Comparing Suture Strengths for Clinical Applications: A Novel In Vitro Study

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Background: The purpose of this study was to compare the tensile strengths of commonly used sutures over a 2-week period under simulated oral conditions.

Methods: Three suture materials (chromic gut [CG], polyglactin [PG], and polyglactin-fast absorbing [PG-FA]) were used in 4-0 and 5-0 gauges. After pretensioning, 252 suture samples (42 of each material and gauge) were used. A biologic simulation was created in vitro by mixing 9 ml sterile human saliva and human serum in a 1:1 ratio in a petri dish maintained at a pH of 7.4 to 8.1 at 37°C. All samples were tested preimmersion and 1 hour and 1, 3, 7, 10, and 14 days postimmersion. The tensile strength was assessed using a microtensile tester, and the maximum load required to cause suture breakage was determined. The point of breakage in the samples and the samples themselves were also assessed.

Results: During the first 24 hours of immersion, all 4-0 and 5-0 samples of CG and PG maintained their initial level of tensile strength; PG-FA 5-0 decreased in strength, which was statistically significant ($P = 0.001$). Between days 1 and 3, the tensile strength of PG and PG-FA decreased significantly, with PG-FA 5-0 showing a greater and more precipitous decrease than PG-FA 4-0; the tensile strength of CG changed little during this time. After 7 days of immersion, PG 4-0 had significantly greater tensile strength than CG, and both were significantly greater than that of PG-FA. By day 10, CG and PG had statistically greater strength ($P = 0.01$) than PG-FA, and values were similar for the 4-0 and 5-0 gauge materials. All samples of PG-FA 5-0 and most samples of the PG-FA 4-0 exhibited 0.00 N strength (i.e., they had disintegrated) at the 10- and 14-day periods of evaluation.

Conclusions: 4-0 sutures are stronger and have greater tensile strength than 5-0 sutures. CG seems to sustain its strength better than PG and PG-FA after 2 weeks. PG-FA may not be a desirable suture if tensile strength is required after 10 days. Appropriately designed clinical studies are necessary to confirm this finding in an in vivo environment. *J Periodontol 2009; 80:618-624.*

KEY WORDS

Polyglactin; resorption; suture; tensile strength.

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The goal of suturing after a surgical procedure is to stabilize the tissue flaps in close approximation for an intended period of time. Sutures are made of different bioinert materials based on their physical and chemical properties.

Proper positioning and stabilization of the surgical flap are important to achieve healing by primary intention. Improper positioning of the flaps can lead to delayed or compromised healing. In some cases, this may compromise the result of the procedure, which makes suturing an important step for a successful outcome.

Suturing in dentistry is different from suturing in the other parts of the body because of the type of tissues involved, the constant presence of saliva, high tissue vascularization, and functions related to speech, mastication, and swallowing. Appropriate sutures require specific physical characteristics and properties, such as good tensile strength, dimensional stability, lack of memory, knot security, and sufficient flexibility to avoid damage to the oral mucosa.[1,2]

Primary closure of the surgical flap is an important and critical step in most regenerative procedures and is obtained by close approximation of the flap margins. Failure to obtain primary closure and maintain it over the initial healing phase can be detrimental to the desired outcome of the surgical procedure. Surgical tissue edges that are not correctly approximated can lead to open wound

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margins and a hematoma that forms and separates the healing flap from the underlying bone. This may result in observable tissue scarring. When evaluating healing in esthetic surgery, precise tissue approximation leads to early and rapid revascularization, which accelerates wound healing and promotes successful treatment.[3] The strength and adherence of the sutured tissue increase over time, and investigators[4] have noted that a significant increase in flap strength is achieved between 1 and 2 weeks. Suture material of insufficient strength can result in untimely suture breakage, leading to poor adaptation of the surgical flaps and inducing the healing of tissues by secondary intention.[5]

Sutures can be divided into bioabsorbable and non-resorbable types based on their physical degradation and resorption in the tissues. Non-resorbable sutures are made of materials that are durable and resist dissolution in reaction to oral fluids, saliva, and serum. However, non-resorbable sutures need to be removed, which necessitates another appointment, and they can become an irritant if part inadvertently remains after suture removal. Many surgeons consider silk the standard of performance (superior handling characteristics) among non-resorbable suture materials.[6-8] Commonly used bioabsorbable suture materials that have shown the desirable properties in relation to tissue reactions are gut, polyglycolic acid, polyglactin (PG), and chromic gut (CG).

The selection of appropriate suture material is a critical step that is based on appropriate tensile strength, tissue biocompatibility, and resorption rates. In the dental literature, there seems to be a greater emphasis on tissue response to suture materials than on the assessment of the physical and biochemical properties of the suture materials.[6-8] In general, practitioners tend to rely on the package insert for information regarding the properties and durability of the sutures. Studies[5,9,10] have examined the tensile strength and resorption rates of different suture materials; they found that the tensile strength of the sutures decreased over time and was dependent on the rate of resorption. However, to the best of our knowledge, no study has compared the strengths of suture materials over time under simulated oral conditions.

The goal of our study was to compare the tensile strength of three commonly used suture materials over a 2-week period under simulated oral conditions.

MATERIALS AND METHODS

The study consisted of three types of suture materials: CG,[§] PG,[‖] and PG-fast absorbing (PG-FA).[¶] Two gauges (4-0 and 5-0) of each type were used. The materials and gauges were selected based on common usage in periodontal surgery.

Suture Specimens

Each sample was tied with a square surgeon's knot around two metal posts fitted to a microtensile tester[#] with a fixed distance of 24.0 mm between the two posts. The samples were pretensioned to 10.2 N using the microtensile tester to avoid knot slippage during testing. All knots that slipped during the pretensioning were discarded. After pretensioning, 252 suture specimens (42 of each material and gauge) were used for the study.

Simulation of Oral Environment

A biologic simulation of the oral environment was created in vitro by mixing 9 ml each sterile human saliva** and human serum[††] in a 1:1 ratio in a petri dish. This biologic solution was prepared and maintained at a pH of 7.4 to 8.1 in an incubator at 37°C.

Six samples (one suture of each material and gauge) were placed in a petri dish containing the serum saliva mixture simulating the oral environment and maintained for a specified time in a non-tensioned state. The biologic solution was replenished every 2 days.

Tensile Strength

Tensile strengths of the suture samples were tested at specified time points: preimmersion and 1 hour and 1, 3, 7, 10, and 14 days postimmersion. Tensile strength assessment of the suture samples was done using the microtensile tester at a cross-head speed of 2.0 mm/minute. Each specimen was stretched to failure; the maximum load was recorded in Newtons (N) and tabulated for analysis. The point of breakage and the samples were assessed at a magnification ×10 using a microscope[‡‡] with an attached digital camera.

Statistical Analyses

The knot slippage data were compared descriptively and with the Fisher exact test. Preliminary analyses were conducted with analysis of variance (ANOVA) to determine if the materials were different with respect to tensile strength at preimmersion; pairwise comparisons were conducted using the least significant difference post hoc analysis. In addition, a three-factor ANOVA was used to assess the tensile strength of materials at different thicknesses over time. Time was treated as a non-repeated measures variable because materials tested at each time frame were independent. Pairwise comparisons of particular interest were explored using the Fisher-Hayter post hoc analysis if the omnibus test indicated statistically significant effects.

§ Hu-Friedy, Chicago, IL.
‖ Vicryl, Hu-Friedy.
¶ Vicryl-FA, Hu-Friedy.
# Bisco Microtensile Tester, Schaumburg, IL.
** Fisher Scientific, Pittsburgh, PA.
†† Fisher Scientific.
‡‡ Zoom, Qioptiq Imaging Solutions, Rochester, NY.

RESULTS

Pretensioning

All sutures were pretensioned to 10.2 N using the microtensile tester and knotted using a standardized technique. Within each group (4-0 and 5-0), a sufficient number was prepared to achieve 42 samples for testing. The frequency of material failures in each group during the pretensioning phase (defined as knot slippage/breakage) was recorded (Table 1). A Fisher exact test showed that the frequency of failures for the 4-0 materials was significantly higher for PG-FA (P= 0.002). Within the 4-0 gauge samples, PG showed the greatest resistance to slippage (4.5%), followed by CG (10.6%) and PG-FA (28.8%). There was a statistically significant difference (P= 0.006) between PG 5-0 and the other 5-0 materials. PG 5-0 had the greatest knot slippage rate of 34.4%, compared to 12.5% each for PG-FA 5-0 and CG 5-0.

Tensile Strength of Materials Over Time

Analyses were conducted to determine whether the tensile strength of the materials differed at baseline (under dry conditions). At baseline (preimmersion), there was a statistically significant (P= 0.0001) difference between the 4-0 and 5-0 gauges. PG consistently demonstrated significantly greater tensile strength (P <0.002) compared to CG, with CG being significantly greater than PG-FA (P <0.002), irrespective of material thickness. Although the effects for both material thicknesses were similar, the magnitude of difference was slightly less for the 5-0 material.

The three-factor ANOVA showed a statistically significant (P= 0.0001; η^2 = 0.369) three-way interaction between the materials over time for the two gauges (Table 2; Figs. 1 and 2). Within the first 24 hours of immersion in solution, the 4-0 and 5-0 samples of CG and PG, as well as PG-FA 4-0, maintained their initial levels of tensile strength. However, PG-FA 5-0 decreased in strength to 15.68 N, and the difference was statistically significant (P = 0.001). Between days 1 and 3, the tensile strength of PG and PG-FA decreased significantly, with PG-FA 5-0 showing a greater and more precipitous decrease than the 4-0 gauge; the tensile strength of CG changed little across this time period. After 7 days of immersion, PG 4-0 had significantly greater tensile strength compared to CG, and both were significantly higher than PG-FA. By day 10, CG and PG had statistically greater strength (P= 0.01) than PG-FA, and were not different from one another. This was true for the 4-0 and 5-0 gauge materials. Samples of PG-FA 4-0 showed 4% of initial strength at 10 days but no strength on day 14. All PG-FA 5-0 samples had disintegrated at day 10.

Table 1.

Knot Slippage Data

Material	Gauge	Samples Tied (n)	Samples Slipped (n)
CG	4-0	47	5
	5-0	48	6
PG	4-0	44	2
	5-0	64	22
PG-FA	4-0	48	6
	5-0	59	17

Microscopic Examination

Samples were evaluated microscopically for the type of breakage following tensile testing. CG consistently showed uneven breakage (Fig. 3A), whereas PG and PG-FA consistently showed evidence of more even breakage through each filament (Figs. 3B and 3C).

Samples were also evaluated for evidence of resorption throughout the length of the suture. Figure 4 depicts the resorption patterns of the different materials. CG showed evidence of slow resorption; by day 14 the sample showed a small split of a strand off the main sample. PG did not show marked evidence of resorption. The samples appeared to be more translucent as time progressed, but there was no evidence of irregularity. PG-FA showed marked resorption by day 7, with thinning of the individual filaments; by day 14 there were marked internal severances of the individual filaments of the sample.

DISCUSSION

Pretensioning of sutures was performed to assess the loads required to untie them.[9] Because the study involved suture materials with knots tied to mimic the clinical setting and then tested for durability, one of the key steps was to assess the stability of the knot. Several studies[10-13] have examined the tensile properties of various sutures. Typically, flat knots are more secure than sliding knots. Flat knots include square knots and surgeon's knots.[14] When using synthetic bioabsorbable sutures, it is recommended that the surgeon's knot be used to prevent knot untying.[15,16] Our study used the surgeon's knot for all samples for this reason, and slippage or untying was analyzed.

The microtensile tester was used to pretension these knots at increasing loads that were stopped at 10.2 N, which seemed to be the ideal amount of force to test the sutures for slippage. Although the clinical situation does not show the amount of force applied in each situation, there usually is increased tension in the suture materials because of inflammation in the first 48 hours.[17] Within the 4-0 samples, PG-FA showed greater knot slippage; it is a multifilament suture compared to CG, which is a monofilament. In the 5-0 samples, CG showed a much lesser rate of slippage than PG and PG-FA. One possible explanation is

Table 2.

Tensile Strength (N) for Each Suture Material and Gauge at Different Time Points

Material	Time	4-0 Tensile Strength*†		5-0 Tensile Strength*‡	
		Mean (SD)	Percentage of Original Strength	Mean (SD)	Percentage of Original Strength
CG	Preimmersion	19.63 (2.06)	NA	13.30 (1.55)	NA
	1 hour	20.88 (2.75)	106.37	14.00 (1.38)	105.26
	1 day	20.35 (2.25)	103.67	13.67 (1.13)	102.78
	3 days	22.43 (1.77)	114.26	10.13 (3.50)	76.17
	7 days	18.92 (0.63)	96.38	12.22 (1.33)	91.88
	10 days	19.12 (3.69)	97.40	11.82 (2.64)	88.87
	14 days	20.58 (2.74)	104.84	10.43 (2.32)	78.42
PG	Preimmersion	41.43 (3.25)	NA	24.22 (2.86)	NA
	1 hour	40.82 (2.01)	98.53	22.17 (1.90)	91.54
	1 day	38.67 (3.08)	93.34	22.05 (1.98)	91.04
	3 days	33.18 (2.68)	80.09	18.46 (1.97)	76.22
	7 days	28.63 (1.69)	69.10	16.23 (0.88)	67.01
	10 days	19.88 (1.43)	47.98	11.53 (1.43)	47.61
	14 days	8.80 (1.53)	21.24	6.42 (1.07)	26.51
PG-FA	Preimmersion	25.53 (0.66)	NA	19.20 (1.63)	NA
	1 hour	25.75 (1.90)	100.86	18.87 (1.88)	98.28
	1 day	23.94 (2.96)	93.77	15.68 (1.41)	81.67
	3 days	14.40 (1.10)	56.40	8.23 (1.66)	42.86
	7 days	7.58 (1.22)	29.69	4.43 (1.06)	23.07
	10 days	1.07 (0.41)	4.19	0.00 (0.00)	0.00
	14 days	0.00 (0.00)	0.00	0.00 (0.00)	0.00

* P value = 0.0001.
† $\eta^2 = 0.882$.
‡ $\eta^2 = 0.776$.
NA = not applicable.

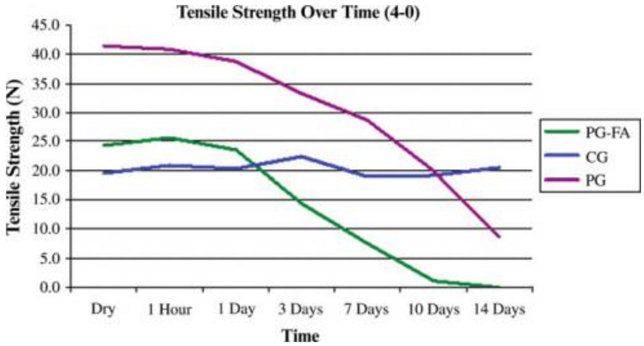

Figure 1.
Comparison of the decrease in tensile strength in three materials of the same gauge (4-0).

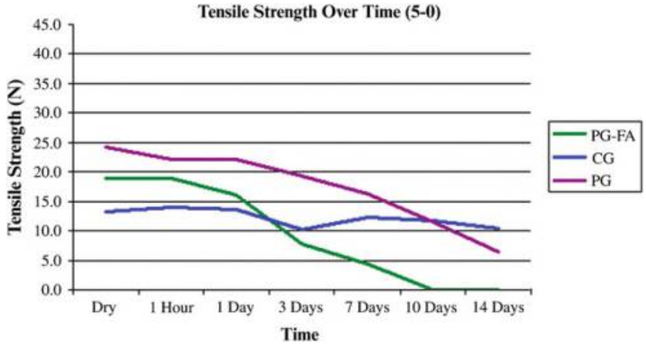

Figure 2.
Comparison of the decrease in tensile strength in three materials of the same gauge (5-0).

that CG is a monofilament with possibly uniform strength through the material, whereas the other sutures are multifilament and braided. Although the multifilament, braided sutures should show greater knot stability, it may be possible that as the gauge increases (material gets thinner) the multifilament materials have a tendency for greater slippage of the knot. Another possible explanation for CG showing greater knot stability may originate from the presence of chromic coating of the monofilament gut, which could prevent slippage of the knot and keep it engaged.

Although various combinations of saliva and serum have been reported in the literature,[18,19] a 1:1 ratio was used in our study to simulate the oral conditions. Serum within the oral cavity is present in the form of gingival crevicular fluid. Although the ratio of saliva

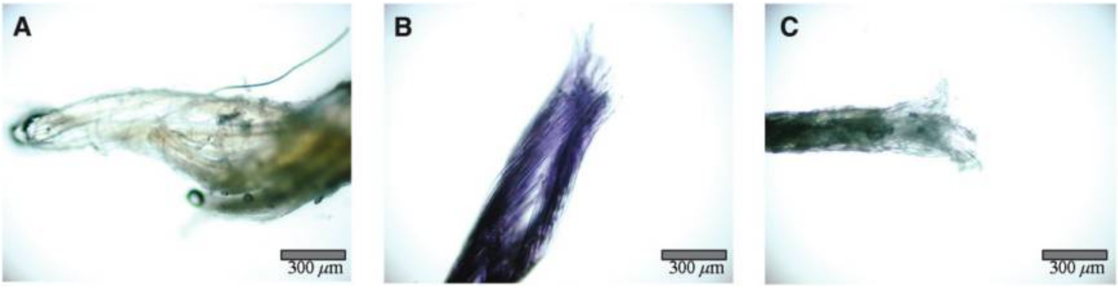

Figure 3.
Photomicrographs of the point of breakage of suture samples at day 10. ***A)*** *CG 4-0 exhibits uneven breakage. PG 4-0* ***(B)*** *and PG-FA 4-0* ***(C)*** *exhibit even breakage through all filaments. (Original magnification ×10.)*

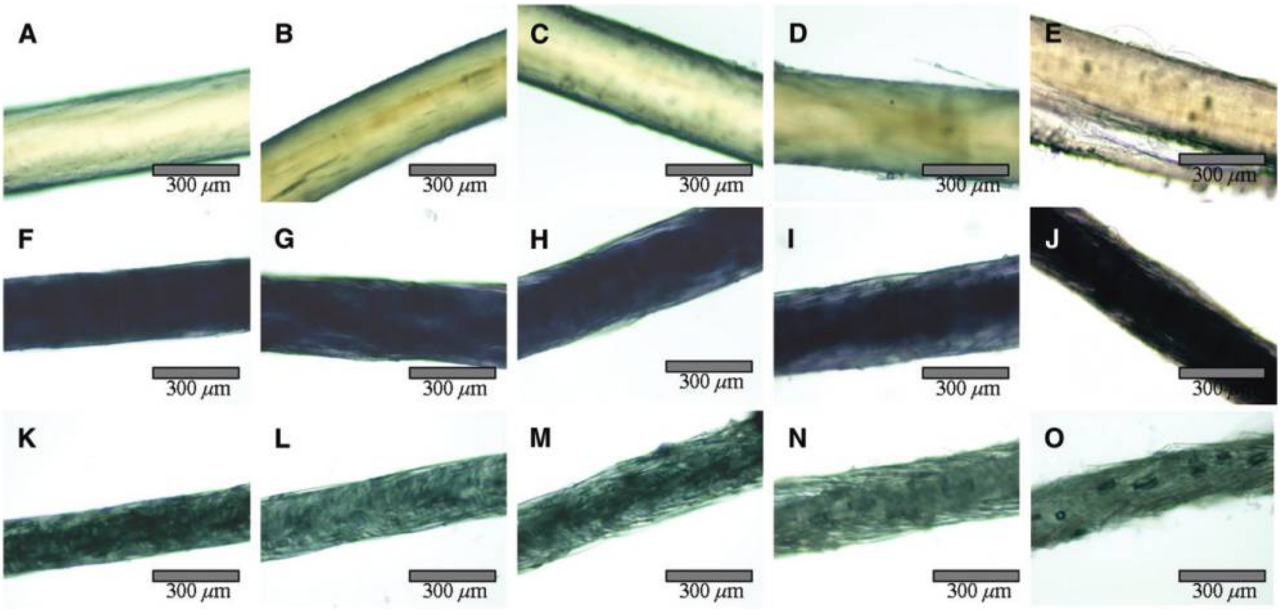

Figure 4.
Photomicrographs of the resorption of the suture samples. ***A through E)*** *CG 4-0 from days 1 to 14 (left to right). Images depict a slow degradation of the material and eventual splitting of the suture strand.* ***F through J)*** *PG 4-0 from days 1 to 14 (left to right). Images do not show a marked degradation.* ***K through O)*** *PG-FA 4-0 from days 1 to 14 (left to right). Images show a marked degradation of the samples with multiple severed filaments. (Original magnification ×10.)*

to serum in the oral cavity is not 1:1, the ratio was selected based on the theory that suture material tied under the gingiva will largely come in contact with serum on the inside and saliva on the outside of the gingival tissues. Also, when used in maxillofacial surgery in the face and around the oral cavity, saliva may rarely come in contact with the sutures, and hence, the 1:1 ratio was selected to best mimic possible periodontal and maxillofacial surgical scenarios.

The pH of the medium is another factor that gains more importance in the resorption of suture materials. Because a decrease in the pH leads to earlier resorption of the material,[20] the pH of our medium was maintained between 7.4 and 8.1 by checking it daily and replenishing the solution every 2 days when changes in pH were noted. The duration of our study and the selection of testing points were based on clinical relevance; the study was conducted for only 2 weeks because the sutures for most periodontal procedures are removed at that time.

Our results showed that CG sutures maintained their tensile strength in a relatively stable manner over the study period. Of the three suture materials used in our study, the PG sutures had the highest tensile strength at baseline, but it decreased rapidly over time. The PG-FA sutures lost all of their tensile strength by 7 days. This contradicts the finding that polyglycolic acid sutures have excellent knot-holding capacity and tensile strength.[21]

When used intraorally, a surgical gut suture loses most of its tensile strength in 24 to 48 hours unless it is treated with a chromic compound that extends the period of resorption for 7 to 10 days and delays the loss of tensile strength for up to 5 days.[22] CG sutures maintain their tensile strength for 10 to 14 days and do not completely absorb until at least day 90.[14] However, the inferior handling properties, tissue drag, and higher rate of inflammation in the surrounding tissues have made gut sutures less desirable.[23]

In an evaluation of the tensile strength and knot stability of surgical sutures, Kim et al.[10] used bioabsorbable sutures immersed in Hanks balanced salt solution for 14 days and then attempted a surgeon's knot. They noted that the tensile strength following linear loading decreased significantly for the CG suture after 14 days. It is not known if the different medium used had any significant effect on these findings. Unlike in the study by Kim et al.,[10] the sutures in our investigation were initially tied in tension, pretensioned linearly to 10.2 N, and immersed in the solution in an attempt to mimic the clinical situation. This difference in the approach could explain the variation in tensile strength between the studies.

Previous investigations[5,24-27] of PG sutures showed excellent handling properties, high initial tensile strength, and less tissue reactions. The specific multistranded suture used in this study was PG 910 coated with PG 370. The PG 370 coating is intended to facilitate knot tying and decrease tissue drag.[14] The other suture material (PG-FA), which is newer, is the same as PG but is modified by ionizing with gamma rays. In theory, this results in faster absorption without a compromise in strength.

In our investigation, the CG sutures maintained most of their original strength over the 2-week study period, which contradicts the findings of Selvig et al.[6] They reported that CG sutures used in the oral tissues of dogs were unpredictably and quickly absorbed in an environment characterized by moisture. The controlled aseptic in vitro environment in our study, without the influence of bacterial proteolytic enzymes, might explain the different results.

CONCLUSIONS

All 4-0 sutures were stronger and had greater tensile strength than 5-0 sutures. CG seemed to sustain its strength better than PG and PG-FA after 2 weeks. PG-FA may not be a desirable suture if tensile strength is required after 10 days. Clinical studies are necessary to confirm these findings.

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