Research Article

In-vitro Comparison of Tensile Strength of Commonly Used Suture Materials for Oral and Periodontal Surgeries by simulating Oral Environment

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Abstract

Objectives: The present *in vitro* study sought to evaluate the effect of saliva on the tensile strength of the commonly used suture material over a period of two weeks. Three suture materials Silk (SL), polyglactin 910 (PG) and polypropylene (PP) were used in 4-0 gauge. **Methods:** A total of 120 suture samples (40 from each material) were used for the experiment. Artificial saliva was mixed with human serum in 1:1 to simulate oral environment. All samples were tested at pre-immersion (baseline), 3rd, 7th and 14th day post-immersion period. Universal testing machine was used to test the selected mechanical properties. **Results:** The distribution of mean baseline tensile strength was significantly higher in PP group (P-value<0.001). Inter-group comparison revealed that PP group has maximum tensile strength when compared with PG and SL groups at all point of time. Intra-group comparison showed that all the three suture materials had significant difference in mechanical properties when pre-immersion values were compared with 14th day post-immersion values (P-value<0.001). **Conclusion:** PP sutures are strongest and have highest tensile strength and elongation property. PP seems to sustain its tensile strength better than SL and PG at the end of 14th day. Planned clinical experiments are necessary to verify this finding in an *in-vivo* setting.

Keywords: Silk; Polyglactin 910; Polypropylene; Periodontal surgery; Tensile strength

Introduction

The number of needed surgeries worldwide is increasing every day. One of the main success factors is the proper selection of the suture type. The ideal suture material should not breakdown suddenly while in use, have proper elongation property, biocompatible, easily to be handle, able to form a secure knot, and, biodegrade in an appropriate situations. [1] This on the other hand depends on several factors, including the mechanical properties of the suture materials.

Oral suturing is unalike suturing in other parts of the body due to the constant presence of saliva, high tissue vascularization, and functions related to speech, mastication, and swallowing. [2] Suitable sutures require precise physical characteristics and properties. One of the most important mechanical properties is the tensile strength of the suture material. The tensile properties, elasticity and stiffness of the suture material are some of the factors that control the function of the suture while in clinical use. [3]

The key importance of suturing after surgery is to keep the flap edges in close opposition to provide a primary closure. Failure to attain primary closure and preserve it over the early healing phase can be harmful to the desired outcome of the surgical procedure. Tensile strength is a characteristic that required to be upheld due to the fact that suture material tends to lose between 70% and 80% of its original strength. Consequently, the necessary original tensile strength must be guaranteed to avoid breaking the suture material. [4,5] Therefore, a deficit in the resistance of the suture material can lead to untimely rupture of the suture, which can lead to incapable adaptation of the surgical flaps and the healing by second intention. [6] The comprehensive studies that are available on sutures materials are much less relevant to materials used for oral and periodontal surgical procedures. [7,8]

In the oral cavity, different suture materials show different behaviors. [9-11] amongst the several available suture materials, silk, polyglactin are commonly used in oral and periodontal procedures. Silk is the most commonly used natural suture material, due to its superior handling characteristics. [12] Three different suture materials were included in the present study (Silk which consider by many surgeon as gold stone due to it easy handling, [12] Polyglactin 910 (Vicryl) is a multifilament absorbable synthetic coated suture composed of a copolymer made from 90% glycolide and 10% L-lactide. and Polypropylene monofilament, non-absorbable which composed of an isotactic crystalline stereoisomer of polypropylene.

Therefore, the aim of the current study is to evaluate and compare the tensile strength of silk, Polyglactin 910 and polypropylene suture material in an orally simulated environment (immersed in artificial saliva) and a pre-immersed dry condition during a period of fourteen days.

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Materials and Methods

The present *in-vitro* study protocol was reviewed and approved by the King Khalid University Ethical Review Committee (ERC), Abha, Saudi Arabia with approval no [SRC/ETH/2017-18/090]. The study was conducted in period of August 2018 to September 2018. Three different types of suture materials were selected and their physical properties were evaluated in the current study [Table 1 and Figure 1]. Suture materials were divided in to control (pre-immersed) and test group (immersed in artificial saliva). All the test suture materials were exposed to thermo-cycling (alternate temperature change from 5°C to 55°C), so as to simulate the challenges in the oral cavity.

A total of 120 suture samples were collected from commercially available stocks. Forty samples were obtained from each suture material type. All the suture samples were measured to a uniform length of 18 cm. Ten specimen from each group were tested for tensile strength before immersing into artificial saliva and referred as control group. Remaining suture specimens were kept in artificial saliva until exposed to experimental procedure. The complete study protocol has been described in detail in the Figure 2 (Flow chart).

Artificial saliva was formulated by mixing the compounds shown in Table 2 in one liter of distilled water.[13] To prevent any chemical changes in the prepared mixture, it was kept secured in an amber color bottle until used for the experiment. During the experiment, the prepared artificial saliva was mixed with Human serum in 1:1 concentration, to simulate oral environment. This biologic mixture was kept at a pH of 7.4 to 8.1 in an incubator at 37°C.[14]

Mechanical properties of the suture samples were evaluated by using universal testing machine (Quasar 100, Schutz-Licht, Langenfeld, Germany) coupled to a computer for digital productivity. Tensile strength of the suture samples were checked at particular time period: pre-immersion (dried), 3rd, 7th and 14th days post-immersion into artificial saliva. Each suture sample was fixed around two metal hooks attached to the opposite arms of the universal testing machine with a preset distance of 18 cm. Pilot testing revealed that this type of experimental setup did not result in the suture sample failure at the hooks or at the knots. Measurements were recorded for tensile strength. Tensile Strength is the maximum load that can be applied to a suture material before the suture breaks and it is measured in the unit of Newtons (N).

The data on continuous variables is presented as mean and standard deviation (SD) across the study groups. Statistical test Analysis of Variance (ANOVA) was used for the inter-group and intra-group comparison. In the entire study, the p-values less than 0.05 were considered to be statistically significant. The entire data is statistically analyzed using Statistical Package for Social Sciences (SPSS version 21.0, IBM Corporation, USA) for MS Windows.

Results

All the suture materials were intact without any visual deterioration during and at the end of the soaking period in saliva. Each suture specimen showed and evident breaking point while testing on universal testing machine. Baseline (pre-immersion) comparison of mean tensile strength is presented in Table 3. The distribution of mean baseline strength was significantly higher in PP group followed by PG group and the least with SL group (P-value<0.001 for all).

Table 4 is showing the distribution and comparison of mean tensile strength among three suture groups at 3rd, 7th and 14th day post-immersion in the saliva. PP group was exhibiting the

Table 1: Description of the suture material used in the study.

Suture material	Brand	Degradation	Manufacturer
Silk (SL)	Mersilk®	Non- Absorbable	Ethicon, Johnson & Johnson Pvt. Ltd. India.
Polyglactin 910 (PG)	Vicryl®	Absorbable	Ethicon, Johnson & Johnson Pvt. Ltd. India.
Polypropylene (PP)	Prolene®	Non- Absorbable	Ethicon, Johnson & Johnson Pvt. Ltd. India.

Figure 1: Suture materials used in the study.

maximum tensile strength when compared with PG and SL groups at all point of time (P-value<0.001).

Table 5 presented intra-group comparison of different suture material with respect to tensile strength from pre-immersion to 14th day post-immersion period. All the three suture material showed significant difference in strength when mean values from baseline (pre-immersion) is compared with 14th day post-immersion period.

Discussion

In the past, materials like animal hair, natural fibers, silk, nylon and gut mucosa have been used to close the surgical wounds. [15,16] A surgeon always looks for good handling characteristics and tensile strength of a suture while selecting a suture material. The tensile strength of a suture material is an indispensable property due to which suture material tolerates the tissue tension at the flap margin. [17] Suture materials exhibiting low tensile strength are more vulnerable to breakage during the healing period because of tension created by edema and tissue tension.

Different type of suture materials having the same diameter size may varies drastically in their tensile strengths measurement. In the literature most of the documented studies on mechanical

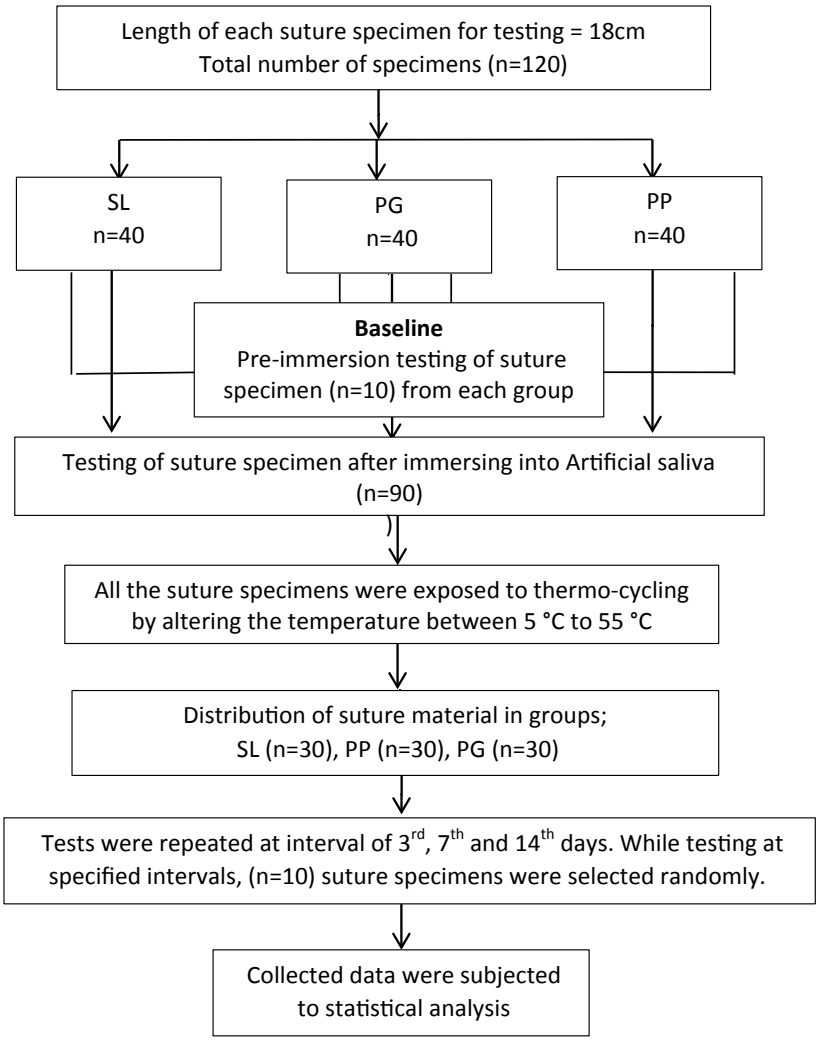

Figure 2: Flowchart of the study design.

Table 2: Chemical composition of artificial saliva.

Chemical components	Concentration (gm/L)
Sodium chloride (NaCl)	0.125
Potassium chloride (KCl)	0.963
Potassium thiocyanate (KSCN)	0.189
Monopotassium phosphate (KH_2PO_4)	0.654
Uréa (CH_4N_2O)	0.200
Sodium sulfate decahydrate (Na_2SO_4 $10H_2O$)	0.763
Ammonium chloride (NH_4Cl)	0.178
Calcium Chloride Dihydrate ($CaCl_2$ $2H_2O$)	0.227
Sodium bicarbonate ($NaHCO_3$)	0.630

Table 3: Tensile strength, percentage elongation and stiffness of different suture material groups at baseline (pre-immersion).

Parameters Suture material	Tensile strength (N)
Silk (SL)	10.60 ± 1.26
Polyglactin 910 (PG)	14.50 ± 1.27
Polypropylene (PP)	20.40 ± 1.26
P value	0.001***

p-value<0.05 is considered to be statistically significant; *** *p-value*<0.001= Highly significant

Table 4: Inter-group comparison of tensile strength pre and post immersion in saliva.

Suture	Silk (SL)	Polyglactin 910 (PG)	Polypropylene (PP)	*P-value* (Inter-group)		
	Mean ±SD	Mean ±SD	Mean ±SD	SL v PG	SL v PP	PG v PP
Pre-immersion	10.60 ± 1.26	14.50 ± 1.27	20.40 ± 1.26	0.001***	0.001***	0.001***
	Post immersion in saliva					
3-Days	9.75 ± 1.21	12.80 ± 1.64	19.40 ± 1.39	0.05**	0.001***	0.001***
7-Days	8.80 ± 0.83	11.80 ± 1.10	18.15 ± 1.59	0.05**	0.001***	0.001***
14-Days	8.25 ± 1.07	10.80 ± 1.76	15.40 ± 1.27	0.05**	0.001***	0.001***

p-value<0.05 is considered to be statistically significant. ** *p-value*<0.05= Significant, *** *p-value*<0.001= Highly significant

Table 5: Intra-group comparisons of tensile strength of different suture materials from pre-immersion (baseline) to 14th day.

Baseline to 14th day comparison	Silk (SL)	Polyglactin 910 (PG)	Polypropylene (PP)
Tensile strength	0.001***	0.001***	0.001***

p-value<0.05 is considered to be statistically significant. *** *p-value*<0.001= Highly significant

properties of sutures are performed on skin and subcutaneous tissues. [18-20] In such experimental design, sutures were exposed to limited environmental elements that can influence physical and mechanical properties of the sutures. Studies involving oral cavity poses multiple challenges like; presence of saliva, reflux gastric juice, pressure from the surrounding soft tissues and occlusal forces that may significantly modify the properties of suture materials. [21,22]

In the present study silk, polygalactin 910 and polypropylene suture materials were used because of their versatility and popularity of use in various periodontal flap surgical procedures. [23] Suture immersed in artificial saliva was used as a control because earlier studies have shown a possible detrimental effect on suture material's mechanical properties. [24,25] To the best of authors' knowledge, this is the first of its kind experimental study that evaluates the mechanical properties such as tensile strength, elongation and stiffness of different suture materials used for oral application by simulating the oral environment.

Studies have recorded a positive relationship between the reduction in tensile strength and resorption rates of different suture materials under controlled experimental conditions. [26-28] One of the important factor that could affect the resorption rate of suture materials is the fluctuation in pH of the solution. It has been shown in the literature that a decrease in the pH leads to rapid resorption of the suture. [24] The pH in our study was maintained between 7.4 and 8.1 by checking it daily for stability and replacing the solution every 2 days. The result of the present study showed that PP group exhibited maximum tensile strength as compared to PG and silk group. Owing to the fact that no study has been conducted in vitro, to evaluate the mechanical properties of PP suture material in comparison to PG and SL in the oral environment, we have selected this material in our investigation.

Previous studies on PG sutures revealed excellent handling characteristics,, high initial tensile strength, and less tissue reactions while healing. [29,30] A strong relationship between suture degradation and tensile strength has been reported in the literature under controlled *in vitro* and *in vivo* settings. PG degradation *in-vivo* is mainly due to proteolytic enzymatic degradation. PG sutures retained more than two-thirds of their original tensile strength at the 14 day post-immersion period. [31] The findings of the current study also revealed that more than tow third of the original tensile strength is retained at 14th day post immersion. According to the findings of the other study, when PG was exposed to saliva, showed more rapid tensile strength loss, especially after 7 days. [10] This finding is contradictory to the finding of the current research.

SL is the most commonly used suture material in the surgical field even though it carries suboptimal mechanical properties. Although SL is classified as a non-resorbable suture, but recognized to be subject to proteolytic degradation over a longer period. [32] Studies have shown that SL is one of the most susceptible sutures to variation in pH conditions. [24] In the current study it was reported that mechanical properties of SL suture were decreases at 14th post immersion period. These findings are in agreement with the respites presented by Banche et al. where tensile strength of SL decreased upon exposure to saliva. [14]

Conclusion

The present study affirms that the suture a material tends to lose a significant amount of tensile strength when exposed to oral environment. PP suture showed highest mechanical properties when compared with the PG, and SL suture. Under the limitation of the present study authors conclude that PP is best suture material for wound closure after oral and periodontal surgical procedure followed by PG and SL respectively.

Competing Interests

The authors declare that they have no competing interests.

References

1. Naleway SE, Lear W, Kruzic JJ, Maughan CB. Mechanical properties of suture materials in general and cutaneous surgery. J Biomed Mater Res B. 2015;103:735-742.
2. Vasantha A, Satheesh K, Hoopes W, Lucaci P, Williams, K, Rapley J. Comparing suture strengths for clinical applications: A novel *in vitro* study. J Periodontol. 2009;80:618-624.
3. Burkhart SS, Wirth MA, Simonich M, Salem D, Lanctot D, Athanasiou K. Knot. Security in simple sliding knots and its relationship to rotator cuff repair: How secure must the knot be? Arthroscopy. 2000;16:202-607.
4. Arce J, Palacios A, Alvitez-Temoche D, Mendoza-Azpur G, Romero-Tapia P, Mayta-Tovalino F. Tensile Strength of Novel Non-absorbable PTFE (Teflon(R) versus Other Suture Materials: An *in vitro* study. Int J Dent. 2019.
5. Hiatt WH, Stallard RE, Butler E, Badgett B. Repair following mucoperiosteal flap surgery with full gingival retention. The J Periodontol.1968;39:11-16.
6. Burkhardt R, Lang NP. Coverage of localized gingival recessions: comparison of micro□and macrosurgical techniques. J Clin Periodontol. 2005;32:287-293.
7. Chu CC. Mechanical-properties of suture materials-An important characterization. Ann Surg 1981;193:365-371.
8. Von Fraunhofer JA, Storey RJ, Masterson BJ. Tensile properties of suture materials. Biomaterials. 1988; 9:324-327.
9. Racey G, Wallace W, Cavalaris C, Marguard J. Comparison of a polyglycolic-polylactic acid suture to black silk and plain catgut in human oral tissues. J. oral surg.1978;36:766-770.
10. Ferguson Jr RE, Schuler K, Thornton BP, Vasconez HC, Rinker B. The effect of saliva and oral intake on the tensile properties of sutures: an experimental study. Ann. plast. surg. 2007;58:268-272.
11. Alsarhan M, Alnofaie H, Ateeq R, Almahdy A. The effect of chlorhexidine and listerine mouthwashes on the tensile strength of selected absorbable sutures: An *in vitro* study. BioMed Res Int. 2018.
12. Banche G, Roana J, Mandras N, Amasio M, Gallesio C, Allizond V, et al. Microbial adherence on various intraoral suture materials in patients undergoing dental surgery. J Oral Maxillofac Surg. 2007;65:1503-1507.
13. GaL JY. About a synthetic saliva for *in vitro* studies. Talanta. 2001; 53:1103-1111.
14. Vasanthan A, Satheesh K, Hoopes W, Lucaci P, Williams K, Rapley J. Comparing suture strengths for clinical applications: a novel *in vitro* study. J Periodontol. 2009;80:618-624.
15. Lai SY, Becker DG, Edlich RF. Sutures and needles. In: Scalafani AP, editor: emedicine from WebMD. 2009.
16. Pillai C, Sharma CP. Review paper: Absorbable polymeric surgical sutures. Chemistry, production, properties, biodegradability, and performance. J Biomater Appl. 2010;25:291-366.
17. Von Fraunhofer JA, Storeym RS, Stone IK, Masterson BJ. Tensile strength of suture materials. J Biomed Mater Res. 1985;19:595-600.
18. Edlich RF, Panek PH, Rodeheaver GT, Turnbull VG, Kurtz LD, Edgerton MT. Physical and chemical configuration of sutures in the development of surgical infection. Ann Surg. 1973;177:679-688.
19. Moy RL, Lee A, Zalka A. Commonly used suture materials in skin surgery. Am Fam Physician. 1991;44:2123-2128.
20. Ketchum LD. Suture materials and suture techniques used in tendon repair. Hand Clin. 1985;1:43-53.
21. Karabulut R, Sonmez K, Turkyilmaz Z, Bagbanci B, Basaklar AC, Kale N. An *in vitro* and *in vivo* evaluation of tensile strength and durability of seven suture materials in various pH and different conditions: an experimental study in rats. Indian. J Surg. 2010;72:386-390.
22. McCaul L K, Bagg J, Jenkins WM. Rate of loss of irradiated polyglactin 910 (vicryl rapide) from the mouth: A prospective study. Br. J Oral Maxillofac Surg. 2000;38:328-330.
23. Siervo S. 1st ed. Berlin, Germany: Quintessence Publication Co. 2008. Suturing Techniques in Oral Surgery.
24. Chu CC, Moncrief G. An *in vitro* evaluation of the stability of mechanical properties of surgical suture materials in various pH conditions, Ann Surg. 1983;198:223-228.
25. Mohammed A, Hourya A, Rawan A, Ahmed A. The Effect of Chlorhexidine and Listerine® Mouthwashes on the Tensile Strength of Selected Absorbable Sutures: An *in vitro* study. BioMed Res Int. 2018;2018:8531706.
26. Ferguson RE, Schuler K, Thornton BP, Vasconez HC, Rinker B. The Effect of Saliva and Oral Intake on the Tensile Properties of Sutures, Ann Plast Surg. 2007;58:268-272.
27. Alshehri MA, Baskaradoss JK, Geevarghese A, Ramakrishnaiah R, Tatakis DN. Effects of myrrh on the strength of suture materials: An *in vitro* study. Dent Mater J. 2015;34:148-153.
28. Arcuri C, Cecchetti F, Dri M, Muzzi F, Bartuli FN. Suture in oral surgery. A comparative study, Minerva stomatologica. 2006;55:17-31.
29. Debus ESA, Geiger D, Sailer M, Ederer J, Thiede A. Physical, biological and handling characteristics of surgical suture material: A comparison of four different multifilament absorbable sutures. Eur Surg Res. 1997;29:52-61.
30. Yaltirik M, Dedeoglu K, Bilgic B, Koray M, Ersev H, Issever H, et al. Comparison of four different suture materials in soft tissues of rats. Oral Dis. 2003;9:284-286.
31. Hochberg JK, Meyer M, Marion MD. Suture choice and other methods of skin closure, Surgical Clinics of North America. 2009;89:627-641.
32. Altman GH, Diaz F, Jakuba C, Calabro T, Horan RL, Chen J, et al. Silk-based biomaterials. Biomaterials. 2003;24:401-416.