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Research article

Immediate effect of different herbal solutions on tensile strength of suture materials in oral cavity

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ABSTRACT

This pilot study evaluated the immediate effect of different herbal solutions in oral use on the tensile strength of the sutures used in oral surgical procedures. Three frequently used suture materials, polyglactin 910 (PGA), poliglecaprone (PGCL), and polypropylene (PP), were chosen in a 4-0-gauge size. The sutures' tensile stress was evaluated before being immersed (baseline) and after immersion at 24 h, 1 week, and 2 weeks in four different media: artificial saliva, chlorhexidine, Commiphora myrrh, and frankincense. The tensile strength was assessed by applying a 50 N load at a standardized speed of 2 mm/min. The data were analyzed using one-way and three-way analysis of variance (ANOVA) and the Tukey *post hoc* test with a significance level of $p \leq 0.05$ significance level. The mean values of the maximum load showed a significant statistical difference across the three types of sutures (PGA, PGCL, and PP). The mean tensile strength of the PP suture was statistically lower than that of the other sutures. There was a statistically significant difference in the mean tensile strength of the PGA suture when stored in chlorohexidine media and the PGCL suture for frankincense media. The tensile strength for all sutures was the lowest value when immersed in Commiphora myrrh media. Home-prepared herbal solutions can affect the tensile strength and maximum load of suture materials. Careful and controlled use of herbal solutions after any dental surgical procedures is advisable.

1. Introduction

Conventional dental surgery procedures often involve intervention creating a wound for treatment purposes before closing the tissue which allows for the control of bleeding [1] and primary healing [2]. The most popular means of closing tissue is through sutures, and properly selecting the suture material is one of the most important factors for a successful surgical procedure [3]. According to the ancient Egyptian literature, suture materials, such as cotton and linen have been the method of closing wounds in use since 3500 BCE. Materials such as animal hair, silk, leather, natural fibers, and gut mucosa have since been effectively utilized to close

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wound closure [4]. The selection of suture material depends on several factors related to tissue reactivity and tensile strength [5]. Sutures with low tissue reactivity are favored because they are associated with a lower inflammatory reaction and, thus, promote quick healing [6].

Furthermore, The sutures' tensile strength allows them to withstand knotting and the stress of pulling soft tissue into position. Sutures with low tensile strength are more likely to fail during surgery or, more importantly, post-surgery [7,8]. Material selection for suture purposes is more critical when it comes to the oral cavity since it is characterized by a complex environment with varying temperatures and pH levels. These changes are linked, in addition to the presence of saliva, to consuming various foods and beverages and using oral care products such as toothpaste and mouthwash [9–11].

Practitioners consider various criteria when choosing the suture material, including knot stability, stretchability, tissue response, and wound safety [1,2]. That said, suture materials are categorized by their origin as synthetic or natural, biodegradability as resorbable or non-resorbable, and structure as monofilament or multifilament [12]. Monofilament sutures often pass smoothly through tissue; however, knots might be loose. Braided sutures may not pass as smoothly through tissue; however, they knot better [13]. The multifilament synthetic suture material is favored in anatomic regions requiring higher tensile strength, such as the nasal and oral mucosa. Failing to keep the surgical flaps in place until the sutures are removed might result in several complications, including wound dehiscence [7]. A common unintended consequence of surgery that results from flap and suture tension following procedures like oroantral fistula treatment, guided bone regeneration (GBR), or bone block grafts [14]. Given these risks, maintaining a minimal bacterial load is a major post-operative concern, usually achieved using mouthwashes [9]. Herbal medications are becoming more popular as mouth rinses, and multiple studies have estimated that approximately 70 % of the world's population uses herbal agents adjunctly [15]. Herbal agents are derived from plant extracts used in traditional medicine. For instance, myrrh and frankincense were commonly used in Chinese, Greek, Roman, and Egyptian treatments. Herbal agents are known for lowering infections, wounds, and inflammatory diseases and have been used as solutions for reducing gingival inflammation in the oral cavity [16]. It is noteworthy that in South -East Asian countries herbal medicines are widely studied and used alongside with Western medicines. Several studies have assessed the use of myrrh in endodontic irrigation against several bacterial species and as a mouth rinse after extraction [17]. One study used myrrh in different concentrations as a mouthwash to evaluate the tensile strength of sutures after dental surgery [9]. Given the increase in the use of traditional medicine after dental surgical procedures, there is a need to evaluate the effect these solutions have on the integrity of sutures placed in a surgical site.

The current pilot study aimed to investigate the effect of different herbal media on the tensile strength of different suture materials. The null hypothesis that guided this study was as follows: the tensile strength of the suture material will not vary over time according to the solution in which it was immersed.

2. Experimental details

2.1. Materials

Three commonly used types of sutures materials, polyglactin (PGA), poliglecaprone 25 (PGCL), and polypropylene (PP) in uniform size (4-0), were obtained (Table 1).

2.2. Sample preparation

The study involved testing three-hundred-and-seventy sutures (n = 370) by exposing to four media to measure the tensile strength. Measurement was carried out at four timeframes: pre-immersion, 1 day (24 h), 7 days (1 week), and 14 days (2 weeks). The experimental media were artificial saliva, chlorhexidine gluconate, Commiphora myrrh powder, and frankincense powder (Table 2).

The sutures were sterile in unexpired packs and measured to a standard length (15 cm) allowing to adapt the suture material in the testing machine. Before immersion in any media, the tensile strength of each type of suture material (n = 10 for each) was tested while dry. Ten strands from each suture material were immersed in each media for a period of 24 h, 1 week, and 2 weeks (n = 10 per suture per media per timeframes).

2.3. Uniaxial tensile strength measurement

The uniaxial tensile strength test was performed using a universal testing machine (Instron Dual Column Tabletop Model-5965) with a vertical load cell capacity of 50 N (Fig. 1). Each sample suture material was placed in a vertical position between the upper and lower grip fixtures of the testing apparatus. To prevent damaging the sutures, the testing speed was set at 2 mm per minute. The maximum load was recorded after stretching each strand to the failure point in Newton (MaxloadN).

Table 1
Suture materials used in the experimental study.

Suture material	Composition	Degradation	Manufacturer
Polyglactin 910 (PGA)	Synthetic - multifilament	Resorbable	Vicryl™, Ethicon, Somerville, NJ, USA
Poliglecaprone 25 (PGCL)	Synthetic – monofilament	Resorbable	Monofast™, Medipac, Kilkis, Greece
Polypropylene (PP)	Synthetic – monofilament	Non-resorbable	Prolene™, Ethicon, Somerville, NJ, USA

Table 2
The media and preparation technique.

Media	Preparation	Manufacturer
Artificial saliva	Mixing 100 mL each of 25 mM K_2HPO_4, 24 mM Na_2HPO_4, 1.570 mM $KHCO_3$, 100 mM NaCl, and 1.5 mM $MgCl_2$,followed by adding 6 mL of 25 mM citric acid and 100 mL of 15 mM $CaCl_2$	Not applicable
Chlorhexidine gluconate 0.2 %	Obtained commercially	Avalon AVOHEX, Middle East pharmaceutical industries, Saudi Arabia
Commiphora myrrh	0.5 % w/w [17,18] (0.5 g of Commiphora myrrh in 100 g of water)	Not applicable
Frankincense	0.5 % w/w [17,18] (0.5 g of Frankincense in 100 g of water)	Not applicable

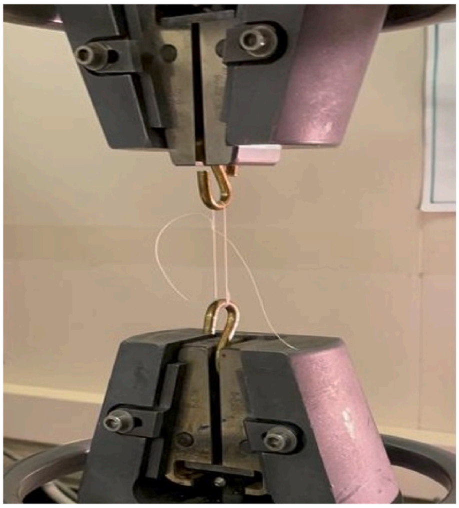

Fig. 1. Instron-5965 universal testing machine with a suture specimen.

Tensile strength was calculated using the following formula:

$$S = \frac{F}{A} \quad \text{(Eq. 1)}$$

where S is the tensile strength value in megapascal (MPa), F is the maximum load in Newton (N), and A is the cross-section area of the sample in square millimeters (mm^2).

2.4. Statistical analysis

The sample size was calculated using G* power 3.1. to be 360 with a power of 95 % and an error probability of 0.05. Data were

Table 3
Descriptive statistics (mean and standard deviation) and mean ranks of MaxLoadN across the three time frames in each of the four media types for each of the three types of sutures.

Suture type	Type of media	Time duration			Test statistic value (Mean rank)	p-value
		24 h	1 week	2 weeks		
PGA	Artificial saliva	22.40(3.8)	22.23(0.9)	19.67(1.5)	3.20	0.202
	Chlorhexidine	23.74(1.6)	22.16(0.6)	21.38(0.7)	5.96	0.051*
	Frankincense	23.79(1.3)	22.01(1.4)	19.86(3.3)	3.47	0.177
	Myrrh	20.10(1.6)	18.80(4.8)	17.87(1.9)	2.40	0.301
PGCL	Artificial saliva	25.74(2.6)	25.58(1.9)	24.27(0.6)	0.62	0.733
	Chlorhexidine	28.52(2.4)	27.22(4.8)	24.15(2.9)	2.22	0.329
	Frankincense	29.24(2.4)	25.88(1.1)	21.91(3.4)	6.49	0.039[a]
	Myrrh	28.87(2.0)	27.73(2.6)	21.36(3.7)	4.62	0.099
PP	Artificial saliva	19.13(1.4)	17.60(1.2)	15.37(4.3)	3.20	0.202
	Chlorhexidine	17.99(0.6)	16.72(1.3)	15.79(1.2)	4.62	0.099
	Frankincense	17.62(1.9)	17.27(1.6)	16.70(1.8)	0.27	0.875
	Myrrh	17.37(0.7)	16.63(1.3)	13.67(7.7)	1.07	0.587

[a] Indicate a significant difference ($p < 0.05$) within a suture type at a different types of media.

analyzed using SPSS 26.0 statistical software (IBM, Chicago, IL, USA). Descriptive statistics (mean and standard deviation) were used to describe the quantitative variables (MaxLoadN and tensile strength). A one-way analysis of variance (ANOVA) followed by Tukey's *post hoc* test was used to compare the mean values of MaxLoadN and tensile strength across the study variables; four types of media, three types of sutures, and three-time frames (24 h, 1 week, and 2 weeks), A non-parametric test (Kruskal Wallis) followed by the Conover *post hoc* test was used to compare the mean ranks of MaxLoadN and tensile strength across the study variables. The findings were considered statistically significant at a p-value of $\leq$0.05.

3. Results and discussion

The descriptive statistics of MaxLoandN and tensile strength across the three timeframes (24 h, 1 week and 2 weeks) with four media types for each of the three suture types are given in Table 3.

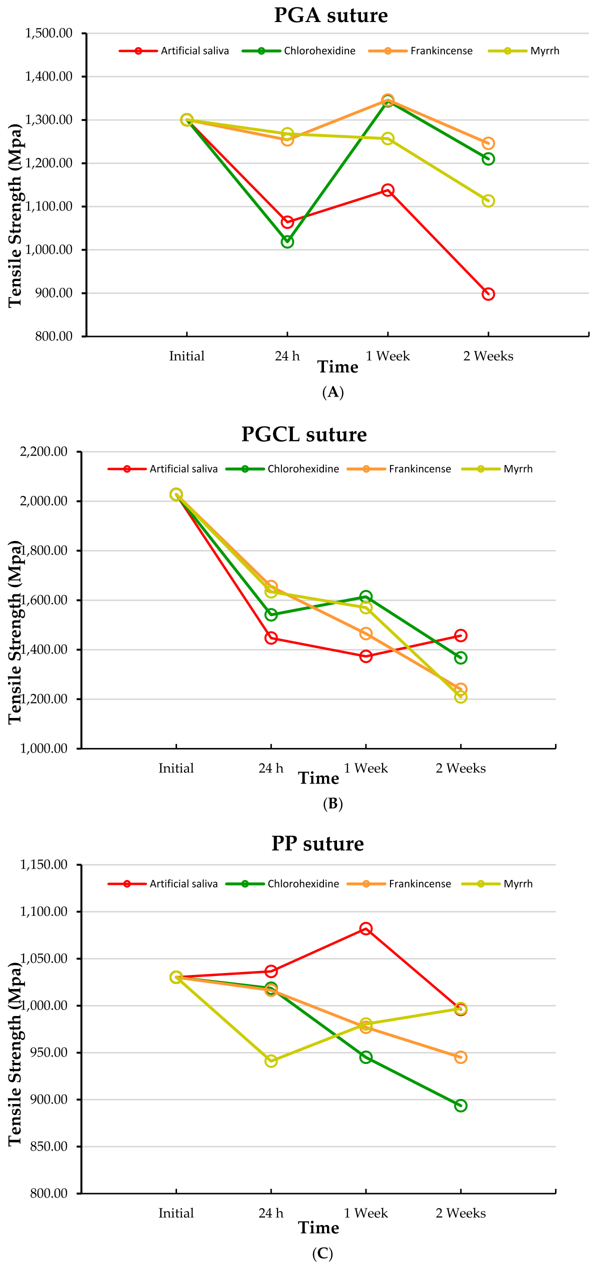

Fig. 2. Tensile strength of tested sutures pre-immersion and post-immersion in four media for three different time frames (**A**) PGA suture, (**B**) PGCL suture, (**C**) PP suture.

3.1. MaxLoadN

At each tested media and each study period, a comparison of the mean values of MaxLoadN showed statistically significant differences among the three types of sutures (PGA, PGCL, and PP) ($F = 80.70$, $p < 0.0001$). The *post hoc* test showed that the mean values between the different suture materials were statistically significant, with a significantly the lowest mean MaxLoadN of the PP suture compared to the other two sutures (PGCL and PGA).

There was no statistically significant difference in the mean values of MaxLoadN when the three time points (24 h, 1 week, and 2 weeks) of the observation were considered ($F = 2.108$, $p = 0.127$) and between the four types of media, *i.e.,* artificial saliva, chlorhexidine, frankincense, and myrrh) ($F = 0.611$, $p = 0.609$).

When comparing the mean ranks of MaxLoadN values across the three time points in each of the four media types, the mean MaxLoadN of the PGA suture was statistically significantly higher in the chlorhexidine media than it was in the other media ($p = 0.051$). The *post hoc* tests indicated the values of MaxLoadN at 1 week to be statistically significantly higher when compared with the values at 24 h and 2 weeks ($p < 0.01$). The mean ranks of MaxLoadN did not show a statistically significant difference for the PGA suture stored in the other three media (artificial salvia, frankincense, and myrrh).

The mean of the MaxLoadN values of the PGCL suture was statistically significantly different at some time points when stored in the frankincense media ($p = 0.039$). The post-hoc test shows that the MaxLoadN values were significantly higher at 24 h and 1 week compared with the values at 2 weeks ($p < 0.01$). There was no difference between 24 h and 1 week. No statistically significant difference was found in the MaxLoadN values of the PP suture across the three time points in each of the four media types.

3.2. Uniaxial tensile strength

The comparison of the mean values of tensile strength showed statistically significant differences among the three types of sutures, PGA, PGCL and PP ($F = 69.75$, $p < 0.0001$) (Fig. 2a,b, and c). The mean tensile strength of the PP suture was statistically lower than that of the other two sutures (PGCL and PGA) in all study conditions (time and media). In the contrast, the PGCL suture had the highest tensile strength among different times and media compared to the PGA and PP sutures ($p < 0.00$). The *post hoc* test showed a significant difference in the mean values of each of these three sutures to the other. The tensile strength of all suture materials was the least when immersed in myrrh ($p = 0.00$).

This laboratory study compared the effect three mouth rinses that are regularly used in the Middle Eastern region had on three common surgical suture materials. One of the major elements of successful surgical procedures is stability in wound margins, which must be closed properly using sutures. The wound healing process passes through different phases, from matrix formation and cell adhesion to angiogenesis, which strengthens the tissue's ability to resist stresses. Failing to keep the seal closed by early wound instability will cause wound opening and possible tearing of the soft tissue. Selecting suture material is vital and linked to the requirement to fully heal soft tissues. Moreover, the oral environment is challenging because jaw movement, food debris, dental plaque biofilm, and changing pH all affect the suture stability, making the healing process more challenging.

Three suture materials, PGA, PGCL, and PP, were immersed in different media commonly used as therapeutic mouthwash after dental surgical procedures. This was simulating the contact effect with the media. While the study settings are different than reality, where the contact time in clinical settings is not prolonged, the study focuses purely on the effect of the herbal mouthwashes on the tensile strength of sutures. The null hypothesis was rejected as the effect of storage media was evident for both PGA and PGCL sutures, although it had less effect in the PP suture. This can be attributed to the nature of the sutures' absorption, as previous studies have reported a direct correlation between the decrease in tensile strength and resorption rates of various suture materials [9,19,20]. PGA is a monofilament suture known for its relatively fast absorption rate. Studies have shown significant loss of tensile strength within 2–4 weeks after surgery, with complete absorption occurring within 60 days [21]. PGCL offers a slower degradation profile compared to PGA as it contains Higher caprolactone content. PGCL sutures can retain about 50 % of their tensile strength at 4 weeks, with complete absorption taking around 90–120 days [22].

Numerous of studies have investigated the effect commonly used mouthwashes, such as chlorhexidine and Listerine®, have on suture strength [23,24]. However, it is very common in the Middle East and South-East Asia to use traditional medicines involving different home remedies for oral care, such as myrrh, which is believed to ease infection and can be used as a herbal solution [25]. Frankincense is another common rinse used in the Middle East for infections and oral conditions; however, there is a lack of studies on its benefits and effects [26].

This study assessed the impact that different immersion media had on the tensile strength of PGCL, PGA and PP sutures.

Artificial saliva and chlorhexidine media were added as control groups to simulate natural oral conditions without mouthwashes. PGCL exhibited the maximum tensile strength throughout the different settings' study periods. However, a comparison of the two resorbable sutures (PGCL and PGA) revealed that the tensile strength of the suture was more retainable than the PGCL suture. This finding is consistent with previous studies [27–29]. These differences are understandable, as resistance to forces is higher in monofilaments than in multifilament [6,30,31].

The study also found that the mean uniaxial tensile strength of the PP suture was statistically significantly lower than the other two sutures (PGCL and PGA). This was anticipated since it had the lowest tensile strength in pre-immersion. Yet, the effect of the PP as a non-resorbable suture was maintained at the maximum load across the different study parameters. This finding agrees a study of with Kim et al., which found that nylon sutures exhibited a high maximal tensile strength and high elongation [32]. However, the low tensile strength of the PP suture was contrary to the findings of a study by Alamer et al. [3], study which found that the PP suture had the highest tensile strength. This might be attributed to the study design, as Alamer et al. used artificial saliva only [3]. The composition of the artificial saliva preparation between the two studies was different. Previous studies have found that it is nearly impossible to develop a universally applicable artificial saliva model [33]. As such, a comparison between different studies in which artificial saliva has been used would not be reliable. It is noteworthy that uniaxial tensile strength testing is widely and frequently used in biomaterials and dental materials research to assess a material's key mechanical properties.

When the sutures were immersed in chlorhexidine solution, all sutures showed a non-statistical decrease in tensile strength. We didn't carry out analysis on the suture diameter, structure, or other suture material analysis *per se*; that will be one of our future studies. Neither was any chemical analysis on leached components from sutures into the solutions carried out as that was not in our focus. The decrease of tensile strength of the monofilament suture (PGCL) was significant between 1 week and 2 weeks. This might be attributed to the nature of this suture where it is a monofilament suture which could affect the degradation with longer immersion time. The finding agrees with a study by Alsarhan et al. in which two absorbable sutures, monofilament and multifilament, were used in combination with two different gauge sizes [32]. The findings revealed that the strength of the sutures decreased between 24 h and 2 weeks [27]. The same results were also reported by Verma et al., despite the fact test period was limited to 24 h and hydrolysis might not have started [10]. The effects of Commiphora myrrh on sutures have been examined in several studies. Research by Verma et al. found that the effect of myrrh effect was not significant. This finding can be accepted since the study lasted for only 24 h [10]. In the current study, the largest change in tensile strength among all sutures was evident following storage in myrrh. Different concentrations of myrrh have also been studied in the past, and the findings have revealed that an increased concentration of myrrh results in lower tensile strength [9]. This could explain the tensile strength of the PP suture in the current study, which was comparable between 24h and 2 weeks. Another common solution in Middle East countries is frankincense. In the current study, a significant change in the maximum load was observed in the PGCL sutures only. The only study on frankincense was that performed by Verma et al. [10].This study spanned a short period only (24 h), the findings revealed that frankincense did not affect PGCL's tensile strength, which contradicts our findings. The difference between the findings could be related to the variation in the concentration of the herbal solutions or even the quality of the herbs themselves. Our current study showed that the PGA sutures exhibited no statistically significant difference in tensile strength after storage in three medias. This is aligned with the results of several previous studies, which found that the PGA exhibited excellent handling capabilities and a high initial tensile strength [3,34,35].

We didn't measure changes in the suture cross-sections as that has no clinical relevance. One factor that was not evaluated in the current study is different suture gauge sizes. Sutures with smaller gauges might have reacted differently to the herbal media [27]. The relatively small sample size in this study might affected the findings. A further limitation of the present study is the standard concentration of the herbal media. People do not typically use a precise or standardized ratio of herbal powder to water. This might influence the study results [9]. Other factors, such as serum fluids within periodontal flaps, the effect of medications, and different dietary habits, could also have an impact on the results. These aspects will be included in our near future research. Moreover, further *in vitro* and *in vivo* testing involving larger parameters is advised to confirm the mechanical, molecular, and bacterial effects of different herbal solutions have on the properties of sutures.

4. Conclusions

The current pilot study has demonstrated that the tensile strength of the different selected suture materials differs according to the storage conditions. Home-prepared herbal solutions can affect the tensile strength and maximum load of post-operative sutures. Patients should be warned that the use of any herbal solution could have a negative impact on sutures after dental surgical procedures. A combination of strong sutures and the ability to withstand different herbal mouthwashes are mandatory in oral sutures. Using home-prepared herb-containing mouth rinses might affect the strength of sutures during the soft tissue healing period after surgical procedures.

Ethical compliance

N\A.

Data availability statement

Data will be available and provided upon request.

CRediT authorship contribution statement

Razan Alaqeely: Writing – review & editing, Validation, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Rabab Bukhamseen:** Software, Resources, Methodology. **Reema Alshehri:** Writing – original draft, Software, Resources, Methodology. **Hussain Alsayed:** Writing – review & editing, Investigation, Data curation. **Jukka Matinlinna:** Writing – review & editing, Validation. **Abdulaziz Alhotan:** Writing – review & editing, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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