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In-vitro evaluation of commonly used beverages on tensile strength of different suture materials used in dental surgeries

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Abstract

Sutures are used for the approximation of incised flaps, assistance in primary healing, and hemorrhage control. In oral and periodontal surgery, the appropriate selection of suture material is vital for favorable healing.

The aim of the present in-vitro experiment was to evaluate the tensile strengths of 4 different types of suture materials (silk, polygalactine 910, polypropylene, chromic catgut) by simulating potential short-term intraoral exposure to various beverages (saliva, Arabic coffee, tea, cola).

A total of 280 suture specimens were prepared, out of which 10 specimens from each group were selected for pre-immersion testing. Remaining suture specimens were immersed in 4 different thermostatically controlled media (1 control [artificial saliva], 3 tests [Cola drink, Arabic coffee, Tea]). Tensile strength was measured at pre-immersion, 3, 7, and 14 days using a universal tensile testing machine. The maximum load required to break the suture material was recorded in Newton.

At day 3, tea caused significant reduction in tensile strength of silk and cola caused significant reduction in tensile strengths of polygalactine 910 and chromic catgut. Whereas, at day 7, silk and polypropylene retained their tensile strengths better than others.

The authors recommend precaution in the use of these beverages in the first postoperative week, to avoid adverse effect on the mechanical strength of sutures. When exposure to these beverages are anticipated, it is better to use polypropylene sutures that resists rapid fall in tensile strengths in the early postoperative period.

Abbreviations: CC = chromic catgut, PCT = positive control, PG = polygalactine 910, PP = polypropylene, SL = surgical silk, TS = tensile strength, TT-1 = test group-1, TT-2 = test group-2, TT-3= test group-3.

Keywords: beverages, oral surgery, periodontics, suture materials, tensile strength

1. Introduction

The main purpose of suturing after surgery is to keep the flap edges in close apposition for an intended period of time. Suturing in the oral cavity is different as compared to the other parts of the body because of the diverse tissue types and functions, compounded by the presence of saliva.[1,2] Moreover various suture materials elicit varied responses and behaviors in the oral environment.[3–8] A thorough understanding of the physical, mechanical, and biologic properties of commonly used suture materials is essential for the dental surgeons.

Of the various characteristics inherent in a suture, the tensile strength is one of the most important, to sustain the surgical flaps in position until removal of the sutures.[9] Thus, it is of utmost importance to maintain the approximate wound margins via sutures that have an acceptable level of tensile strength with minimal tissue reaction. The selection of suture material should focus on the physical and biomechanical characteristics that contribute to better wound healing.[10,11]

The oral environment witnesses significant variations in temperature and pH due to the ingestion of various foods and drinks. In a study carried out by Hans et al, statistically significant difference was observed in the mean salivary pH at baseline and at varied time intervals post-consumption of cola, fruit drink, coffee, and sweetened milk.[12] Liquid beverages seem to have a lesser oral clearance time as compared to solid food, but they maintain a low pH level for a longer period.[13,14]

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Polygalactine 910 (PG) is braided suture which is composed of the copolymer of lactide and glycolid. The absorption of this suture material is essentially complete by 42 days. Several studies have reported the effect of orally consumed fluids on the tensile strength (TS) of sutures. Ferguson et al, have demonstrated a progressive loss of TS in PG after subjecting it to saliva, bovine milk and soy milk over a 35 day period.[15] The suture specimens that were immersed in saliva demonstrated an accelerated loss in TS as compared to other fluids.[16] Another study concluded that PG demonstrated better breaking strength after soaking in physiologic solutions and those with acidic pH, as compared to natural sutures.[17]

If we take a pertinent overview of the various commonly used suture materials, it is recommended that surgical silk (SL) should be used dry, otherwise it loses its TS in the presence of moisture.[18] Furthermore, although labeled as non-resorbable, studies have demonstrated its behavior as that of a resorbable suture, albeit at a very slow rate. The proportion of collagen in chromic catgut (CC) determines its TS and the ability to be absorbed into the body without adverse reaction. TS may be retained for 10 to 14 days, with some measurable strength remaining for up to 21 days. Polypropylene (PP) is a synthetic, monofilament, nonabsorbable suture material, that exhibits minimal tissue reactivity, high durability and also retains its TS over a wide range of pH.[19]

Generally suturing in the oral cavity is required for a short period. With the changing pattern of human diet, it has become extremely important to know that which suture material is best suited to withstand the diverse, hostile environment with minimum change in its innate characteristics. So with this background we intended to compare the TS of 4 different types of suture materials by simulating potential short-term intraoral exposure to various beverages.

2. Material and methods

The current in-vitro experimental study design was approved by the institutional Ethical Review Board (King Khalid University, Abha, Saudi Arabia), [SRC/ETH/2017-18/090]. The study was carried out between September 2018 and January 2019. Four different types of thermostatically controlled media (1 control, 3 tests) were used to evaluate the physical properties of suture materials (Table 1). This will simulate potential short-term intraoral exposure to various tested beverages. The experimental media used were as follows;

(1) Artificial saliva as a positive control group (PCT);
(2) Cola drink as a test group-1 (TT-1) (Coca-Cola Company Pvt. Ltd., Atlanta, Georgia);
(3) Arabic Coffee (*Qahwah Arabiyya*) as a test group-2 (TT-2);
(4) Tea as a test group-3 (TT-3) (Black tea; Unilever Pvt. Ltd. London, United Kingdom).

Artificial saliva was prepared by mixing the chemicals presented in Table 2 in 1000 mL of distilled water.[20] Prepared saliva was kept securely in a dark vessel until used for the experiment. During the experimental period, the prepared artificial saliva was mixed with Human serum in 1:1 concentration, to create biologic simulation of the oral environment. This biologic mixture was kept at a pH of 7.4 to 8.1 in an incubator at 37°C.[21]

From each suture type, 70 specimens were obtained, so a total of 280 suture specimens were collected from commercially available unexpired stocks. All the suture specimens were measuring a uniform length of 18 cm. Ten specimen from each group were tested for TS before immersing into the test media in the dried state and considered as negative control. Remaining suture specimens were kept in artificial saliva until exposed to the test media. Every day all the suture samples were exposed 5 times to test media for 5 minutes and after washing with normal saline returned back to artificial saliva, except the PCT (artificial saliva group). The complete study protocol has been described in detail in the Figure 1 (flow chart).

Mechanical properties of the suture specimens were tested by using Universal Testing Machine (Quasar 100; Schutz-Licht, Langenfeld, Germany) connected to a computer for digital output (Fig. 2). TS of the suture specimens were evaluated at specified time intervals: pre-immersion (dried), 3rd, 7th, and 14th days post-immersion into test media. Each suture specimen was tied with a surgeon's knot around 2 metal hooks attached to the opposite arms of the machine with a fixed distance of 18 cm between the 2 hooks. Pilot testing showed that this experimental arrangement did not result in the specimen failure at the hooks or knots. Maximum force in Newtons delivered to the specimen preceding failure was documented as the TS (breaking strength) for that suture sample.

The data on continuous variables is presented as mean and standard deviation across the 4 study groups. The inter-group statistical comparison of means of continuous variables is done using analysis of variance with Bonferroni correction for multiple group comparisons. The intra-group statistical comparisons are done by repeated measure analysis of variance in each study group. The underlying normality assumption was tested before subjecting each variable to analysis of variance and repeated measure analysis of variance. In the entire study, the *P*-values less than .05 were considered to be statistically significant. All the hypotheses were formulated using 2 tailed alternatives against each null hypothesis (hypothesis of no difference). The entire data

Table 1

Details about the suture material used for the experiment.

Suture material	Composition	Degradation	Manufacturer
Silk	Natural Braided	Non- Absorbable	Mersilk, Ethicon, J&J Pvt. Ltd. India.
Polyglactin 910	Synthetic braided	Absorbable	Vicryl, Ethicon, J&J Pvt. Ltd. India.
Polypropylene	Synthetic Monofilament	Non- Absorbable	Prolene, Ethicon, J&J Pvt. Ltd. India.
Chromic catgut	Natural Monofilament	Absorbable	Mersutures, Ethicon, J&J Pvt. Ltd. India.

Table 2

Chemical composition of artificial saliva.

Chemical components	Concentration (mg/L)
Sodium chloride	125.6
Potassium chloride	963.9
Potassium thiocyanate	189.2
Monopotassium phosphate	654.5
Uréa	200.0
Sodium sulfate decahydrate	763.2
Ammonium chloride	178.0
Calcium Chloride Dihydrate	227.8
Sodium bicarbonate	630.8

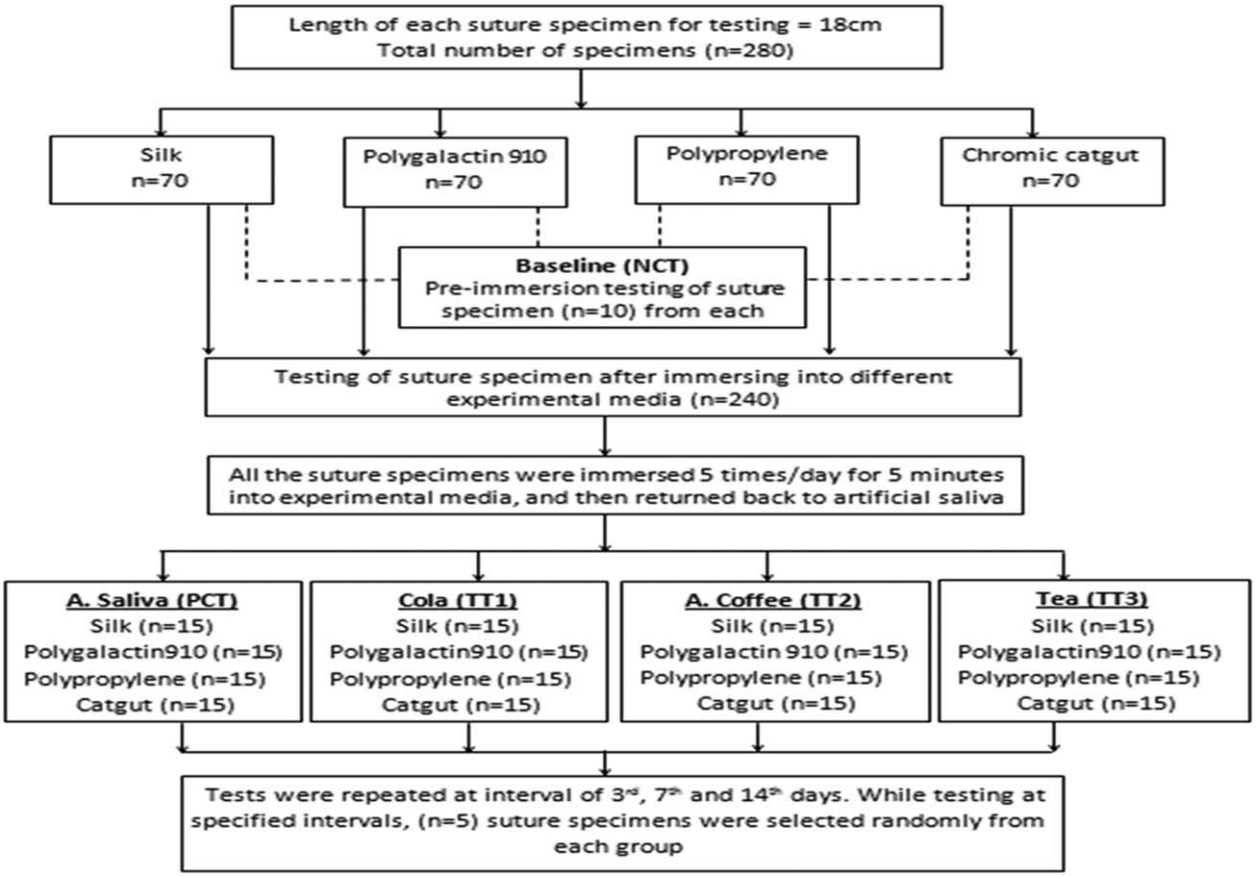

Figure 1. Flowchart of the study design.

is statistically analyzed using Statistical Package for Social Sciences (Statistical Package for Social Sciences ver 21.0, IBM Corporation, New Orchard Road Armonk, New York 10504-1722 United States) for Microsoft Windows.

3. Results

The suture materials exhibited difference in TS when exposed to different media. With the passage of time, the TS values showed gradual and progressive reduction, having the maximum TS at day 0 and least at day 14 in all groups (Table 3).

3.1. Effects in artificial saliva (PCT)

SL maintained its TS up to day 3 but showed significant reduction on day 14 ($P < .01$). PG suture showed statistically significant reduction in TS by day 7 ($P < .01$). The PP suture showed the highest initial TS that was maintained at day 3 then significantly reduced at day 7 ($P < .05$) and reduced progressively till day 14 ($P < .001$). The CC suture in PCT showed significant reduction in TS on day 7 ($P < .05$) and reduction continued until day 14 (Fig. 3).

3.2. Effects in cola (TT1)

TS for SL was maintained up to day 3, marginally reduced at day 7 but reduced significantly by day 14 ($P < .05$). TS of PG showed a significant reduction on day 3 ($P < .01$) and further gradual reduction upto day 14. TS of PP was marginally reduced by day 7 but significantly reduced by day 14 ($P < .01$). TS of CC revealed significant reduction on day 3 ($p < 0.05$) and TS reduction continued progressively up to day 14 ($P < .01$) (Fig. 4).

3.3. Effects in Arabic coffee (TT2)

TS of SL was marginally reduced at day 3, decreased significantly by day 7 ($P < .05$) and reduction continued up to day 14 ($P < .01$). TS, was marginally reduced at day 3, but was significantly reduced by day 7 ($P < .05$) for PG, ($P < .01$) for PP and continued progressively up to day 14 ($P < .01$). Whereas, TS of CC was marginally reduced on day 3 followed by significant reduction by day 7 ($P < .05$) and day 14 ($P < .01$) (Fig. 5).

3.4. Effects in tea (TT3)

TS of SL decreased significantly on day 3 ($P < .05$) and progressively reduced by day 14. TS of PG significantly reduced by day 7 ($P < .05$) and continued till day 14. TS of PP was reduced marginally on day 3, but significantly on day 7 ($P < .05$) with progressive reduction by day 14 ($P < .001$) (Fig. 6). The reduction in TS of CC on day 3 was significant ($P < .05$) followed by progressive reduction upto day 14 ($P < .001$).

Statistical analysis of the comparison among different test groups revealed variable levels of significance in the reduction of TS for different type of sutures. SL and PP sutures showed no statistically significant changes in TS values while comparing

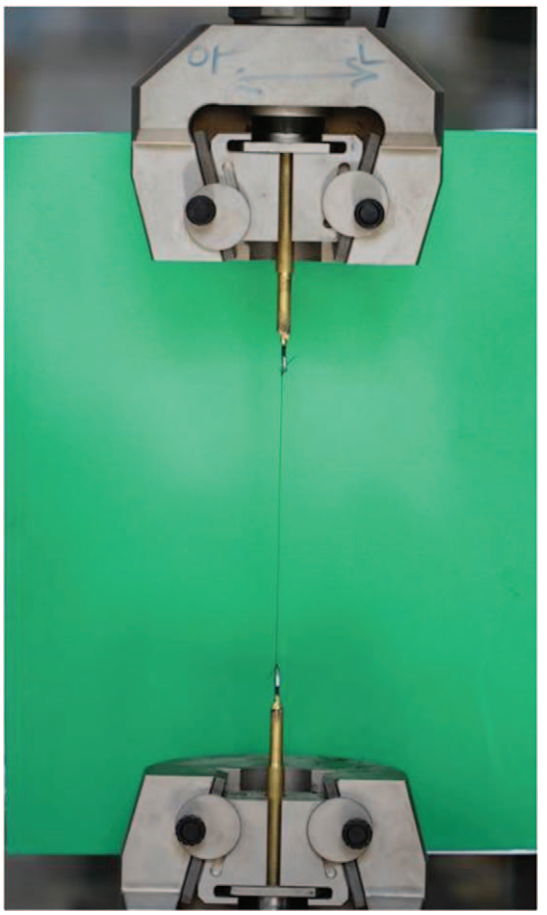

Figure 2. Suture specimen mounted by using hooks between the crossheads of universal testing machine.

exposure to PCT against TT1 ($P > .05$). The PG and CC sutures showed statistically significant reduction in TS values at day 14 when exposure to PCT was compared with TT1 ($P < .001$). The effect of TT2 exposure compared to PCT on SL suture showed statistically significant reduction in TS values at day 3 ($P > .01$), but TS was maintained thereafter on day 7 and 14 ($P > .05$). Whereas, PG suture showed no significant difference in TS values while comparing the groups ($P > .05$). CC suture showed statistically significant reduction in TS values on day 7 and day 14, respectively when PCT was compared with TT2 ($P < .001$). The effect of exposure of TT3 to CC suture showed significant reduction in TS values at day 3 compared to PCT ($P < .05$). SL and PP suture showed no statistically significant reduction in TS values when compared with PCT at any point of time ($P > .05$). The CC suture showed significant difference in the TS values at day 3, 7, and 14 while comparing PCT with TT3 ($P > .05$) and ($P < .001$), respectively (Table 4).

4. Discussion

The archives from the ancient Egyptian literature have unfolded the fact that suture materials like linen and cotton were being used for wound closure since 3500 Before Christ. Subsequently, materials like animal hair, natural fibers, silk, leather, and gut mucosa have been used successfully for closure of the wounds.[22] Tissue suturing delivers an even distribution and maintenance of TS across the wound area until the TS reaches the optimum level.[23] The handling characteristics and strength are the two most coveted properties that the surgeon always looks for while selecting a suture material. The TS of a suture material is an indispensable characteristic that determines the capability of the suture to endure the tissue tension due to the approximation of the flap margins.[24] Suture materials exhibiting low TS are more vulnerable to breakage during the healing period because of edema and tissue tension.

There are multiple types of suture materials available that can be classified into absorbable and nonabsorbable, natural and synthetic polymers, braided polyfilament and monofilament fibers.[25] Different suture materials of the same diameter differ significantly in their TSs. It is observed that small diameter materials that exhibit low fracture loads may, in fact have higher TS.[26]

Most of the studies available in the literature on the physical and mechanical properties of suture material were performed on skin and subcutaneous tissues.[25,27,28] In such studies, sutures were exposed to limited environmental factors that were influencing their physical and mechanical properties. The presence of saliva, reflux gastric juice in the oral cavity along with the masticatory load and pressure from the surrounding soft tissues significantly alter the properties of suture materials.[29–31]

There is scarce scientific literature related to the effect of beverages on the mechanical properties of suture materials namely; silk, PG, catgut, PP. These suture materials were selected because of their versatility and popularity in use for various oral maxillofacial and periodontal flap procedures.[32] In the present research, artificial saliva was used as a positive control because previous studies have shown a possible deleterious effect on suture material's strength.[16,33] Whereas, dry state was selected to calculate the unsoaked TS of the same suture material which was considered as the negative control (baseline value for reference). Three different types of test media viz coca cola, Arabic coffee, and tea were selected because of their prevalence and frequent consumption in the Middle Eastern countries.

All the tests was conducted and recorded by a single investigator to avoid any inter-examiner bias. The time frame and test frequencies of the current experiment were in agreement with the clinical relevance of the frequent oral and periodontal surgical procedures. The specific material and methods utilized in the present research design was customized according to the previous available literature.[15,34,35] The Universal Testing Machine was calibrated according to the guidelines set by Kim et al.[36] The pH of the media was adjusted according to the findings of the study carried by Chu et al, because pH of the media in contact with the suture material plays a vital role in the degradation of sutures.[16] The pH of artificial saliva was adjusted between 7.4 and 8.1 by constant monitoring and complete replacement, whenever changes in the pH were evident.[21] To the best of authors' knowledge, this is the first experimental research that evaluates the possible effects of commonly used beverages on the TS of different suture materials by simulating the oral environment.

Studies have recorded a positive relationship between the reduction in TS and resorption rates of different suture materials under controlled experimental conditions.[15,35,37] The findings from the current study revealed that TS of different suture materials differ significantly after exposure to the test media at different time. This decrease may be accelerated by the constant fluctuations in pH after exposure to common beverages. This is

Table 3

Intra-group comparison of tensile strength (mean ± SD) of suture materials from pre-immersion/baseline to 14 d in relation to different test media.

Suture	Pre-immersion/baseline (NCT)	Media	Day 3	Day 7	Day 14
Silk (SL)	10.60 ± 1.26	Saliva (PCT)	10.60 ± 0.55^{NS}	9.00 ± 1.00^{NS}	9.00 ± 0.71†
		Cola (TT-1)	10.80 ± 0.84^{NS}	9.40 ± 0.89^{NS}	8.80 ± 0.84*
		Arabic Coffee (TT-2)	9.00 ± 1.00^{NS}	8.40 ± 0.55*	7.80 ± 0.84†
		Tea ((TT-3)	8.60 ± 0.55*	8.40 ± 0.55*	7.40 ± 1.14*
Polyglactin 910 (PG)	14.50 ± 1.27	Saliva (PCT)	13.40 ± 0.89^{NS}	12.20 ± 1.30†	12.60 ± 0.89^{NS}
		Cola (TT-1)	10.80 ± 0.84†	10.80 ± 0.84†	9.00 ± 1.00†
		Arabic Coffee (TT-2)	12.80 ± 0.84^{NS}	12.00 ± 1.00*	10.80 ± 1.48†
		Tea ((TT-3)	14.20 ± 1.64^{NS}	12.20 ± 0.84*	10.80 ± 1.64*
Polypropylene (PP)	20.40 ± 1.26	Saliva (PCT)	20.20 ± 1.30^{NS}	19.00 ± 1.00*	16.20 ± 1.30‡
		Cola (TT-1)	19.40 ± 1.14^{NS}	19.00 ± 1.58^{NS}	15.60 ± 1.14†
		Arabic Coffee (TT-2)	18.20 ± 0.84^{NS}	16.20 ± 0.84†	14.20 ± 0.84†
		Tea ((TT-3)	19.80 ± 1.64^{NS}	18.40 ± 1.14*	15.60 ± 1.14‡
Chromic catgut (CC)	8.60 ± 0.84	Saliva (PCT)	8.00 ± 0.71^{NS}	7.40 ± 0.52*	7.20 ± 0.84*
		Cola (TT-1)	6.20 ± 0.84*	5.40 ± 0.55†	4.00 ± 1.00†
		Arabic Coffee (TT-2)	9.00 ± 0.71^{NS}	6.20 ± 0.84*	5.40 ± 0.55†
		Tea (TT-3)	7.20 ± 0.84*	5.80 ± 0.84†	4.40 ± 0.89‡

^{NS} = statistically non-significant, NCT = negative control, PCT = positive control, TT-1 = test group 1, TT-2 = test group 2, TT-3 = test group.
P-value < .05 is considered to be statistically significant.
* *P*-value < .05.
† *P*-value < .01.
‡ *P*-value < .001.

shown consistently in our study with SL suture being the most affected by TT2 and TT3. The most stable suture type was PG and PP sutures. The CC suture was unaffected by TT2, but showed significant reduction in presence of TT3 and TT1.

Observation on day 3 revealed that, all the 4 sutures maintained their baseline TS in PCT and TT2, whereas in TT1, SL, and PP maintained their baseline TS. However, in TT3, PG, and PP maintained their baseline TS. At day 7, in PCT, of the 4 only SL showed nonsignificant reduction in TS. In TT1, SL, and PP did not show significant reduction in its baseline TS. In TT2 and TT3, all the suture materials showed significant reduction in their TS. At day 14, all the suture materials showed significant reduction in their TS as compared to their baseline.

An in vitro study carried out by Al-Shehri et al, evaluating the effect of myrrh on the strength of suture materials concluded that full-concentration (100%) (*Commiphora*) myrrh oil reduced the TS of silk as well as Vicryl.[35] Ferguson et al, have reported reduced TS of Vicryl when soaked in saliva compared to other liquids like soy, saline, or milk. They justified stating that saliva appears to enhance the degradation of the sutures, resulting in the reduction of TS.[15] In another in vitro study conducted by Khiste et al, Vicryl sutures demonstrated a reduction in the TS under simulated oral conditions. They maintained their TS until day 7 and 10, and had minimal strength by day 14.[38]

Contradictorily, a study carried out by Al-Sarhan et al, on the effect of chlorhexidine and Listerine mouthwashes on the TS of selected absorbable sutures. Results showed non- significant difference in the TS of Vicryl sutures immersed in saliva as compared to those of the dry condition ($P = .563$). However, chlorhexidine and Listerine resulted in a significant increase in TS when compared to the dry condition ($P = .022$ and $P < .001$, respectively).[33]

Chu and Moncrief have demonstrated that silk sutures retained their tensile breaking strength in the physiologic pH solution, while more than half of their original strength was lost under the high alkaline condition. Catgut sutures, however, showed different stress-strain behavior than polyglycolic acid and Vicryl sutures at the corresponding pH levels. pH levels had a significant

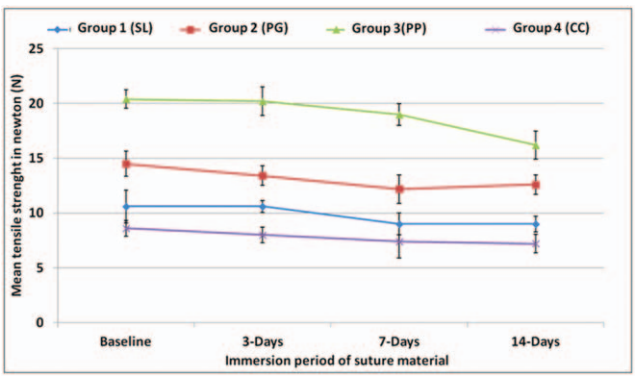

Figure 3. Change in tensile strength of tested suture materials over a period of 14 d after immersion in artificial saliva (positive control).

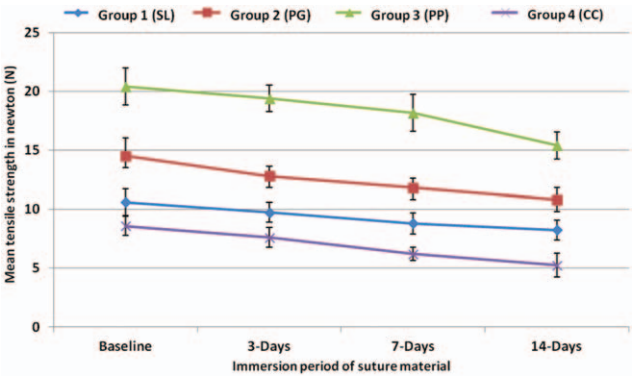

Figure 4. Change in tensile strength of tested suture materials over a period of 14 d after immersion in cola (Test media 1).

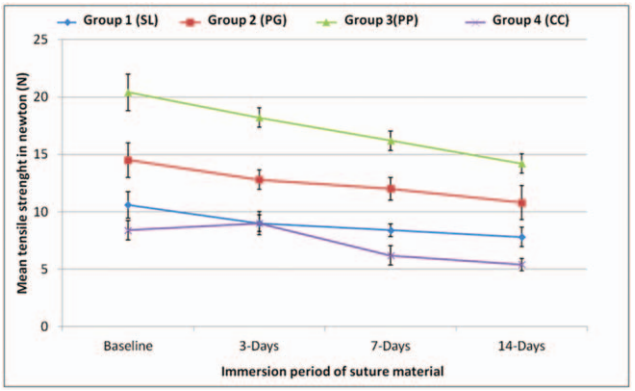

Figure 5. Change in tensile strength of tested suture materials over a period of 14 d after immersion in Arabic coffee (Test media 2).

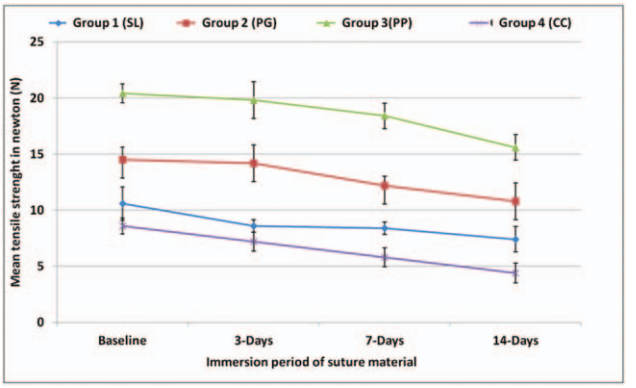

Figure 6. Change in tensile strength of tested suture materials over a period of 14 d after immersion in tea (Test media 3).

Table 4

Inter-group comparison of mean strength at different time interval between control and test groups.

	Silk (SL)			Polyglactin 910 (PG)			Polypropylene (PP)			Catgut (CC)		
	Day 3	Day 7	Day 14	Day 3	Day 7	Day 14	Day 3	Day 7	Day 14	Day 3	Day 7	Day 14
PCT v/s TTI	0.025*	0.999NS	0.299NS	0.999NS	0.999NS	0.258NS	0.142NS	0.010†	0.073NS	0.348NS	0.456NS	0.022*
PCT v/s TT2	0.004†	0.999NS	0.073NS	0.999NS	0.999NS	0.258NS	0.999NS	0.999NS	0.999NS	0.012*	0.134NS	0.001‡
PCT v/s TT3	0.999NS	0.999NS	0.999NS	0.999NS	0.264NS	0.003†	0.999NS	0.999NS	0.999NS	0.012*	0.036*	0.001‡

NS = statistically non-significant.
P-value < .05 is considered to be statistically significant.
* *P*-value < .05.
† *P*-value < .01.
‡ *P*-value < .001.

influence on the stress strain curves for silk as compared to the other non-absorbable sutures such as monofilament nylon, polyfilament nylon, dacron, and PP.[16]

The current experimental design being in-vitro has certain limitations. Considering the fact that it is an in-vitro study, the outcome of this study may not be completely applicable to the clinical scenario. The result of the study may be further influenced by the factors such as diet, habits, and medications that can potentially alter the pH level of saliva and cause alteration in the TS of the suture materials. The exact mechanism by which these beverages cause decrease in the TS of suture materials is uncertain. Additional information can be obtained by performing molecular analysis of the suture materials on their interaction with these beverages. However, this was outside the capacity of the present research project.

5. Conclusion

The present study affirms that the suture a material tends to lose a significant amount of TS when exposed to common beverages used in the Gulf region. Since the compliance on abstinence of common beverages tested in this study is contentious, there is a need to know the effects of consumption of these beverages in the postsurgical period. The study demonstrates that Arabian coffee and tea produced rapid and significant decrease in initial TS of the most commonly used silk suture material. The PG suture and PP suture materials retained their TS after Arabian coffee and tea exposures. The chromic gut was most affected by the cola beverage and tea while remained stable in the presence of Arabian coffee. The authors recommend avoidance of these beverages in the first postoperative week for unimpeded healing. When exposure to these beverages are anticipated, it is better to use PG or PP sutures that resists rapid fall in TS in the early postoperative period.

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