. Suture Material: Conventional and Stimuli Responsive. In: Ducheyne P, editor. Comprehensive Biomaterials II. Elsevier; 2017. p. 746-771.
22. Bhargava D, Anantanarayanan P, Prakash G, Dare BJ, Deshpande A. Initial inflammatory response of skeletal muscle to commonly used suture materials: an animal model study to evaluate muscle healing after surgical repair - histopathological perspective. Medicina Oral Patologia Oral Cirugia Bucal. 2013; 18(3): e491-6. https://doi.org/10.4317/medoral.18608
23. FDA.org [Internet]. Food and Drug Administration, USA [Issued: 2003 June 3; Cited: 2022 Nov 22]. Available from http://www.fda.gov/.