Accepted manuscripts are the articles in press that have been peer reviewed and accepted for publication by the Editorial Board of the Vojnosanitetski Pregled. They have not yet been copy edited and/or formatted in the publication house style, and the text could still be changed before final publication.

Although accepted manuscripts do not yet have all bibliographic details available, they can already be cited using the year of online publication and the DOI, as follows: article title, the author(s), publication (year), the DOI.

Please cite this article EVALUATION OF MECHANICAL PROPERTIES OF THREE COMMONLY USED SUTURE MATERIALS FOR CLINICAL ORAL APPLICATIONS: AN IN VITRO STUDY

Authors Shahabe Saquib Abullais*, Nabeeh Abdullah Al-Qahtani*, Talib Amin Naqash†, Abdul Ahad Khan¥, Suraj Prakash Arora §, Shaeesta Bhavikatti*, Vojnosanitetski pregled (2020); Online First August, 2020.

UDC:

DOI: https://doi.org/10.2298/VSP200114079A

When the final article is assigned to volumes/issues of the Journal, the Article in Press version will be removed and the final version appear in the associated published volumes/issues of the Journal. The date the article was made available online first will be carried over.
EVALUATION OF MECHANICAL PROPERTIES OF THREE COMMONLY USED SUTURE MATERIALS FOR CLINICAL ORAL APPLICATIONS: AN IN VITRO STUDY

Authors:

Shahabe Saquib Abullais*, Nabeeh Abdullah Al-Qahtani*, Talib Amin Naqash†, Abdul Ahad Khan¥, Suraj Prakash Arora §, Shaeesta Bhavikatti*

* Periodontics and Community Dental Sciences, Research Center for Advanced Materials Sciences, College of Dentistry, King Khalid University, Abha, 61321, KSA

† Prosthetic Dentistry, College of Dentistry, King Khalid University, Abha, 61321, KSA

¥ Department of Oral and Maxillofacial Surgery, College of Dentistry, King Khalid University, Abha, 61321, KSA

Corresponding author:

Shahabe Saquib Abullais

Assistant professor, Department of Periodontics and Community Dental Sciences, King Khalid University, College of Dentistry, Abha, KSA.

Phone numbers +966583056343,

E-mail: sshahabe@kku.edu.sa
Running title: Mechanical properties of sutures used in periodontal surgery

**Brief summary**

Appropriate selection of suture material is a crucial step in oral, maxillofacial and periodontal surgery for uneventful healing. The present *in vitro* study sought to evaluate the effect of saliva on the strength, elongation and stiffness of the commonly used suture material over two weeks. The results of the study provide evidence that polypropylene sutures are strongest and have highest tensile strength and elongation property. Polypropylene seems to sustain its tensile strength better than silk and polyglactin 910 at the end of 14\textsuperscript{th} day. Controlled clinical experiments are necessary to verify this finding in an *in-vivo* setting.

**Abstract**

**Background/Aim:** Appropriate selection of suture material is a crucial step in oral, maxillofacial and periodontal surgery for uneventful healing. We have scarcity of comprehensive studies comparing mechanical properties of commonly used suture material in oral surgeries. The present *in vitro* study sought to evaluate the effect of saliva on the strength, elongation and stiffness of the commonly used suture material over a period of two weeks.

**Methods:** Three suture materials Silk (SL), polyglactin 910 (PG) and polypropylene (PP) were used in 4-0 gauge. 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 concentration and maintained at pH of 7.4 to 8.1 to simulate oral environment. All samples were tested at pre-immersion (baseline), 3\textsuperscript{rd}, 7\textsuperscript{th} and 14\textsuperscript{th} day post-immersion periods. Universal testing machine was used to test the selected mechanical properties. The collected data were subjected to statistical analysis.

**Results:** The distribution of mean baseline strength and percentage elongation was significantly higher in PP group (P-value<0.001), whereas stiffness score was highest with SL group (P-value<0.001). Inter-group comparison revealed that PP group had maximum tensile strength compared to PG and SL groups at all time points. When percentage elongation was compared, PP and PG groups showed highest values at 7\textsuperscript{th} and 14\textsuperscript{th} day.
respectively. PP group exhibited highest stiffness values as compared to SL and PG groups at 7th and 14th day post-immersion (P-value<0.001). Intra-group comparison showed that all suture materials had significant difference in mechanical properties when pre-immersion values were compared to 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. Controlled clinical experiments are necessary to verify this finding in an *in-vivo* setting.

**Key Words:** silk; polyglactin 910; polypropylene; periodontal surgery; tensile strength

**Introduction**

Important concerns of periodontal, oral and maxillofacial surgeons refer to the selection of proper suture material. The suture material should be biocompatible and easy to use, it should form proper knot, have the property of elongation, biodegradable in some circumstances and resist breakage during its use. The mechanical properties of the suture materials play an important role in regulating their behavior.

Placing sutures in the oral cavity is challenging due to varied functions of mastication, speech, swallowing and high tissue vascularization along with continuous pooling of saliva. Suitable sutures must possess specific physical and mechanical properties, among which the tensile strength is one of the most important properties. The function of the suture while in use is controlled by its elasticity, stiffness and tensile strength. The flap edges should remain in close apposition after suturing of the surgical site to help primary healing, failure of which can have negative effect on the desired results of the surgery. Tensile strength is an important feature that is required to be maintained because the suture material tends to lose between 70 and 80% of its original strength. Therefore, the required original tensile strength must always be there to avoid breakage of the suture material. Moreover, a compromise in the strength of the suture material can result in incomplete adaptation of the flap and consequent healing by secondary intention. Most of the published studies related to mechanical properties discussed mainly a breaking force. There are very few reports that actually compare other useful aspects, like failure
elongation, failure stress/strain and stiffness across suture materials. However, exhaustive studies that are cited on suture materials are comparatively less pertinent to materials used for oral and periodontal surgical procedures\textsuperscript{7,8}.

A distinct suture materials show discrete behaviors in the oral cavity\textsuperscript{9}. Various experimental researches indicated that the suture’s tensile strength could be affected by saliva, various solutions or consumed fluids. It was found that there is a reduction in strength of Vicryl after it is immersed in saliva, bovine milk, and soy milk for 35 days\textsuperscript{10}. Another study described remarkable reduction in the strength of two different suture types (Vicryl and Monocryl) after they were submerged in artificial saliva, chlorhexidine and essential oil mouth rinse\textsuperscript{11}.

Of the various commercially available suture materials, silk and polyglactin are most often used in oral and periodontal surgery. Silk is the most frequently used natural suture material, due to its better handling properties\textsuperscript{12}.

Consequently, aim of this study is to assess and compare the tensile strength, percentage elongation and stiffness of silk, polyglactin 910 and polypropylene suture material in an environment simulating the oral cavity (immersed in artificial saliva) and a pre-immersed dry condition for an interval of fourteen days. The results mentioned in the present study are meant to provide a baseline data for oral surgeons and periodontist by assembling the mechanical and physical properties of these sutures under controlled conditions. So this data will help in the selection of suitable suture material depending upon the required area of surgical procedure.

**Methods**

The present \textit{in-vitro} experimental study design was approved by the King Khalid University Ethical Review Committee (ERC), Abha, Saudi Arabia [SRC/ETH/2017-18/090]. The study was conducted in period of November 2018 to February 2019. Three distinct suture materials were involved in the current study and their physical properties were evaluated: silk, which is observed by many surgeons as a benchmark due to its easy handling\textsuperscript{12}, polyglactin 910 (Vicryl), which is a multifilament absorbable synthetic suture comprised of a copolymer of glycolide and L-lactide, and polypropylene monofilament, non-absorbable material made of an isotactic crystalline stereoisomer of polypropylene.
(Table 1). Suture materials were divided into the control (pre-immersed) and the test group (immersed in artificial saliva - Table 2). 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.

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.  |
| Polyglactin 910 (PG) | Vicryl®  | Absorbable    | Ethicon, Johnson & Johnson Pvt. Ltd.  |
| Polypropylene (PP) | Prolene® | Non-absorbable | Ethicon, Johnson & Johnson Pvt. Ltd.  |

A total of 120 suture samples were collected from commercially available unexpired stocks. Forty samples were obtained from each suture material type. All the suture samples were measured at a uniform length of 18cm. Ten specimens from each group were tested for tensile strength before immersing into artificial saliva and referred as a control group. Remaining suture specimens were kept in artificial saliva until exposed to an experimental procedure (Figure 1). A detailed description of the study protocol has been described in figure 2 (flow chart).

Figure 1. Different suture specimens immersed in artificial saliva
Artificial saliva was formulated by mixing the compounds shown in table 2 in one liter of distilled water\textsuperscript{13}. To prevent any chemical changes, the prepared mixture 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\textsuperscript{14}.

The setup of the experiment and the testing machine are shown in figure 3.

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$_2$PO$_4$) | 0.654               |
| Uréa (CH$_4$N$_2$O)                  | 0.200                |
| Sodium sulfate decahydrate (Na$_2$SO$_4$ 10H$_2$O) | 0.763            |
| Ammonium chloride (NH$_4$Cl)         | 0.178                |
| Calcium Chloride Dihydrate (CaCl$_2$ 2H$_2$O) | 0.227            |
| Sodium bicarbonate (NaHCO$_3$)       | 0.630                |
Length of each suture specimen for testing = 18cm
Total number of specimens (n=120)

Baseline
Pre-immersion testing of suture specimen (n=10) from each group

Testing of suture specimen after immersing into Artificial saliva (n=90)

All the suture specimens were exposed to thermo-cycling by altering the temperature between 5 °C to 55 °C

Distribution of suture material in groups; SL (n=30), PP (n=30), PG (n=30)

Tests were repeated at interval of 3rd, 7th and 14th days. While testing at specified intervals, (n=10) suture specimens were selected

Collected data were subjected to statistical analysis

*SL= Silk, #PG= Polyglactin 910, $PP= Polypropylene

Figure 2. Flowchart of the study design
Figure 3. Experiment setup showing suture material tied to the hook of the separating arms of universal testing machine

Measurements were recorded for tensile strength, percentage elongation and stiffness. Tensile Strength was defined as maximum load that can be applied to a suture material before the suture breaks; it was measured in Newtons (N). Elongation was defined as cumulative displacement exhibited by a suture material before it breaks when a gradual load is delivered and it was measured in millimeters (mm). Stiffness was defined as a measurement of the capacity of a suture material to elongate by application of gradual increasing load before it breaks and it was measured in Newtons per millimeter (N/mm). The stiffer materials would exhibit lesser elongation.

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. All the hypotheses were formulated using two-tailed alternatives against each null hypothesis (hypothesis of no difference). The entire data is statistically analyzed using Statistical Package for Social Sciences (SPSS version 21.0, IBM Corporation, USA) for MS Windows.

Results

Baseline (pre-immersion) comparison of mean tensile strength, percentage elongation and stiffness are presented in table 3. The distribution of mean baseline strength and percentage elongation was significantly higher in the PP group, followed by PG group and the least with SL group (P-value<0.001 for all). However, stiffness score was highest with the SL group as compared to PP and PG groups, respectively (P-value<0.001 for all).

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

| Parameters | Tensile strength (N) | Percentage (%) Elongation (mm) | Stiffness (N/mm) |
|------------|----------------------|-------------------------------|-----------------|
| Silk (SL)  | 10.60 ± 1.26         | 4.5 ± 0.54                   | 1.33 ± 0.22     |
| Polyglactin 910 (PG) | 14.50 ± 1.27      | 12.11 ± 1.39                | 0.67 ± 0.07     |
| Polypropylene (PP) | 20.40 ± 1.26      | 16.78 ± 0.76                | 0.68 ± 0.06     |
| *P value*  | 0.001***             | 0.001***                     | 0.001***        |

and stiffness are presented in table 3. The distribution of mean baseline strength and percentage elongation was significantly higher in the PP group, followed by PG group and the least with SL group (P-value<0.001 for all). However, stiffness score was highest with the SL group as compared to PP and PG groups, respectively (P-value<0.001 for all).

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

*** p-value<0.001= Highly significant

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, percentage elongation and stiffness while testing on universal testing machine.

Table 4 shows distribution and comparison of mean tensile strength among three suture groups at the 3rd, 7th and 14th day post-immersion in the saliva. The PP group exhibited the maximum tensile strength when compared to the PG and SL groups at all points of time (P-value<0.001).
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           |                       |
| Pre-immersion    | 10.60 ± 1.26 | 14.50 ± 1.27 | 20.40 ± 1.26       | SL v PG 0.001 ***     |
|                  | 1.26      | 1.27                 |                    | SL v PP 0.001 ***     |
|                  |           |                      |                    | PG v PP 0.001 ***     |
| Post immersion in saliva | |                       |                    |                       |
| 3-Days           | 9.75 ± 1.21 | 12.80 ± 1.64 | 19.40 ± 1.39       | 0.05 **                |
|                  |           | 1.64                |                    |                       |
| 7-Days           | 8.80 ± 0.83 | 11.80 ± 1.10 | 18.15 ± 1.59       | 0.05 **                |
|                  |           | 1.10                |                    |                       |
| 14-Days          | 8.25 ± 1.07 | 10.80 ± 1.76 | 15.40 ± 1.27       | 0.05 **                |
|                  |           | 1.76                |                    |                       |

** p-value<0.05= Significant, *** p-value<0.001= Highly significant

Table 5 shows distribution and comparison of mean percentage elongation among three suture groups at the 3rd, 7th and 14th day post-immersion in the saliva. The PP group exhibited the maximum percentage elongation when compared to the PG and SL groups at baseline and the 7th day post-immersion (P<0.05 and P-value<0.001), whereas the PG group exhibited highest percentage elongation as compared to the SL and PP groups at the 3rd and 14th day post-immersion (P<0.05 and P-value<0.001).

Table 5. Inter-group comparison of % elongation pre and post immersion in saliva

| Suture           | Silk (SL) | Polyglactin 910 (PG) | Polypropylene (PP) | P-value (Inter-Group) |
|------------------|-----------|----------------------|--------------------|-----------------------|
|                  | Mean ±SD  | Mean ±SD             | Mean ±SD           |                       |
| Pre-immersion    | 4.5 ± 0.54 | 12.11 ± 1.39 | 16.78 ± 0.76       | SL v PG 0.001 ***     |
|                  |           |                     |                    | SL v PP 0.001 ***     |
|                  |           |                      |                    | PG v PP 0.001 ***     |
| Post immersion in saliva | |                       |                    |                       |
| 3-Days           | 8.67±0.78 | 20.78 ± 6.33 | 17.89 ± 0.82       | 0.001 ***              |
|                  |           |                     |                    |                       |

** p-value<0.05= Significant, *** p-value<0.001= Highly significant
** p-value<0.05= Significant, *** p-value<0.001= Highly significant

Table 6 shows distribution and comparison of mean stiffness among three suture groups at the 3rd, 7th and 14th day post immersion in the saliva. The highest stiffness was recorded by the SL group, followed by the PP and PG groups at baseline and the 3rd day post-immersion (P-value<0.001), whereas the PP group exhibited higher stiffness as compared to the SL and PG groups at the 7th and 14th day post-immersion (P-value<0.001).

Table 7 presents intra-group comparison of different suture material with respect to different variables (strength, percentage of elongation and stiffness) from pre-immersion to the 14th day post-immersion. All three suture material showed a significant difference in strength, percentage of elongation and stiffness when mean values from baseline (pre-immersion) were compared to the 14th day post-immersion.

Table 6. Inter-group comparison of stiffness pre and post immersion in saliva

| Suture          | Silk (SL) | Polylactin 910 (PG) | Polypropylene (PP) | P-value (Inter-Group) |
|-----------------|-----------|---------------------|--------------------|-----------------------|
|                  | Mean ±SD  | Mean ±SD            | Mean ±SD           |                       |
| Pre-immersion   | 1.33 ± 0.22 | 0.67 ± 0.07         | 0.68 ± 0.06        |                       |
| Post immersion in saliva |
| 3-Days          | 0.69 ± 0.07 | 0.36 ± 0.02         | 0.63 ± 0.04        | 0.001*** 0.576NS 0.05** |
| 7-Days          | 0.38 ± 0.09 | 0.42 ± 0.07         | 0.55 ± 0.05        | 0.05** 0.001*** 0.001*** |
| 14-Days         | 0.38 ± 0.12 | 0.39 ± 0.04         | 0.68 ± 0.07        | 0.875NS 0.001*** 0.001*** |

Table 7. Intra-group comparisons of tensile strength, % elongation and stiffness of different suture materials from pre-immersion (baseline) to the 14th day
Discussion

The key step of surgery is meticulous wound closure. The main purpose of wound closure is eradication of dead space, apposition of wound margins to generate a closed secure atmosphere and preservation of tensile strength at the wound margins till the tissue tensile strength is enough to bear external load. Previously, materials like animal hair, natural fibers, silk, nylon and gut mucosa were used to seal the surgical sites. A surgeon always desires for better handling characteristics and tensile strength of a suture while choosing appropriate suture material. The tensile strength of a suture material is an essential property that helps suture material to bear the tissue traction at the flap margin. Suture materials manifesting low tensile strength are more liable to break during the healing phase because of pull created by edema and tissue tension.

Suture materials are mainly categorized as absorbable and non-absorbable, natural and synthetic, braided polyfilament and monofilament fibers. Distinct suture materials bearing the same diameter size may differ significantly in their tensile strengths. Most of the reported studies on mechanical properties of sutures are done on skin and subcutaneous tissues. In these exploratory studies, sutures were exposed to few environmental conditions that can influence physical and mechanical properties of the sutures. Studies associated with oral cavity present a number of difficulties, like presence of saliva, reflux gastric juice, pressure from the surrounding soft tissues and occlusal forces that can markedly change the properties of suture materials.

In the present study the suture gauge designation was fixed at 4-0 in order to help in comparisons of a single gauge of suture. For most of the intra-oral surgeries the commonly used gauges are in the range of 3-0 to 4-0, with an increasing number of zeros making the diameter smaller and weaker. For current study silk, polygalactin 910 and polypropylene suture materials were used because of their demand in various oral surgical procedures.
Sutures were immersed in artificial saliva to be used as a control group as previous studies indicated its possible harmful effect on suture material’s mechanical properties\textsuperscript{24,25}. To the best of authors’ knowledge, it’s a first original study that assesses the mechanical properties of different suture materials used intraorally by simulating a natural environment.

All the experiments were done by a single investigator to circumvent any inter-examiner error. The time frame and test frequencies of the present study were in accordance with the clinical relevance of the frequent oral and periodontal surgical procedures. Different studies have found a positive correlation between the reduction in tensile strength and resorption rates of distinct suture materials under controlled experimental conditions\textsuperscript{26,27,28}. A prime element that can influence the resorption rate of suture materials is the variation in pH of the solution. It’s been well documented that a decrease in the pH increases the resorption rate of the sutures\textsuperscript{24}. The pH of current study was kept between 7.4 and 8.1 by checking it regularly for stability and changing the solution every 2 days.

The outcome of the current study exhibits that the PP group manifested maximum tensile strength and percentage elongation in contrast to the PG and SL group, whereas the PP group manifested the lowest stiffness. Elongation capacity of material is inversely proportional to the stiffness, the stiffer sutures exhibit less elongation. Since no comprehensive study has been done in vitro to assess the mechanical properties of the PP suture material compared to the PG and SL in the oral environment, we chose this material in our study design. In one study different gauge of sutures were used to evaluate the mechanical properties of strength, elongation and stiffness of the PP suture material\textsuperscript{29}. The test values for 4-0 gauge suture were analogous to the values recorded at baseline (pre-immersion) in the present study.

Earlier studies on the PG sutures exhibited good handling properties, high initial tensile strength, and less tissue reactions during healing\textsuperscript{30,31}. A strong correlation between suture degradation and tensile strength has been described in various studies under controlled in vitro and in vivo settings. PG degradation in-vivo is mostly due to proteolytic enzymes. The PG sutures preserved more than two-thirds of their initial tensile strength at the 14\textsuperscript{th} day post-immersion period\textsuperscript{32}. The results of the present study were similar to this study as more than two thirds of the initial tensile strength was conserved at the 14\textsuperscript{th} day.
post immersion. Some studies state that, when PG is immersed in saliva, it shows a fast tensile strength loss, especially after 7 days \(^{10}\). This is in contradiction to the findings of the present experimental study.

SL is the most frequently used suture material in the surgical procedures even though it exhibits inferior mechanical properties. Even though, SL is said to be a non-resorbable suture but acknowledged to be subject to proteolytic degradation over a longer period \(^{33}\). Studies indicate that SL is one of the most vulnerable sutures to differences in pH conditions \(^{24}\). In the present study, it was found that mechanical properties of the SL sutures diminished at the 14\(^{th}\) day post immersion. These outcomes are in accordance with the respites presented by Banche et al. where tensile strength of SL declined upon exposure to saliva \(^{14}\).

As the present study design is in-vitro, it has certain constraints as mentioned below. The outcome of the current experiment may not be completely similar to the oral clinical situations. There are various possible confounding factors such as diet, habits, occlusal forces and medications in the oral cavity that may affect the oral environment and cause variation in the mechanical properties of sutures. More information can be collected by performing molecular interpretation of the selected suture materials upon their reaction with saliva. However, this was beyond the scope of the current experimental study.

Conclusion

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

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 Nonabsorbable PTFE (Teflon(R) versus Other Suture Materials: An In Vitro Study. Int J Dent 2019; 2019:7419708.

5. *Hiatt WH, Stallard RE, Butler E, Badgett B.* Repair following mucoperiosteal flap surgery with full gingival retention. 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 R J,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-polyactic acid suture to black silk and plain catgut in human oral tissues. J Oral Surg.1978; 36: 766-770.

10. *Ferguson Jr, R E, Schuler K, Thornton BP, Vasconez H.C, 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, Alnofae 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; 2018: 8531706.

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. Vol 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 R L, 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 LK, 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, and 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, Ghevarghese A, Ramakrishnaiah R, Tatakos 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 stomatol 2006; 55: 17-31.

29. Debus E S, 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. Rashid RM, Sartori M, White LE, Villa MT, Yoo SS, Alam M. Breaking strength of barbed polypropylene sutures: rater-blinded, controlled comparison with nonbarbed sutures of various calibers. Arch Dermatol 2007, 143, 869-872.

31. 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.

32. Hochberg K, Meyer M, Marion MD. “Suture choice and other methods of skin closure,” Surg Clin North Am 2009: 89: 627–641.

33. Altman GH, Diaz F, Jakuba C, Calabro T, Horan RL, Chen J, et al. Silk-based biomaterials. Biomaterials 2003; 24: 401-416.

34. 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.

Acknowledgments: Authors would like to acknowledge the support of the King Khalid University through a grant RCAMS/KKU/001/20 under the Research Center for Advanced Materials Science at King Khalid University, Saudi Arabia.

Funding source: Nil

Author contributions:

SSA: Concept, literature search, experiments, data collection, manuscript writing, study design, data analysis, interpretation, approval of manuscript.
NAA: Concept, literature search, manuscript writing, study design, data collection, approval of manuscript.

TAN: Literature search, manuscript writing, data collection, data analysis, approval of manuscript.

AAK: Experiments, data collection, manuscript writing, interpretation, approval of manuscript.

SPA: Literature search, manuscript writing, study design, data analysis, approval of manuscript.

SM: Literature search, manuscript writing, study design, data collection, approval of manuscript.

Conflict of interest statement: The authors state that there are no conflicts of interest regarding the publication of this

Received on January 14, 2020.
Revised on August 5, 2020.
Accepted August 10, 2020.
Online First August, 2020.