



OPEN Evaluation of tensile strength and knot security of commonly used sutures in commonly consumed beverages, an in-vitro study

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Suture selection significantly impacts surgical outcomes, with tensile strength and knot security being critical factors. This study investigated the influence of suture material and environmental factors on these parameters. We compared four suture types: polyglactin 910 (PG), polypropylene (PP), silk (SK) and polytetrafluoroethylene (PTFE). Tensile strength was assessed initially and during two weeks of immersion in various media (saliva, tea, coffee and cola). Knot security, specifically knot slippage and breakage, was evaluated across the different suture materials and media. Prolene displayed highest TS of all sutures. However this difference was statistically significant when compared with SK and PTFE sutures ($p < 0.05$). The mean tensile strength is significantly higher at day 3, day 7 and day 10 compared to baseline in Tea, Cola and Coffee with PG suture material (p -value < 0.05 for all). The incidence of knot slippage at baseline is significantly higher for PTFE as compared to all other types of suture materials ($p < 0.05$). The incidence of knot slippage at day 7 and day 14 is significantly higher compared to baseline in Cola by SK, PG and PP (p -value < 0.05 for all) The incidence of knot breakage at baseline is higher for silk as compared to all other sutures but it is statistically significant when compared to PTFE ($p < 0.05$). Environmental factors, such as acidic media, can negatively affect knot security. These findings underscore the importance of careful suture selection based on specific clinical requirements. However, further research needs to be undertaken to confirm these findings in-vivo.

Keywords Knot security, Tensile strength, PTFE, Silk, Polypropylene, Polyglactin, Beverages

The word ‘suturing’ is derived from the Latin word ‘sutura’, which means ‘to sew together’. Sutures are indispensable and beneficial in oral surgery, not only for wound closure but also for tissue healing, as they secure tissue in close approximation after surgery¹.

The oral environment is characterised by dynamic interplay of various events. The temperature and pH of the oral cavity fluctuate considerably due to the ingestion of various foods and drinks². Many beverages, including soft drinks and juices, are acidic³ and can result in reducing the tensile strength and increasing suture degradation². In addition to acidic pH, enzymes in saliva can hydrolyze absorbable sutures at a rate that varies with both the suture material and the composition of the patient’s saliva^{4,5}. Some beverages contain sugars and alcohol that can also change suture characteristics². These factors suggest the need to select sutures that resist the adverse effects of the oral environment⁶.

Sutures can be categorized as either natural or synthetic, monofilament or multifilament, and absorbable or non-absorbable². They have varied characteristics that can be far from ideal. For example, silk (SK) sutures offer flexibility but can cause greater inflammation, resulting in more rapid degradation⁷. Polypropylene (PP) sutures have high tensile strength but can be difficult to handle⁸. Polyglactin 910 (PG) offers a good balance of strength

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and knot security, and is also absorbable but takes a long time to dissolve/ disintegrate. Polytetrafluoroethylene (PTFE) sutures are biocompatible; however, they may not score very high in terms of knot security⁹.

Ideally, suture materials should have high tensile strength, secure knot holding, and minimal tissue reaction¹⁰. Tensile strength is the amount of force the suture can withstand until failure, which is the main characteristic that prevents wound dehiscence during healing¹¹. Tensile strength maintains the alignment of wound edges in the early stages of healing, which is crucial for achieving healing by primary intention¹². Knot security is also critical for optimum healing and is defined as the measure of a knot's ability to hold tension, preventing either slippage or breakage¹³. Reduced knot security leads to wound dehiscence, an increased risk of infection, delayed healing, and scar formation.

Knot security is influenced by a plethora of factors, including suture material, knot type, number of safety throws, technique, and surgeon skill^{14–16}. Measuring knot security is particularly challenging because it is a combined effect of both the material type and knot tying technique that incorporates subjectivity. This is partly the reason for fewer studies addressing knot security and tensile strength as part of the same methodology¹⁵.

Although there are numerous studies investigating tensile strength across a variety of conditions^{2,5,17,18}, those related to the combined effects of beverages and oral environment on tensile strength and knot security is hard to find.

Beverages such as tea, coffee and Coca-Cola reportedly maintain a low pH for a more extended period than solids and may affect sutures to a greater extent. These beverages are popularly consumed in the middle east region, however their ability to alter alkalinity versus a lower pH, potentially affect suture integrity². Besides, it is widely known that these consumables are involved in the postoperative care of oral surgery patients.

Therefore, this study proposes to investigate the tensile strength and knot security of commonly used sutures when exposed to commonly consumed beverages, to produce practical implications for suture selection in the oral environment. Besides we have standardized knot tying in this study to minimize variability. We restricted our tying to the forward-forward-reverse pattern, which is reflective of clinical practice and existing literature¹⁹.

Materials and methods

Study design

The study was submitted to the Institutional Ethical Review Board (College of Dentistry, King Khalid University, Abha, Saudi Arabia) to acquire the ethical waiver letter [SRC/ETH/2017-18/090]. It was carried out between June 2024 and August 2024. Four varieties of suture materials were used to evaluate their tensile strength and knot stability in four test media. All the samples were first tested at baseline (pre-immersion) for tensile strength, knot slippage and knot breakage. This was followed by exposure to various experimental media (one control, three experimental) to mimic short-term exposure within the oral cavity. In summary, all the suture materials were submerged in artificial saliva. In the experimental group, suture samples were submerged in the experimental media 4 times daily for 5 min each time and replaced back to the artificial saliva after washing with normal saline. Tensile strength was measured on 3rd, 7th, 10th and 14th day. Knot slippage and breakage were tested only on the 7th and 14th day (Fig. 1). These materials were selected based on their frequent utilization in periodontal and oral surgical applications²⁰. Artificial saliva was combined with human AB serum in a 1:1 ratio to incorporate saliva-like enzymes and proteins. We attempted to adjust the pH of the combined solutions to a range of 7.4 to 8.1²¹. Sample size was taken from previous studies, and a power analysis was done with an estimated power of 80% and with a significance level of 0.05²². Four samples per media per day were tested each for tensile strength testing, knot slippage/ breakage.

Study materials

The suture materials under consideration were procured from non-expired, sterilized stocks available in the market in Table 1 as follows.

The following experimental media were used:

- (1) Artificial saliva was used as the control group (CG)
- (2) Commercially available tea (Black tea; Unilever Pvt. Ltd. London, United Kingdom) as Experimental group 1
- (3) Commercially available coffee as Experimental group 2
- (4) Coca-Cola soft drink. (Coca-Cola Company Pvt. Ltd., Atlanta, Georgia) as Experimental group 3.

All the above media were thermostatically controlled to mimic oral milieu.

Artificial saliva was prepared by combining the constituents listed in Table 2 below, in the specified proportions, in 1000 mL of distilled water²³.

It was stored in a dark container till the time it was utilized for the study. The experimental setup involved mixing the artificial saliva with human AB serum (Human AB serum, Equitech-Bio, Kerrville, TX, USA) in a 1:1 ratio. This mixture was maintained at a temperature of 37 °C and a pH range of 7.4–8.1 to mimic physiological conditions within the oral cavity²⁰.

Suture Sample: While evaluating the tensile strength, the length was kept as 20 cm for all the suture samples. On the other hand, to evaluate knot slippage or knot breakage, a standardized knotting protocol was employed, involving tying each suture sample around a 26 mm diameter cylinder, ensuring a 3 mm tail as shown in Fig. 2 below.

The knot configuration for each type of suture material was forward–forward–reverse. A constant pressure was applied for 3 s after tying each knot.

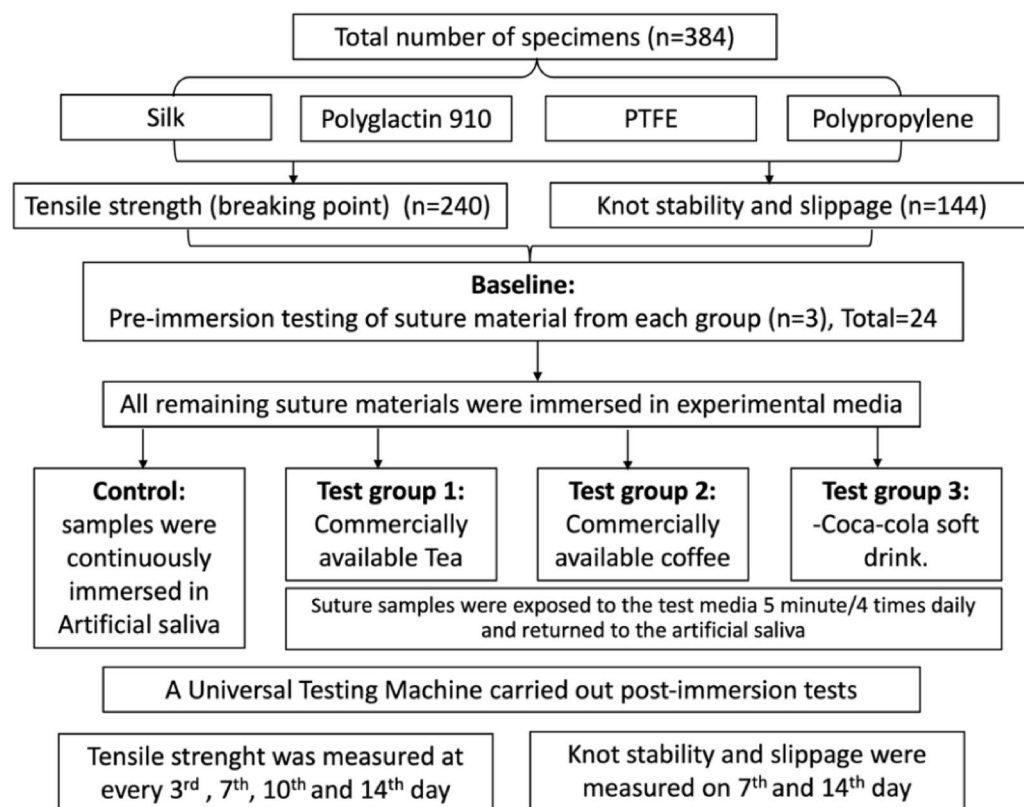


Fig. 1. Flow chart representing the study protocol.

Suture type	Raw origin	Filament type	Resorbability	Manufacturer
Silk (4-0)	Natural	Multifilament	Non-resorbable	Mersilk™, Ethicon, J&J Pvt. Ltd. India
Polyglactin 910 (4-0)	Synthetic	Multifilament	Absorbable	PG™, Ethicon, J&J Pvt. Ltd. India
Polypropylene (4-0)	Synthetic	Monofilament	Non-absorbable	PP™, Ethicon, J&J Pvt. Ltd. Germany
Polytetrafluoroethylene (4-0)	Synthetic	Monofilament	Non-absorbable	Dental-A™, Golnit Ltd., Ukraine

Table 1. Description of the suture materials used in the study.

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

Table 2. Chemical composition of artificial saliva.

Testing procedures

For tensile strength testing, 240 samples were obtained from four types of suture material, each yielding 60 samples. For knot slippage and breakage, 144 samples were obtained from four types of suture material, and each suture material yielded 36 samples. Initially, samples from all groups were tested at baseline (pre-immersion) for tensile strength, knot slippage and knot breakage. All the suture samples were submerged in prepared artificial saliva solution. Each suture material was exposed for 4 min daily to the designated test media for a duration of

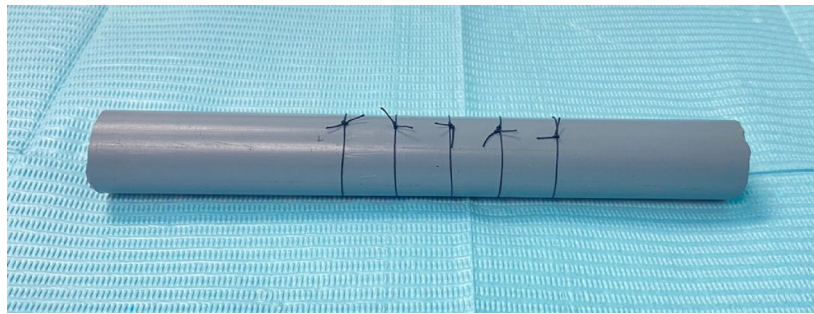


Fig. 2. Knot protocol for all sutures with the tail of 3 mm around 26 mm cylinder to evaluate knot security.

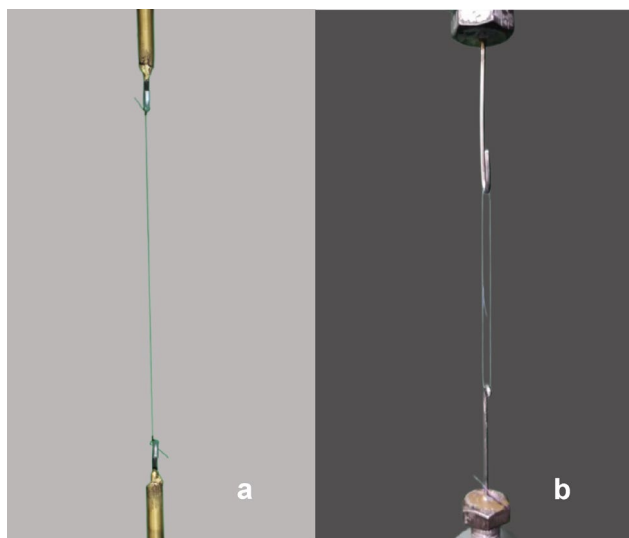


Fig. 3. (a) suture material tied on the hook to evaluate tensile strength, (b) suture loop mounted on hooks with the knot centrally located while testing knot security.

5 min each time. Each group was evaluated for tensile strength on 3rd, 7th, 10th, and 14th day post-immersions. Knot slippage and breakage were assessed on the 7th and 14th day post-immersion.

The tensile strength of the suture samples was evaluated using the Universal Testing Machine (UTM) (Star Testing Systems, India, Model No. STS-248), which was connected to a computer desktop for digital output. Tensile strength was determined by a single pull-to-suture failure under a 50-N capacity load cell at a constant crosshead speed of 5 mm/min². To evaluate knot slippage or knot breaking, the suture material was placed in the testing hooks of UTM, keeping the knot in the center to maintain a uniform distance from the testing hooks as shown in Fig. 3 below.

The maximum load required to split/(break) the suture specimen was recorded in Newtons (N). Statistical analysis was conducted on acquired data to formulate the result. The statistical comparisons employed a repeated-measures ANOVA design to examine within-group differences over time, and an ANOVA design with Bonferroni adjustments to examine between-group comparisons. Non-parametric tests were used for the knot data. Statistical significance was determined at $p < 0.05$.

Results

This section presents the findings of our in vitro study, investigating the impact of above mentioned beverages on the mechanical properties of the stated suture materials. Initially, we have compared the tensile strengths, followed by knot slippage and finally knot breakage. Some tables are attached as supplementary information in a separate document. Mean tensile strength comparisons of different suture materials in various media over time is graphically represented in Fig. 4 below.

Intra-group comparisons of mean tensile strength (Table 3).

At baseline, PP displayed highest TS of all sutures. However, this difference was statistically significant when compared with SK and PTFE sutures ($p < 0.05$). SK ($p < 0.01$) and PG ($p < 0.05$) also had substantially more baseline tensile strength than PTFE ($p < 0.05$).

Inter-group comparisons of tensile strength (Table 4, S1, S2).

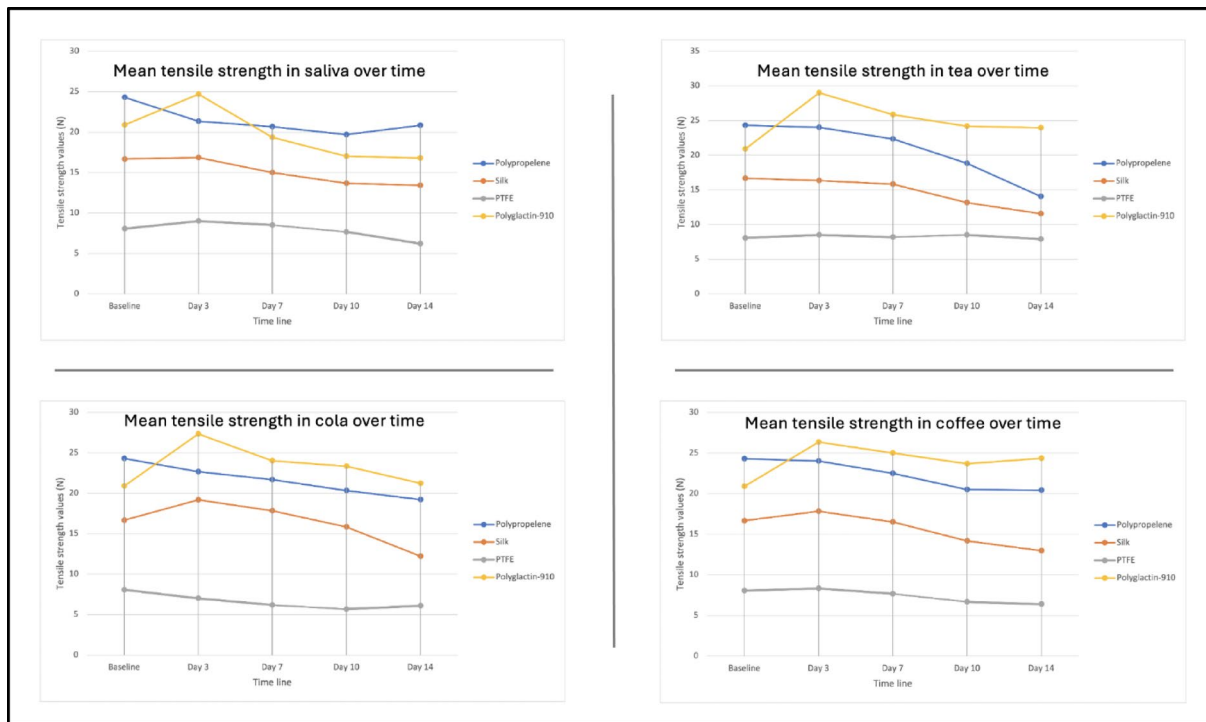


Fig. 4. Mean tensile strength of different suture material in various treatment media over time.

	Suture material	Baseline		Day 3		Day 7		Day 10		Day 14		P-value (Intra-group)			
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Baseline vs Day 3	Baseline vs Day 7	Baseline vs Day 10	Baseline vs Day 14
Saliva	PP	24.30	1.30	21.33	0.29	20.67	0.29	19.67	0.58	20.84	2.76	0.091 ^{NS}	0.054 ^{NS}	0.053 ^{NS}	0.219 ^{NS}
	SK	16.66	1.59	16.83	0.76	15.00	0.50	13.67	0.76	13.43	1.39	0.659 ^{NS}	0.412 ^{NS}	0.186 ^{NS}	0.240 ^{NS}
	PTFE	8.06	2.51	9.00	0.50	8.50	0.50	7.67	0.29	6.20	1.38	0.817 ^{NS}	0.939 ^{NS}	0.551 ^{NS}	0.226 ^{NS}
	PG	20.89	1.48	24.67	1.76	19.33	1.04	17.00	0.50	16.80	1.97	0.043*	0.414 ^{NS}	0.002**	0.061 ^{NS}
Tea	PP	24.30	1.30	24.00	0.50	22.50	0.50	20.50	0.50	20.41	2.02	0.908 ^{NS}	0.270 ^{NS}	0.090 ^{NS}	0.109 ^{NS}
	SK	16.66	1.59	17.83	0.29	16.50	1.00	14.17	0.76	12.97	1.45	0.253 ^{NS}	0.776 ^{NS}	0.254 ^{NS}	0.197 ^{NS}
	PTFE	8.06	2.51	8.33	0.29	7.67	0.29	6.67	0.29	6.39	0.34	0.846 ^{NS}	0.611 ^{NS}	0.289 ^{NS}	0.324 ^{NS}
	PG	20.89	1.48	26.33	1.26	25.00	0.87	23.67	1.76	24.35	2.28	0.026*	0.020*	0.049*	0.061 ^{NS}
Cola	PP	24.30	1.30	24.00	1.80	22.33	0.29	18.83	0.29	14.06	7.26	0.962 ^{NS}	0.225 ^{NS}	0.055 ^{NS}	0.145 ^{NS}
	SK	16.66	1.59	16.33	0.29	15.83	0.29	13.17	1.04	11.55	4.86	0.855 ^{NS}	0.781 ^{NS}	0.178 ^{NS}	0.308 ^{NS}
	PTFE	8.06	2.51	8.50	0.50	8.17	0.29	8.50	0.50	7.89	1.06	0.915 ^{NS}	0.796 ^{NS}	0.917 ^{NS}	0.641 ^{NS}
	PG	20.89	1.48	29.00	0.50	25.83	1.15	24.17	0.29	23.93	1.39	0.004**	0.010**	0.010**	0.053 ^{NS}
Coffee	PP	24.30	1.30	22.67	0.29	21.67	0.29	20.33	0.29	19.19	1.08	0.193 ^{NS}	0.141 ^{NS}	0.066 ^{NS}	0.070 ^{NS}
	SK	16.66	1.59	19.17	0.29	17.83	0.76	15.83	1.76	12.20	2.07	0.053 ^{NS}	0.108 ^{NS}	0.814 ^{NS}	0.193 ^{NS}
	PTFE	8.06	2.51	7.00	0.50	6.17	0.29	5.67	0.29	6.08	1.46	0.399 ^{NS}	0.272 ^{NS}	0.213 ^{NS}	0.354 ^{NS}
	PG	20.89	1.48	27.33	1.53	24.00	1.00	23.33	0.76	21.22	0.62	0.044*	0.046*	0.045*	0.074 ^{NS}

Table 3. Intra-group comparisons of mean tensile strength of sutures. PP, polypropylene; silk-SK; PTFE, polytetrafluoroethylene; PG, polyglactin 910. P value by repeated measures ANOVA (RMANOVA). P-value < 0.05 is considered to be statistically significant. *P-value < 0.05, **P-value < 0.01, NS—Statistically non-significant.

Days 3, 7, and 10: In all media, PG sutures had significantly higher tensile strength than PP, SK, and PTFE ($p < 0.05$) except for day 7 in saliva where it was not statistically significant. By day 10, the tensile strength of the PG sutures in saliva was considerably lower than the baseline ($p < 0.05$). PP was also significantly stronger than SK and PTFE ($p < 0.05$), and SK was stronger than PTFE ($p < 0.05$).

Day 14: In cola, PG had higher tensile strength than PTFE ($p < 0.05$). In tea and coffee, PP and PG were significantly stronger than SK and PTFE ($p < 0.05$), and SK was stronger than PTFE ($p < 0.05$).

Medium	Day	Tensile strengths in decreasing order statistically (P -value < 0.05 for all)
Pre-immersion	Baseline	PP, PG > SK > PTFE
Saliva, tea, cola, coffee	Day 3, Day 7 and Day 10	PG > baseline
	Day 3	PG > PP > SK > PTFE
	Day 7	PP, PG > SK > PTFE
	Day 10	PP > PG > SK > PTFE
Tea	Day 3	PG > PP > SK > PTFE
	Day 7	PG > PP > SK > PTFE
	Day 10	PG > PP > SK > PTFE
	Day 14	PG, PP > SK > PTFE
Coffee	Day 3	PG > PP > SK > PTFE
	Day 7	PG > PP > SK > PTFE
	Day 10	PG > PP > SK > PTFE
	Day 14	PG, PP > SK > PTFE
Cola	Day 3,	PG > PP > SK > PTFE
	Day 7	PG > PP > SK > PTFE
	Day 10	PG > PP > SK > PTFE
	Day 14	PG > PTFE

Table 4. Summary of results for tensile strengths of different suture materials in each medium at different time interval. PP, polypropylene; silk-SK; PTFE, polytetrafluoroethylene; PG, polyglactin 910.

Suture material	Day	Comparative statistically significant tensile strengths across all media (P -value < 0.05 for all)
PP	Day 7	Saliva < Tea, cola, coffee
	Day 10	Saliva < Tea, coffee
PG	Day 3	Saliva < Cola
	Day 7	Saliva < Cola, tea, coffee
	Day 10	Saliva < Cola, tea, coffee
SK	Day 3	Coffee > cola, saliva, tea
	Day 7	Coffee > cola, saliva
PTFE	Day 3	Coffee < Saliva, tea, cola
	Day 7	Coffee < Saliva, tea, cola
	Day 10	Coffee < Saliva, tea, cola

Table 5. Summary of results for tensile strengths of each suture in different media across different time intervals. PP- polypropylene; silk-SK; PTFE-polytetrafluoroethylene; PG-polyglactin 910.

Inter-group comparisons of tensile strength in various treatment media (Table 5, S3, S4):

PP: The mean tensile strength at baseline, day 3, and day 14 did not differ within treatment media. The mean tensile strength at day 7 was significantly greater in tea, cola, and coffee than in artificial saliva ($p < 0.05$). The mean tensile strength at day 10 was significantly greater in tea and coffee than in cola ($p < 0.05$).

PG: At day 3, the tensile strength was significantly higher in cola compared with saliva ($p < 0.05$). At days 7, 10, and 14, tensile strength was significantly higher in tea, cola, and coffee compared with saliva ($p < 0.05$).

SK: The mean tensile strength at baseline, day 10, and day 14 did not differ within treatment media. The mean tensile strength at day 3 was significantly greater in coffee than in saliva, tea, and cola ($p < 0.05$). The mean tensile strength at day 7 was significantly greater in coffee than in artificial saliva and cola ($p < 0.05$).

PTFE: The mean tensile strength at days 3, 7, and 10 was significantly greater in saliva, tea, and cola than in coffee ($p < 0.05$). The mean tensile strength at day 10 was significantly greater in the saliva than in tea ($p < 0.05$). The mean tensile strength at day 14 did not differ within treatment media.

Knot slippage of suture materials in different media

Intra-group comparisons of knot slippage (Table 6).

The incidence of knot slippage at baseline is significantly higher for PTFE as compared to all other types of suture materials ($p < 0.05$). The incidence of knot slippage at day 7 and day 14 is significantly higher compared to baseline in Cola by all types of suture materials (P -value < 0.05 for all) except PTFE. The incidence of knot slippage at days 7 and 14 did not significantly differ from baseline in saliva, tea, and coffee for any of the suture

	Suture material		Baseline		Day 7		Day 14		P-value (Intra-group)		
			n	%	n	%	n	%	Baseline vs Day 7	Baseline vs Day 14	Day 7 vs Day 14
Saliva	PP	Yes	0	0.0	0	0.0	1	25.0	0.999 ^{NS}	0.317 ^{NS}	0.317 ^{NS}
		No	6	100.0	4	100.0	3	75.0			
	SK	Yes	1	16.7	0	0.0	0	0.0	0.999 ^{NS}	0.999 ^{NS}	0.999 ^{NS}
		No	5	83.3	4	100.0	4	100.0			
	PTFE	Yes	6	100.0	1	25.0	1	25.0	0.083 ^{NS}	0.083 ^{NS}	0.999 ^{NS}
		No	0	0.0	3	75.0	3	75.0			
PG	Yes	1	16.7	0	0.0	0	0.0	0.999 ^{NS}	0.999 ^{NS}	0.999 ^{NS}	
	No	5	83.3	4	100.0	4	100.0				
Tea	PP	Yes	0	0.0	0	0.0	1	25.0	0.999 ^{NS}	0.317 ^{NS}	0.317 ^{NS}
		No	6	100.0	4	100.0	3	75.0			
	SK	Yes	1	16.7	0	0.0	0	0.0	0.999 ^{NS}	0.999 ^{NS}	0.999 ^{NS}
		No	5	83.3	4	100.0	4	100.0			
	PTFE	Yes	6	100.0	1	25.0	1	25.0	0.083 ^{NS}	0.083 ^{NS}	0.999 ^{NS}
		No	0	0.0	3	75.0	3	75.0			
PG	Yes	1	16.7	1	25.0	2	50.0	0.317 ^{NS}	0.157 ^{NS}	0.564 ^{NS}	
	No	5	83.3	3	75.0	2	50.0				
Cola	PP	Yes	0	0.0	4	100.0	4	100.0	0.046*	0.046*	0.999 ^{NS}
		No	6	100.0	0	0.0	0	0.0			
	SK	Yes	1	16.7	4	100.0	4	100.0	0.046*	0.046*	0.999 ^{NS}
		No	5	83.3	0	0.0	0	0.0			
	PTFE	Yes	6	100.0	4	100.0	4	100.0	0.999 ^{NS}	0.999 ^{NS}	0.999 ^{NS}
		No	0	0.0	0	0.0	0	0.0			
PG	Yes	1	16.7	4	100.0	4	100.0	0.046*	0.046*	0.999 ^{NS}	
	No	5	83.3	0	0.0	0	0.0				
Coffee	PP	Yes	0	0.0	1	25.0	2	50.0	0.317 ^{NS}	0.157 ^{NS}	0.317 ^{NS}
		No	6	100.0	3	75.0	2	50.0			
	SK	Yes	1	16.7	0	0.0	2	50.0	0.999 ^{NS}	0.157 ^{NS}	0.157 ^{NS}
		No	5	83.3	4	100.0	2	50.0			
	PTFE	Yes	6	100.0	1	25.0	1	25.0	0.083 ^{NS}	0.083 ^{NS}	0.999 ^{NS}
		No	0	0.0	3	75.0	3	75.0			
PG	Yes	1	16.7	0	0.0	2	50.0	0.999 ^{NS}	0.157 ^{NS}	0.157 ^{NS}	
	No	5	83.3	4	100.0	2	50.0				

Table 6. Intra group comparisons of the incidence of knot slippage in suture materials. PP, polypropylene; silk-SK; PTFE, polytetrafluoroethylene; PG, polyglactin 910. *P*-value by Wilcoxon's signed rank sum test. *P*-value < 0.05 is considered to be statistically significant. **P*-value < 0.05, NS—Statistically non-significant.

materials tested. Furthermore, there was no significant difference in knot slippage between day 7 and day 14 across all media and suture types.

Inter-group Comparisons of knot slippage (Table S5,S6,S7,S8):

Prolene: Knot slippage was significantly higher in cola at day 7 compared to saliva, tea, and coffee.

SK: Knot slippage was significantly higher in cola at day 14 compared to saliva and tea.

PTFE: No significant differences in knot slippage were observed across any of the tested media at any time point.

PG: Knot slippage was significantly higher in cola at day 7 compared to saliva, tea, and coffee, and at day 14 compared to saliva.

Knot breakage of suture materials in different media

Intra-group Comparisons from Table 7 of knot breakage (Table 7).

The incidence of knot breakage at baseline is higher for SK as compared to all other sutures but it is statistically significant when compared to PTFE ($p < 0.05$). The incidence of knot breakage at days 7 and 14 did not significantly differ from baseline in saliva, tea, and coffee for any of the suture materials tested except for SK in cola ($p < 0.05$). Similarly, the incidence of knot breakage at day 14 did not differ significantly from day 7 across all media and suture types.

Inter-group Comparisons across all suture materials and across all media (S9,S10,S11,S12):

Prolene, SK, PTFE, and PG suture materials did not exhibit significant differences in knot breakage across all types of media at day 7, and day 14.

	Suture material		Baseline		Day 7		Day 14		P-value (Intra-group)			
			n	%	n	%	n	%	Baseline vs Day 7	Baseline vs Day 14	Day 7 vs Day 14	
Saliva	PP	Yes	1	16.7	3	75.0	1	25.0	0.157 ^{NS}	0.999 ^{NS}	0.157 ^{NS}	
		No	5	83.3	1	25.0	3	75.0				
	SK	Yes	5	83.3	3	75.0	2	50.0	0.317 ^{NS}	0.157 ^{NS}	0.317 ^{NS}	
		No	1	16.7	1	25.0	2	50.0				
	PTFE	Yes	0	0.0	0	0.0	1	25.0	0.999 ^{NS}	0.317 ^{NS}	0.317 ^{NS}	
		No	6	100.0	4	100.0	3	75.0				
	PG	Yes	1	16.7	2	50.0	1	25.0	0.564 ^{NS}	0.999 ^{NS}	0.564 ^{NS}	
		No	5	83.3	2	50.0	3	75.0				
	Tea	PP	Yes	1	16.7	3	75.0	1	25.0	0.157 ^{NS}	0.999 ^{NS}	0.157 ^{NS}
			No	5	83.3	1	25.0	3	75.0			
		SK	Yes	5	83.3	3	75.0	2	50.0	0.317 ^{NS}	0.157 ^{NS}	0.317 ^{NS}
			No	1	16.7	1	25.0	2	50.0			
PTFE		Yes	0	0.0	3	75.0	0	0.0	0.083 ^{NS}	0.999 ^{NS}	0.083 ^{NS}	
		No	6	100.0	1	25.0	4	100.0				
PG		Yes	1	16.7	2	50.0	0	0.0	0.564 ^{NS}	0.317 ^{NS}	0.157 ^{NS}	
		No	5	83.3	2	50.0	4	100.0				
Cola		PP	Yes	1	16.7	0	0.0	0	0.0	0.317 ^{NS}	0.317 ^{NS}	0.999 ^{NS}
			No	5	83.3	4	100.0	4	100.0			
		SK	Yes	5	83.3	0	0.0	0	0.0	0.046*	0.046*	0.999 ^{NS}
			No	1	16.7	4	100.0	4	100.0			
	PTFE	Yes	0	0.0	0	0.0	0	0.0	0.999 ^{NS}	0.999 ^{NS}	0.999 ^{NS}	
		No	6	100.0	4	100.0	4	100.0				
	PG	Yes	1	16.7	0	0.0	0	0.0	0.317 ^{NS}	0.317 ^{NS}	0.999 ^{NS}	
		No	5	83.3	4	100.0	4	100.0				
	Coffee	PP	Yes	1	16.7	2	50.0	2	50.0	0.317 ^{NS}	0.317 ^{NS}	0.999 ^{NS}
			No	5	83.3	2	50.0	2	50.0			
		SK	Yes	5	83.3	3	75.0	2	50.0	0.317 ^{NS}	0.157 ^{NS}	0.317 ^{NS}
			No	1	16.7	1	25.0	2	50.0			
PTFE		Yes	0	0.0	3	75.0	3	75.0	0.083 ^{NS}	0.083 ^{NS}	0.999 ^{NS}	
		No	6	100.0	1	25.0	1	25.0				
PG		Yes	1	16.7	3	75.0	2	50.0	0.157 ^{NS}	0.564 ^{NS}	0.317 ^{NS}	
		No	5	83.3	1	25.0	2	50.0				

Table 7. Intra group comparisons of incidence of knot breakage in suture materials. *P*-value by Wilcoxon's signed rank sum test. *P*-value < 0.05 is considered to be statistically significant. **P*-value < 0.05, NS—Statistically non-significant. PP- polypropylene; silk-SK; PTFE-polytetrafluoroethylene; PG-polyglactin 910.

Discussion

The results highlight the dynamic interplay between suture materials and the oral environment, particularly the impact of common beverages on tensile strength and knot security (slippage and knot breakage). We have chosen to study these sutures as they are the most commonly used suture materials in oral surgical procedures²⁰. We have standardized the knot tying technique by using same number of knots and similar knot configuration (forward-forward-reverse) as it reflects clinical practice and supported by existing literature^{15,19}. Also to reduce confounding due to variability in suture tying technique^{15,19}. To mimic the oral environment, the experiment used a temperature-controlled setup. Further human AB serum was mixed artificial saliva to simulate the presence of proteins and enzymes²³. Tea coffee and cola were studied as these are the most commonly consumed beverages in the middle east and they have effects on the performance of these sutures².

Tensile strength

According to our results, the tensile strength varied considerably across sutures and immersion media. PP had the highest tensile strength on average and is consistent, which is coherent with its properties of a synthetic monofilament suture that exhibits resistance to hydrolysis (does not undergo hydrolysis easily)^{11,24}.

PG had highest tensile strength at day 3 as compared to baseline as well as other sutures in all media. This increased strength may have been a byproduct of the absorption of fluid, which impacted its physical properties. This coincides with results of Taysi et al. 2021 that polyfilament, resorbable, synthetic suture materials have improved tensile strengths over others.²⁴ This coincides with the results of another in vitro study wherein they found that synthetic polyfilament resorbable sutures maintained their tensile strength in acidic as well as neutral pH^{9,24–27}. However, this result needs to be interpreted cautiously, as one would expect PG to degrade over time.

Further, there is contradictory results for TS in alkaline pH, as evidenced the study of Ferguson et al., who inferred reduced TS of PG in saliva (alkaline pH) as compared to soy, saline, or milk (all of which are acidic). They hypothesised that exposure to saliva seems to accelerate suture degradation, leading to a decrease in tensile strength²⁸. Similarly, Khiste et al. further highlighted a decrease in tensile strength when sutures were exposed to a simulated oral environment. They maintained their TS until 7th and 10th day and had minimal strength by day 14²⁹.

In contrast to all the previous studies, Al-Sarhan et al., found no statistically significant difference in the tensile strength of PG sutures before and after saliva immersion ($P=0.563$)³⁰. Similarly, Arce J et al. observed no significant change in the tensile strength of PG, SK, and PTFE sutures at various time points up to 21 days of immersion on stereomicroscopic comparison of their tensile strengths²⁷.

SK had lesser strength than PP and PG, reflecting its natural origin, multifilament structure and susceptibility to mechanical and chemical degradation⁷. Highlighting the impact of pH on suture integrity, research by Chu et al., suggested that SK sutures are particularly vulnerable to changes in pH, with significant loss of tensile strength (over 50%) observed under high alkaline conditions compared to a physiologic pH solution²⁶.

PTFE had least tensile strength of all sutures that can be attributed to its structure. PTFE fibers consist of nodules interconnected by thin crystalline fibers, and their microporous nature contributes to lower bending stiffness. This porosity weakens the overall structure, potentially explaining the lower tensile strength observed in this study and previous reports^{24,26,31,32}. This finding in our study is supported by other studies as well^{20,27,33,34}. This finding aligns with previous research, including an in vitro study that also observed lower tensile strength for PTFE sutures, although it's important to note that this study evaluated untied sutures without knots^{24,34}.

Knot slippage

Knot failure can manifest as either suture rupture or knot slippage, with the latter occurring at lower tension levels. The literature presents inconsistent findings regarding the factors influencing knot security^{15,35–38}. Riboh et al., highlights friction, internal interference and slack between throws as factors impacting knot security³⁵. Similarly, Wong et al., suggested that knot configuration, suture material, suture size, and the number of throws are key determinants³⁷. However, a literature review using a logistic regression model contradicts the impact of suture size on knot security. Further, Silver et al., found knot security to be highest with PG, followed by chromic gut, nylon, and silk³⁸.

Silver et al.³⁸, findings on knot security were further supported by Faris et al.⁶, who emphasized the significance of both suture material and knot configuration in determining knot security. Their research indicated that non-absorbable, synthetic monofilament sutures were more prone to untying, aligning with the present study's observation of significantly higher knot slippage with PTFE compared to PG, PP, and SK (p -value < 0.001).

The finding of increased knot slippage with PTFE aligns with Abellan's study, which demonstrated the lowest knot failure load for PTFE and the highest for polyglycolic acid⁹. This susceptibility of PTFE to knot slippage is further supported by Kim et al., and others, who observed a higher incidence of knot slippage with monofilament absorbable sutures in a salt solution^{34,39–42}. However, these findings contrast with other studies that report PGA as the most prone to unwinding^{39,43–45}.

Further, our study shows no statistically significant difference in knot slippage in any media between PG and SK. This is in contrast to Silver et al. wherein PG has stronger knot security as compared to SK³⁸. The consistent incidence of knot slippage by PTFE suture at baseline, day 7 and at day 14 is supported by the Fares et al., in that they noted that the physical contact with biodegradable agents did not affect the quality or knot resistance of sutures⁶.

Specifically, PP, PG, and SK sutures all showed increased knot slippage in cola, which could possibly be due to its highly acidic nature. Previous studies have shown that prolonged immersion may lead to weakening of the knots⁴⁶. Since cola is acidic, the acidic components likely reduced frictional resistance on the sutures, leading to greater slippage^{16,47}. PTFE sutures had a low coefficient of friction and tended to slip regardless of the media used⁹.

Knot breakage

While knot breakage was consistent over time, the loss of knot security appeared to occur primarily from slippage rather than complete breakage^{8,19}.

Knot breakage rates remained consistent across sutures and immersion media, suggesting that there were more environmental exposures affecting knot holding through slippage than there were evident breaks that required greater forces to achieve^{8,19}.

Conclusion

This study emphasizes the critical role of suture selection in oral surgery and the detrimental effects of common beverages on suture integrity. From the present study we can draw the following conclusions. No restrictions are needed in the post operative period with either tea, coffee and cola till day 7 if PP is used. If sutures need to be maintained for 10 days, restriction for cola applies. If PG is used, no restrictions are needed with either tea, cola or coffee. If SK sutures are used, coffee contributes to greater strength till day 7. With PTFE sutures, coffee should be avoided till day 10. PTFE is prone to knot slippage, so additional knots are required and more attention to be paid to tying technique. SK suture is more prone to breakage but only at baseline after that it is constant.

Data availability

All data generated or analysed during this study are included in this published article.

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Author contributions

“A.A.G.K.: conceptualization; methodology; investigation; validation; writing—original draft; S.S.A.: conceptualization; methodology; investigation; validation; formal analysis; resources; writing—original draft; writing—review and editing; A.F.J.A.: conceptualization; methodology; investigation; validation; writing—original draft; writing—review and editing; A.A.: conceptualization; methodology; investigation; validation; writing—original draft; writing—review and editing; N.M.A.: investigation; formal analysis; A.S.A.E.: investigation; formal analysis; P.D.: investigation; formal analysis; W.A.K.: investigation; formal analysis. All authors have read and agreed to the published version of the manuscript.”

Declarations

Competing interests

The authors declare no competing interests.

Ethical approval

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Ethical Review Board (College of Dentistry, King Khalid University, Abha, Saudi Arabia) [SRC/ETH/2017–18/090].

Informed consent

Not required as the study design is pure in-vitro.

Additional information

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