

# Evaluation of the tensile strengths of four monofilament absorbable suture materials after immersion in canine urine with or without bacteria

Chelsea B. Greenberg, DVM; Ellen B. Davidson, DVM; Danielle D. Bellmer, PhD; Rebecca J. Morton, DVM, PhD; Mark E. Payton, PhD

**Objective**—To evaluate the tensile strength, elongation, and degradation of 4 monofilament absorbable suture materials that undergo degradation by hydrolysis in specimens of canine urine with various physical characteristics.

**Sample Population**—4 monofilament absorbable sutures (polydioxanone, poliglecaprone 25, polyglyconate, and glycomer 631).

**Procedure**—Voided urine was collected from 6 healthy dogs, pooled, filter-sterilized, and prepared to provide 5 media: sterile neutral (pH, 7.0), sterile acidic (pH, 6.2), sterile basic (pH, 8.8), *Escherichia coli*-inoculated, and *Proteus mirabilis*-inoculated urine. Ten strands of each suture material were immersed in each of the media for 0 to 28 days. Tensile strength and elongation of each suture material were evaluated by use of a texture analyzer on days 0, 1, 3, 7, 10, 14, 21, and 28.

**Results**—Reduction in tensile strength was detected for all materials in all urine specimens over time. Polyglyconate and polydioxanone had superior tensile strengths in sterile neutral and *E coli*-inoculated urine, and polydioxanone retained the greatest tensile strength throughout the study period. All suture materials disintegrated before day 7 in *P mirabilis*-inoculated urine.

**Conclusions and Clinical Relevance**—Polydioxanone, polyglyconate, and glycomer 631 may be acceptable for urinary bladder closure in the presence of sterile neutral and *E coli*-contaminated urine. Tensile strength of poliglecaprone 25 in urine may be unacceptable by the critical healing time for bladder tissue (14 to 21 days). During bladder surgery, exposure of suture material that degrades via hydrolysis to urine containing *Proteus* spp should be minimized. *Am J Vet Res* (2004;65:847–853)

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From the Departments of Veterinary Clinical Sciences (Greenberg, Davidson) and Veterinary Pathobiology (Morton), College of Veterinary Medicine, the Department of Biosystems and Agricultural Engineering, (Bellmer), College of Agricultural Sciences and Natural Resources, and the Department of Statistics (Payton), College of Arts and Sciences, Oklahoma State University, Stillwater, OK 74078. Dr. Greenberg's present address is Department of Veterinary Clinical Sciences, School of Veterinary Medicine, Purdue University, West Lafayette, IN 47907.

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Address correspondence to Dr. Davidson.

Surgical procedures involving the urinary tract such as cystotomy and urethrotomy are common in veterinary practice. A strong, watertight closure is desirable after cystotomy to prevent leakage of urine into the abdomen.<sup>1</sup> Sutures are the most effective means of bringing urinary tract tissue into apposition for healing after cystotomy.<sup>2</sup> The urinary bladder regains about 100% of normal tissue strength at the incision site within 14 to 21 days.<sup>3,5</sup> The ideal suture material for use in the urinary tract should maintain tissue apposition and conserve its tensile strength until tissue healing is well underway; it should also become absorbed at a dependable rate after healing is complete. The material should not be associated with increased risk of infection or numerous postoperative complications. Ideal suture material for use in the urinary bladder also must incite minimal inflammation, decrease potential for calculus formation, and withstand contact with urine.<sup>2</sup> Suture materials that are inappropriate for use in the urinary tract include nonabsorbable and braided multifilament absorbable suture. Nonabsorbable suture materials provide a nidus for calculus formation and have long deterioration times<sup>6</sup>; braided multifilament suture materials may harbor bacteria in crevices and undergo excessively rapid degradation in urine.<sup>7,8</sup>

Because of these potential problems, synthetic monofilament absorbable suture materials are recommended for tissue repair of the urinary bladder.<sup>2,9</sup> Advantages of monofilament absorbable suture material include reduced tissue drag and greater strength per size, compared with their braided counterparts.<sup>10</sup> Tensile strengths of polydioxanone<sup>a</sup> and polyglyconate<sup>b</sup> have been studied.<sup>11</sup> Two other monofilament absorbable suture materials, poliglecaprone 25<sup>c</sup> and glycomer 631,<sup>d</sup> are available, but studies to compare tensile strengths in urine have not yet been completed. Both materials are reported to have excellent tensile strength and pliability and minimal tissue reactivity.<sup>12e</sup> These handling characteristics make them potentially good choices for use in surgical procedures involving viscera. The purpose of this study was to evaluate the tensile strength, elongation, and degradation of 4 monofilament absorbable suture materials in specimens of canine urine with various characteristics.

## Materials and Methods

**Bacterial strains**—In these experiments, isolates of *Escherichia coli* and *Proteus mirabilis* strains obtained from dogs with cystitis (provided by the Oklahoma Animal Disease Diagnostic Laboratory, Stillwater, Okla) were used.

**Urine preparation**—Samples of voided urine were collected from 6 healthy male and female dogs, pooled, and sterilized by passage through 0.2- $\mu$ m membrane filters.<sup>1</sup> To confirm sterility of the samples, filtered urine was cultured by incubation in blood agar and brain heart infusion agar at 37°C for 5 days.

The pH of aliquots of the sterile urine was adjusted by the addition of appropriate amounts of hydrochloric acid or sodium hydroxide to achieve a pH of 7.0 (neutral), 6.2 (acidic), or 8.4 (basic). To provide specimens of infected urine, *E coli* or *P mirabilis* organisms were added to other aliquots of urine 24 hours before the start of the experiments. The amount of inoculum was previously determined to provide > 10<sup>5</sup> CFUs of bacteria/mL after 18 to 24 hours of incubation at 37°C; throughout the experiment, the concentration of bacteria was monitored to maintain > 10<sup>5</sup> bacteria/mL. The inoculated aliquots were incubated in culture bottles so that on the day of the experiments (day 0), the urine contained > 10<sup>5</sup> CFUs of bacteria/mL. All quantitative assessments of the bacterial population in the urine were determined via bacteriologic culture (by use of the Miles-Misra technique<sup>13</sup>) throughout the study period; 10-fold dilutions of urine were prepared from which six 10- $\mu$ L aliquots of each dilution were plated on MacConkey agar. Colony counts were determined after incubation for 18 to 24 hours at 37°C; suture was placed into the urine after colony counts were confirmed. Throughout the experiment, an aliquot of urine was removed from each bottle daily to determine pH, monitor sample purity, and quantify the bacterial population. When the bacterial concentration was  $\leq$  10<sup>5</sup> CFUs/mL, the urine in the bottle was replaced to maintain adequate bacterial numbers.

**Suture material**—For all of the experiments, a standard suture size of 3-0 (0.2 mm) was used, and suture materials were immersed in urine for 1 to 28 days; however, materials

tested on day 0 were not immersed in urine and simply washed in sterile physiologic saline (0.9% NaCl) solution prior to testing. Four absorbable monofilament sutures (polydioxanone, poliglecaprone 25, polyglyconate, and glycomer 631) were used in 5 test groups. Suture material was placed in 1 of 5 pooled, filter-sterilized urine environments: neutral (pH, 7.0) sterile urine, acidic (pH, 6.2) sterile urine, basic (pH, 8.4) sterile urine, urine inoculated with *E coli*, or urine inoculated with *P mirabilis*. To prepare the sutures for immersion, the individual suture packages were opened aseptically in a biological safety cabinet. For each of the urine media, 10 strands of the suture material for each testing day were placed into sterilized 250-mL glass bottles; for testing days 1, 3, and 7, the suture strands were placed into 1 sterile bottle with 1 of the 5 media; for days 10, 14, 21, and 28, the suture strands were placed in another bottle with that medium. All bottles in all groups were incubated at 37°C throughout the study period.

**Biomechanical testing**—All suture samples were collected and tested within 24 hours after removal from the urine sample. Biomechanical testing for tensile strength and elongation was performed concurrently by use of a texture analyzer<sup>8</sup> in a controlled environment (20°C and 65% humidity). Biomechanical testing of the suture materials in 4 of the 5 groups was performed on day 0 (after the saline solution wash) and days 1, 3, 7, 10, 14, 21, and 28 after immersion in urine. For suture materials immersed in *Proteus*-inoculated urine, the schedule of the testing after day 1 was adjusted by 24 to 48 hours because of the limited availability of the tensiometer on particular days (ie, data were scheduled to be on day 3 or 4 and on day 5 or 7). On each testing day, suture strands were removed from their packets (day 0) or incubation bottles (days 1 to 28), rinsed in physiologic saline solution, and lightly patted dry with towels before testing. A single throw was placed in the middle of each suture strand to provide a uniform break-

Table 1—Mean tensile strengths (g) of 10 strands each of glycomer 631, polyglyconate, poliglecaprone 25, and polydioxanone at days 0 and 1, 3 and 7, 10 and 14, and 21 and 28 after immersion in specimens of canine urine of various compositions

Days of immersion	Suture material	Variable				
		Immersion medium				
		Sterile neutral urine	Sterile acidic urine	Sterile basic inoculated urine	<i>Escherichia coli</i> -inoculated urine	<i>Proteus mirabilis</i> -urine
Days 0 and 1	Glycomer 631	2,839 <sup>aA</sup>	2,726 <sup>aA</sup>	2,579 <sup>aA</sup>	2,748 <sup>aA</sup>	2,672 <sup>aA</sup>
	Polyglyconate	2,799 <sup>aA</sup>	2,928 <sup>aA</sup>	2,731 <sup>aA</sup>	2,779 <sup>aA</sup>	2,817 <sup>aA</sup>
	Poliglecaprone	2,763 <sup>aA</sup>	2,792 <sup>aA</sup>	2,643 <sup>aA</sup>	2,818 <sup>aA</sup>	2,674 <sup>aA</sup>
	Polydioxanone	2,466 <sup>aA</sup>	2,328 <sup>aA</sup>	2,437 <sup>aA</sup>	2,507 <sup>aA</sup>	2,400 <sup>aA</sup>
Days 3 and 7	Glycomer 631	2,154 <sup>aA</sup>	2,652 <sup>aA</sup>	1,032 <sup>bB</sup>	2,037 <sup>aA</sup>	517 <sup>aB</sup>
	Polyglyconate	2,761 <sup>aA</sup>	3,160 <sup>aA</sup>	1,710 <sup>a,bB</sup>	2,651 <sup>aA</sup>	137 <sup>aC</sup>
	Poliglecaprone	1,605 <sup>aA,B</sup>	2,456 <sup>aA</sup>	873 <sup>b,B,C</sup>	1,478 <sup>aB</sup>	238 <sup>aC</sup>
	Polydioxanone	2,039 <sup>aA</sup>	2,317 <sup>aA</sup>	2,045 <sup>aA</sup>	2,175 <sup>aA</sup>	1,241 <sup>aA</sup>
Days 10 and 14	Glycomer 631	1,714 <sup>aA</sup>	1,035 <sup>bA,B</sup>	469 <sup>a,B,C</sup>	1,183 <sup>a,bA,B</sup>	0 <sup>aC</sup>
	Polyglyconate	2,264 <sup>aA</sup>	2,481 <sup>aA</sup>	697 <sup>aB</sup>	1,679 <sup>aA</sup>	0 <sup>aB</sup>
	Poliglecaprone	311 <sup>bA</sup>	914 <sup>bA</sup>	187 <sup>aA</sup>	415 <sup>bA</sup>	0 <sup>aA</sup>
	Polydioxanone	2,022 <sup>aA</sup>	1,987 <sup>aA</sup>	1,215 <sup>aA</sup>	1,950 <sup>aA</sup>	0 <sup>aB</sup>
Days 21 and 28	Glycomer 631	458 <sup>bA</sup>	1,45 <sup>bA</sup>	0 <sup>aA</sup>	259 <sup>aA</sup>	0 <sup>aA</sup>
	Polyglyconate	407 <sup>bB</sup>	1,282 <sup>aA</sup>	227 <sup>aB</sup>	333 <sup>bB</sup>	0 <sup>aB</sup>
	Poliglecaprone	340 <sup>bA</sup>	0 <sup>bA</sup>	0 <sup>aA</sup>	0 <sup>aA</sup>	0 <sup>aA</sup>
	Polydioxanone	2,016 <sup>aA</sup>	2,020 <sup>aA</sup>	0 <sup>aB</sup>	1,897 <sup>aA</sup>	0 <sup>aB</sup>

<sup>a,b</sup>For given variable (immersion medium), tensile strength values within each of the 4 testing periods (days 0 and 1, 3 and 7, 10 and 14, and 21 and 28) with different superscript lower case letters are significantly ( $P < 0.05$ ) different.

<sup>A,B,C</sup>For given variable (suture material), tensile strength values within each row of the table with different superscript upper case letters are significantly ( $P < 0.05$ ) different.

age site and avoid breakage at the tensile bars. The strands of suture were positioned in the texture analyzer so that the single throw was midway between the 2 tensile bars. The suture strands were wrapped around the tensile bars several times and tightly secured with a lock nut. Peak tensile strength and elongation values were determined from the force-versus-distance curve generated by the texture analyzer. At a testing speed of 1 mm/s, the 6-cm suture lengths were stretched until breakage occurred and peak force was recorded; reported values represent the mean of 10 tests/suture-media combination. The relative and absolute stiffness of each suture was determined from elongation values.

**Statistical analyses**—All data were analyzed by use of computer software.<sup>11</sup> For statistical analyses, data from testing days were assessed as 4 groups: days 0 and 1, 3 and 7, 10 and 14, and 21 and 28. The effect of time on the different suture types and media was analyzed with the use of indicator variable regression included in the software. For

each medium and suture type, a simple linear regression of response was calculated. The value of the slope indicated the rate of deterioration for that suture-medium combination. Slopes associated with suture type for a given medium and those associated with medium for a given suture type were compared by use of a simple linear regression model with an indicator variable; the difference in the 2 slopes was tested with a *t* test. Analysis for elongation was performed with an ANOVA. Because ANOVA demonstrated no interaction among time, suture, and medium, means of the main effects of all factors were used during elongation analysis.

## Results

In neutral sterile urine (pH, 7.0), polydioxanone retained 81% of its original tensile strength during the 28-day immersion period (Table 1). In comparison, glycomer 631, polyglyconate, and poliglecaprone 25 retained significantly less tensile strength after 28 days of immersion (16%, 14%, and 12%, respectively; Fig 1).

In acidic urine, there were no differences in tensile strengths among suture materials at days 0, 3, and 7; at day 10 and thereafter, polydioxanone and polyglyconate had significantly greater tensile strengths than glycomer 631 and poliglecaprone 25 (Fig 2). At days 21 and 28, polydioxanone, polyglyconate, and glycomer 631 retained 86%, 43%, and 5% of their original strength, respectively, but poliglecaprone 25 had completely dissolved (Table 1). In basic urine, differences in suture performance were only evident on days 3 and 7; polyglyconate and polydioxanone had greater tensile strength on these days, compared with values for the other suture materials, but no differences in suture performance were evident after day 10 (Fig 3). There were no significant differences in tensile strengths on days 21 and 28 because essentially no suture types remained; polydioxanone, poliglecaprone 25, and glycomer 631 were completely dissolved, and polyglyconate retained only 8% of its original strength (Table 1).

Similar to the findings in acidic urine, there was no difference in tensile strengths among sutures in *E coli*-inoculated urine until days 10 and 14; at these time points, polydioxanone and polyglyconate had greater tensile strengths than poliglecaprone 25 and glycomer 631 (Table 1). At day 28, polydioxanone retained significantly more of its original strength (75%) than did glycomer 631, polyglyconate, and poliglecaprone 25 (9%, 12%, and 0%, respectively; Fig 4). The pH of the *E coli*-inoculated urine was approximately 7.18 for all suture groups.

In *P mirabilis*-inoculated urine, tensile strength of all sutures was similar throughout the testing period (Fig 5). Because of the tensiometer and the rapid degradation of suture materials, testing days varied in

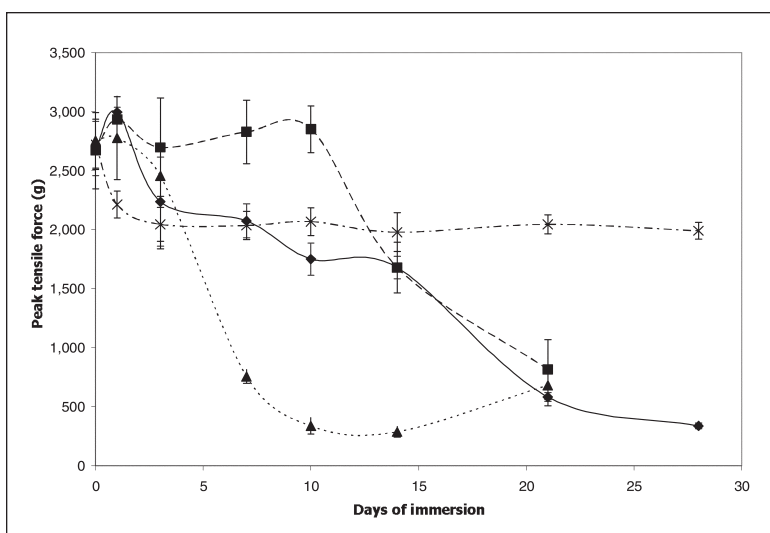


Figure 1—Mean  $\pm$  SD tensile strength (peak tensile force) of 10 strands each of glycomer 631 (diamonds), polyglyconate (squares), poliglecaprone 25 (triangles), and polydioxanone (cross) at 0, 1, 3, 7, 10, 14, 21, and 28 days after immersion in sterile neutral (pH, 7.0) canine urine.

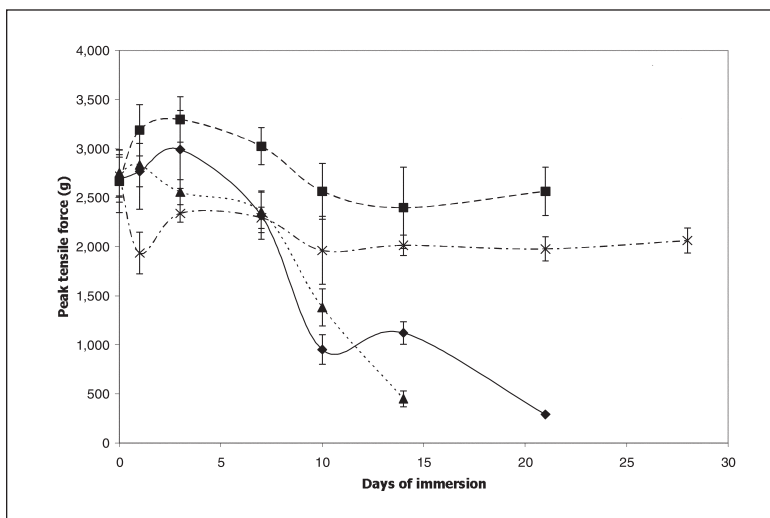


Figure 2—Mean  $\pm$  SD tensile strength (peak tensile force) of 10 strands each of glycomer 631 (diamonds), polyglyconate (squares), poliglecaprone 25 (triangles), and polydioxanone (cross) at 0, 1, 3, 7, 10, 14, 21, and 28 days after immersion in sterile acidic (pH, 6.2) canine urine.

this experiment. On days 3 and 4, polydioxanone retained 51% of its original strength, but glycomer 631, polyglyconate, and poliglecaprone 25 retained only 19%, 5%, and 9% of their original strengths, respectively. On day 6, all sutures had degraded completely, making further testing impossible (Table 1). The pH for the *P mirabilis*-inoculated urine was approximately 8.83 for all suture groups.

On days 0 and 1, there were no significant differences in suture tensile strengths or in individual suture strengths among media. The greatest effect of urine media on all suture performances was associated with the period including days 3 and 7. In this period, the tensile strengths of glycomer 631, poliglecaprone 25, and polyglyconate were reduced in basic and *P mirabilis*-inoculated urine; furthermore, the tensile strength of poliglecaprone 25 was also reduced

in *E coli*-inoculated urine. However, polydioxanone was unaffected by urine media on days 3 and 7. On days 10 and 14, the tensile strengths of glycomer 631 and poliglecaprone 25 were much less than those of polydioxanone or polyglyconate, especially in acidic and *E coli*-inoculated urine. Only poliglecaprone 25 tensile strength was unaffected by media on days 10 and 14; however, it had significantly less tensile strength in sterile neutral, sterile acidic, and *E coli*-inoculated urine specimens than polyglyconate and polydioxanone and had the lowest tensile strength overall (Table 1). The tensile strength of polydioxanone also was unaffected by all media except *P mirabilis*-inoculated urine on days 10 and 14. On days 21 and 28, suture degradation had progressed for all suture materials. However, media did not affect tensile strength of polyglyconate (except in sterile acidic urine), glycomer 631, or poliglecaprone 25 on days 21 and 28. Conversely, glycomer 631 only retained 16% of its original tensile strength in sterile neutral urine and < 10% in all other media on days 21 and 28. At this time, polyglyconate retained only 43% of its original tensile strength in sterile acidic urine and < 14% in all other media. Poliglecaprone 25 retained only 12% of its original tensile strength in sterile neutral urine and had completely degraded in all other media. Polydioxanone retained greater tensile strength, compared with other types of suture in all media; however, greater tensile strength was significant only for sterile neutral urine and *E coli*-inoculated urine, in which it retained 81% and 75% of its original tensile strength, respectively.

**Elongation**—Assessment of elongation and tensile strength testing were performed concurrently on all

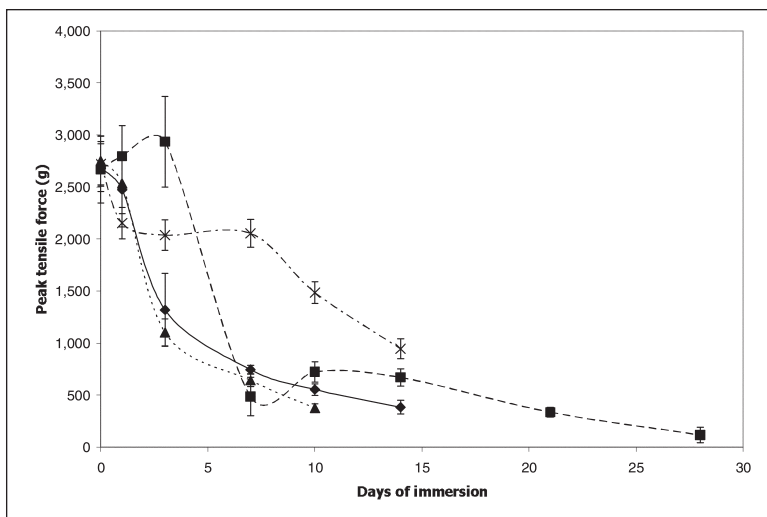


Figure 3—Mean  $\pm$  SD tensile strength (peak tensile force) of 10 strands each of glycomer 631 (diamonds), polyglyconate (squares), poliglecaprone 25 (triangles), and polydioxanone (cross) at 0, 1, 3, 7, 10, 14, 21, and 28 days after immersion in sterile basic (pH, 8.4) canine urine.

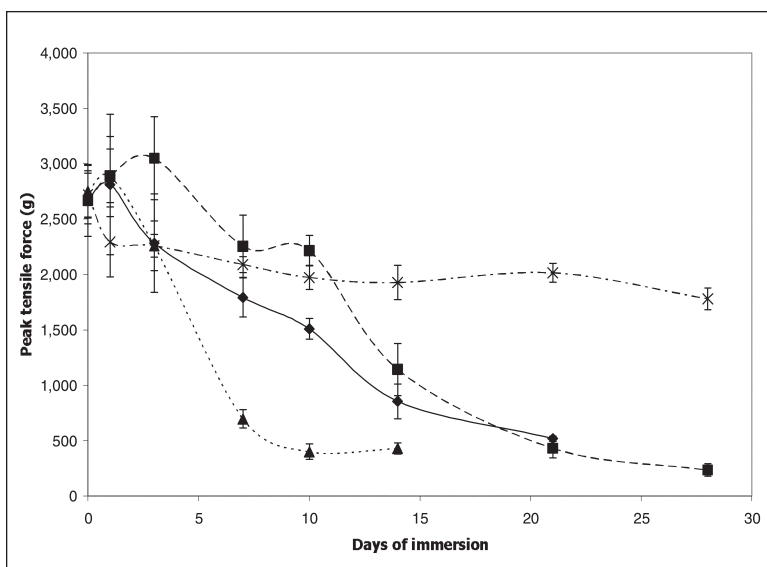


Figure 4—Mean  $\pm$  SD tensile strength (peak tensile force) of 10 strands each of glycomer 631 (diamonds), polyglyconate (squares), poliglecaprone 25 (triangles), and polydioxanone (cross) at 0, 1, 3, 7, 10, 14, 21, and 28 days after immersion in canine urine inoculated with *Escherichia coli*.

suture strands. All evaluations were completed within 24 hours of removal from urine. Because statistical analysis of elongation revealed no interaction between time, suture, and media, mean elongation was reported for each suture type, medium, and time point group. Mean elongation for suture materials was 17.94 mm (glycomer 631), 19.47 mm (polyglyconate), 13.90 mm (poliglecaprone 25), and 23.69 mm (polydioxanone). Poliglecaprone 25 and glycomer 631 were significantly stiffer than polyglyconate and polydioxanone. Mean elongation for each medium was 20.20 mm (sterile neutral urine), 25.00 mm (sterile acidic urine), 16.32 mm (sterile basic urine), 20.45 mm (*E coli*-inoculated urine), and 11.78 mm (*P mirabilis*-inoculated urine). Sutures were significantly stiffer in basic and *P mirabilis*-inoculated urine specimens. As suture break-

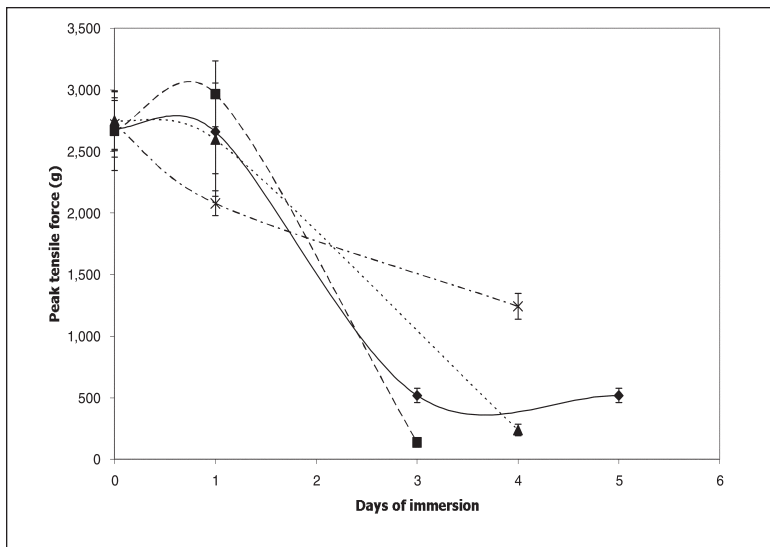


Figure 5—Mean  $\pm$  SD tensile strength (peak tensile force) of 10 strands each of glycomer 631 (diamonds), polyglyconate (squares), poliglecaprone 25 (triangles), and polydioxanone (cross) at 0 to 5 days after immersion in canine urine inoculated with *Proteus mirabilis*.

down progressed, suture stiffness increased. Mean elongation for all sutures was 38.47 mm on days 0 and 1, 19.90 mm on days 3 and 7, 10.68 mm on days 10 and 14, and 5.93 mm on days 21 and 28. Stiffness was significantly greater for each subsequent time period.

## Discussion

In the study of this report, the tensile force and elongation of strands of suture that had been immersed in urine under different conditions were measured; measurement of force indicates the suture material's tensile strength, and measurement of elongation indicates the stiffness of the material. In clinical practice, suture material must be strong enough to withstand disruptive forces across a surgical wound until the tissue regains adequate tensile strength through healing. Assessment of the breaking point of a particular suture material is an indication of the material's tensile strength, from which the structural strength of the material can be inferred. The tensile strength of suture material may be evaluated with a tensiometer.

It is known that stiff suture material is less pliable and more difficult to handle than material with minimal stiffness. In general, monofilament suture material is stiffer than multifilament suture material of the same composition. In our study, we did not include any multifilament absorbable suture material because tissue drag and tissue reaction may be excessive with these sutures and such material is not recommended for use in urinary tract surgery because bacteria may be harbored within the suture fibers.<sup>5</sup> In addition, polyglycolic acid<sup>1</sup> (a multifilament absorbable suture material) is not recommended for surgical use in the urinary bladder because it may be absorbed prematurely in an environment in which it is exposed to urine.<sup>2,9</sup>

Absorbable suture material degrades with time and, by definition, undergoes rapid loss of tensile strength within 60 days as it is absorbed.<sup>14</sup> Glycomer 631 and poliglecaprone 25 are suture materials that

have become available quite recently, and there is little information published regarding assessment of their use in tissues, especially those of the urinary tract.<sup>5,12</sup> Data indicate that poliglecaprone 25 has highest initial tensile strength per suture size of all commercially available absorbable sutures (that have been tested), excellent pliability, and relatively rapid loss of tensile strength; it loses approximately 75% of its tissue strength after 14 days and essentially 100% after 21 days.<sup>5,12</sup> It is completely absorbed by 4 months after implantation.<sup>12,15</sup> Findings of our study regarding characteristics of poliglecaprone 25 after immersion in urine were similar; at days 10 and 14, the tensile strength of this material was reduced significantly more than that of polydioxanone and polyglyconate in sterile neutral, sterile acidic, and *E coli*-inoculated urine (retaining only 11%, 32%, and 14%, respectively, of its original strength).

Overall, the tensile strength of poliglecaprone 25 decreased more than that of any of the other suture materials during immersion in urine; it retained less than 32% of its original tensile strength in any of the urine specimens at days 10 and 14 and was completely degraded in all media except sterile neutral urine by days 21 and 28. Therefore, poliglecaprone 25 should be reserved for use in tissues that regain tensile strength quickly or do not require critical holding power.<sup>5</sup>

Glycomer 631 elicits minimal inflammatory reaction in tissues and undergoes progressive loss of tensile strength without relative loss of mass. After implantation, data<sup>c</sup> indicate that the mean tensile strength of glycomer 631 is 75% of its original value at 2 weeks and 40% at 3 weeks. On days 10 and 14 in our study, glycomer 631 retained 60%, 38%, 18%, 43%, and 0% of its original tensile strength in sterile neutral, sterile acidic, sterile basic, *E coli*-inoculated, and *P mirabilis*-inoculated urine specimens, respectively. On days 21 and 28, this material retained 16%, 5%, 0%, 9%, and 0% of its original tensile strength in sterile neutral, sterile acidic, sterile basic, *E coli*-inoculated, and *P mirabilis*-inoculated urine, respectively. These data suggest that glycomer 631 degrades in urine more rapidly than previously reported.

Polydioxanone is degraded by hydrolysis at a slow rate; on implantation, it has been reported<sup>16</sup> to lose 26% of its original tensile strength after 14 days, 42% after 28 days, and 86% after 56 days. Results of our study were similar. At days 10 and 14, polydioxanone retained 82%, 85%, 58%, and 77% of its original tensile strength in sterile neutral, sterile acidic, sterile basic, and *E coli*-inoculated urine, respectively; at days 21 and 28, it retained 81%, 86%, and 75% of its original tensile strength in sterile neutral, sterile acidic, and *E coli*-inoculated urine, respectively. Only immersion in sterile basic and *P mirabilis*-inoculated urine adversely affected its tensile strength.

Polyglyconate has tensile strength similar to that

of polydioxanone; overall, its characteristics during use are similar to those of polydioxanone.<sup>17</sup> Polyglyconate maintains its strength in tissue with minimal or no absorption during the critical healing period. The tensile strength half-life for polyglyconate is 3 weeks, compared with 6 weeks for polydioxanone.<sup>18</sup> Polyglyconate is absorbed between 6 and 7 months after implantation. Our data confirmed the overall similarity in characteristics between polydioxanone and polyglyconate; on days 10 and 14, there was no difference in tensile strengths between polydioxanone and polyglyconate in any of the urine specimens, although (unlike polydioxanone) polyglyconate was affected by immersion in sterile basic urine. On days 21 and 24, polydioxanone had significantly greater tensile strength than polyglyconate only in sterile neutral urine (81% vs 14%, respectively) and *E coli*-inoculated urine (75% vs 10%, respectively). Interestingly, polyglyconate was the only suture material that did not completely degrade in sterile basic urine by the end of the study period.

Characteristics of the urine in which the suture strands were immersed played an important role in the reduction in tensile strengths of the suture materials. As expected, for all suture materials, the least reduction in tensile strength was associated with immersion in sterile urine (with the exception of polyglyconate at days 21 and 28). Urinary tract infection and changes in pH can delay the rate of re-epithelialization of urinary bladder mucosa and can later reduce fibroblast and collagenase activity.<sup>8,19</sup> In the urinary tract, infection may prolong the need for suture material to retain sufficient tensile strength to allow sufficient tissue healing. Infection with various microbial organisms can increase the rate of suture degradations and alter the pH and chemical composition of the urine.<sup>11,20</sup>

Results of the study reported here confirmed that *P mirabilis* has a pronounced effect on suture material. *Proteus* spp produce urease that acts on urea to produce ammonia, which accelerates the destruction of absorbable suture materials that undergo hydrolysis. Such accelerated destruction may result in complete loss of suture strength in < 7 days.<sup>20</sup> In our study, all suture types were degraded by day 10 after immersion in *P mirabilis*-inoculated urine. Therefore, suture materials that undergo degradation by means other than hydrolysis are recommended for use in urologic surgical procedures performed in the presence of urinary tract infection with *Proteus* spp.

*Escherichia coli* also may cause rapid degradation of suture materials. The mechanism of the accelerated breakdown by this bacterium is unknown, but results of another study<sup>11</sup> indicate that the original breaking strength of polydioxanone was reduced by < 13% after immersion in *E coli*-inoculated urine for 28 days, compared with a reduction of < 10% after immersion in sterile urine for 28 days. Similarly, the original breaking strength of polyglyconate was reduced by 59% after immersion in *E coli*-inoculated urine for 21 days, compared with a reduction of 54% after immersion in sterile urine for 21 days.<sup>11</sup>

In our study, differences in elongation were detected in association with type of suture material, medium, and time. Glycomer 631 and poliglecaprone 25 were

significantly stiffer than polyglyconate and polydioxanone throughout the study. Glycomer 631 and poliglecaprone 25 also had consistently poor tensile strength throughout the study period. Increased stiffness of a suture material may be associated with its tendency to break. Mean elongation detected with strands of glycomer 631 and poliglecaprone 25 was significantly less in sterile basic and *P mirabilis*-inoculated urine, compared with all other media. This corresponded to the decreased tensile strengths and early degradation of glycomer 631 and poliglecaprone 25 in those urine specimens. As expected, elongation decreased for all suture materials from days 0 through 28, as the materials degraded.

Normal wound healing in tissues of the urinary bladder consists of a lag phase (3 to 4 days' duration), a proliferative stage (occurring from day 3 through day 14 of healing), and a maturation phase (occurring from day 14 to day 70 of healing).<sup>4</sup> During the lag phase after closure of an incision in the urinary bladder, the epithelium provides minimal biomechanical support for adjacent tissue and sutures and a fibrin seal provide protection against dehiscence and leakage at the incision site.<sup>21</sup> During the proliferative phase, fibroblast proliferation occurs and wound strength subsequently develops rapidly.<sup>3,21</sup> Through the healing process, the bladder regains 100% of normal tissue strength at the wound site at 14 to 21 days.<sup>3</sup> The maturation phase is unimportant clinically in visceral wound healing because satisfactory tissue strengths are established at the wound sites by that time.<sup>22</sup>

For effective repair of bladder tissue wounds or incisions, a suture material that maintains acceptable tensile strength through 21 days should be used. In the presence of a urinary tract infection or in a basic urine environment, incision sites in the bladder should be closed with a slowly absorbable suture material such as polydioxanone or polyglyconate; a 2-layered closure should be performed that minimizes exposure of the suture material to urine within the bladder lumen. Our data indicated that polydioxanone and polyglyconate satisfy this requirement and consistently maintain adequate tensile strength while in contact with urine of various compositions.

<sup>a</sup>PDS-II, Ethicon Inc, Somerville, NJ.

<sup>b</sup>Maxon, Kendall-Tyco International Ltd, Mansfield, Mass.

<sup>c</sup>Monocryl, Ethicon Inc, Somerville, NJ.

<sup>d</sup>Biosyn, US Surgical-Tyco International Ltd, Norwalk, Conn.

<sup>e</sup>Product insert information, Biosyn, United States Surgical Division of Tyco Healthcare Group, Norwalk, Conn.

<sup>f</sup>Millipore Corp, Bedford, Mass.

<sup>g</sup>TA-XT2i, Stable Micro Systems Ltd, Surrey, UK.

<sup>h</sup>SAS, version 8.2, SAS Institute Inc, Cary, NC.

<sup>i</sup>Dexon, Kendall-Tyco International Ltd, Mansfield, Mass.

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