Assessment of time to completion, number of errors, and knot-holding capacity of square knots and Aberdeen knots tied by veterinary students and student perceptions of knot security and knot-tying difficulty

OBJECTIVE
To assess the time to completion, number of errors, and knot-holding capacity (KHC) for starting and ending square knots (SSKs and ESKs) of a continuous pattern and Aberdeen knots tied by veterinary students and to investigate student perceptions of knot security and knot-tying difficulty for the 3 knot types.

SAMPLE
16 second-year veterinary students.

PROCEDURES
Students created 3 (4-throw) SSKs, 3 (5-throw) ESKs, and 3 (3 + 1 configuration) Aberdeen knots with 2-0 polydioxanone on a custom test apparatus. Time to complete each knot, the number of errors in each knot, and student ratings of knot-tying difficulty and confidence in knot security were recorded. Each knot was tested to failure on a uniaxial tensiometer to determine KHC and mode of failure. Variables of interest were compared by repeated-measures ANOVA or the Friedman test with post hoc pairwise comparisons.

RESULTS
Mean knot completion time for Aberdeen knots was significantly less than mean completion time for SSKs or ESKs. Mean KHC was significantly lower for ESKs than for SSKs; KHC for Aberdeen knots was not compared with these values because of methodological differences. Median error rate was higher for ESKs than for other knot types. Mean difficulty rating for Aberdeen knots was lower than that for ESKs. Most tested knots failed by breakage at the knot.

CONCLUSIONS AND CLINICAL RELEVANCE
Aberdeen knots appeared to be easy for veterinary students to learn and were completed more rapidly and with fewer errors than ESKs. Including this type of knot in surgical skills curriculum for novices may be beneficial.

Since the late 1980s and early 1990s, surgical training for veterinary medical students has been skills-oriented, focusing on the acquisition of fundamental surgical skills that are applicable to a wide variety of surgical procedures, including an emphasis on basic surgical knot tying.1-8 Most veterinary students in the United States learn these skills through a combination of mandatory and optional training in their first through third years of veterinary school, culminating in supervised live-animal survival surgeries during the third or fourth year of the curriculum.3,9,10

During fundamental skills training, it has been the authors' experience that most veterinary students are taught the square knot as an exclusive means of beginning or ending a continuous suture pattern. The basic square knot is formed by 2 alternating half-hitch throws, and this type of knot is frequently used in an interrupted pattern or at the beginning and end of a continuous suture line. When created with small gauge monofilament suture, the SSK of a continuous suture line is generally formed with 4 to 5 throws, and the ESK is formed with 5 to 7 throws.11-13 Knots used to end a continuous pattern are believed to require additional throws owing to the incorporation of 3 suture strands in the knot instead of 2.13,14 However, a variety of technical errors can lead to decreased knot security of square knots, including the creation of slip knots or granny knots or formation of an incompletely tightened knot.15,16 These technical errors can lead to decreased tensile strength or increase slippage of the knot,17,18 which can result in dehiscence of the surgically apposed surfaces and potentially costly or life-threatening complications.19

An alternative to the square knot is the Aberdeen knot, which can be used to begin or end continuous patterns or be used in the middle of a continuous pattern.20-24 This knot is composed of a number of...
identically performed throws that are locked with \( \geq 1 \) turn. A knot with 3 throws plus 1 turn (termed 3 + 1 configuration) has been shown to be secure if coated in plasma or fat.\(^{21}\) The biomechanical properties of the Aberdeen knot have been evaluated in human and veterinary medicine.\(^{21,25-29}\) The results of in vitro studies indicate that the Aberdeen knot typically has greater tensile strength, \(^{21,25}\) KHC, \(^{26}\) and relative knot security\(^{26}\) and has lower knot volume.\(^ {21,29}\) compared with square knots made from the same type and size of suture. Investigations involving the use of canine cadaveric tissue\(^ {23,26}\) or porcine skin\(^ {27}\) revealed that Aberdeen knots have less slippage than square knots\(^ {27}\) and comparable maximum load at failure.\(^ {23,26}\) When instructing veterinary surgical skills laboratories, the authors have observed that veterinary students typically find creating square knots difficult and that it is common for students to inadvertently create slip knots instead of appropriate ESKs. It has also been our observation that students find the Aberdeen knot easy to learn and perform; because of the technique used to create this knot, it is not possible to inadvertently create slip knots.

The purpose of the study reported here was to compare the time to completion, number of errors, and KHC of 4-throw SSKs, 5-throw ESKs, and Aberdeen knots of 3 + 1 configuration tied by veterinary students during fundamental skills training. Student confidence that each knot they tied was secure and perceived difficulty of each knot type was also assessed. The authors hypothesized that Aberdeen knots would be completed more rapidly and would be perceived to be easier to perform than SSKs or ESKs and that the KHC of the 3 knot types would not differ significantly.

**Materials and Methods**

The prospective, cross-sectional study was granted an informed consent form prior to enrollment. Participants were recruited from the second year of the 4-year veterinary curriculum at Michigan State University College of Veterinary Medicine. All participants were recruited during the last of 6 mandatory laboratory classes during which basic surgical principles, including knot tying, were taught. During these laboratory classes, groups of 30 students were instructed by 3 to 5 faculty members. Creation of SSKs and ESKs, but not Aberdeen knots, was included in the mandatory skills learned during the laboratory classes. Students repeated these skills each class period, with a focus on refining their technique and increasing efficiency. Prior to enrollment in the study, participants were asked whether they had additional experience tying any of the 3 knot types, and if so, what the nature of that experience was.

At the start of the study, students were given instructions by 1 board-certified veterinary surgeon (DAU) on how to tie SSKs, ESKs, and Aberdeen knots on the test apparatus. Each student was given 1 opportunity to practice each knot on the test apparatus prior to data collection.

The test apparatus consisted of a 3.175-cm-diameter, 30-cm-long PVC pipe\(^ {a}\) with each end embedded into the center of a block of floral craft foam\(^ {b}\) so that the pipe was elevated above the surface of the testing station (Figure 1). During testing, the apparatus was manually secured to the underlying table to prevent motion during knot tying. Each test was performed in the same location and evaluated by the same board-certified surgeon (DAU), and all participants used the same equipment. Participants were not allowed to watch each other during the study.

Each participant was asked to tie 3 of each type of knot around the test apparatus with 70-cm-long strands of 2-0 polydioxanone.\(^ {c}\) All suture used was from the same lot. For SSKs and ESKs, participants were asked to perform instrument ties, whereas for the Aberdeen knot, hand ties were performed. Participants started by tying a 4-throw SSK. After completion of this knot, it was left on the apparatus and the remaining suture was looped around the testing apparatus twice. Participants tied a 5-throw ESK at this time by tying the free suture end to the second loop of the suture. Completed knots were removed from the test apparatus by sliding over the end of the PVC pipe. Participants repeated this procedure twice, using a new strand of suture for each pair of knots, to create a total of 3 SSK and 3 ESK/participant. After all square knots were complete, participants were asked to tie 3 Aberdeen knots in 3 + 1 configuration (Figure 2). A new strand of suture was used for each knot. Once completed, each knot was removed from the test apparatus as

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\(^{a}\) PVC pipe:

Diameter: 3.175 cm
Length: 30 cm
Ends embedded into floral craft foam block

\(^{b}\) Floral craft foam:

Used to elevate test apparatus above table surface

\(^{c}\) Polydioxanone:

Suture material for knot tying

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**Figure 1**—Photograph of a test apparatus on which surgical knots were tied in a study to assess the time to completion, number of errors, and KHC of 4-throw SSKs, 5-throw ESKs, and 3 + 1 configuration Aberdeen knots tied with 2-0 polydioxanone by second-year veterinary students during fundamental skills training and investigate student perceptions of knot security and knot-tying difficulty. A 3.175-cm-diameter, 30-cm-long PVC pipe had both ends embedded in floral craft foam. The apparatus provided stability during knot tying and facilitated removal of completed knots.
was stored in an airtight plastic bag for 7 months until mechanical testing could be performed. The load end (the portion of suture usually apposed to the wound edges) of the Aberdeen knot was left full-length to allow it to be loaded into the tensiometer. All of the knots were photographed with a 30X optical zoom camera. Photographs were examined on a computer screen at this magnification by 1 evaluator (DAU), and the number and type of errors (granny knots, slip knots, or loosely tied knots) detected photographically was quantified for each knot. Each knot was recorded with a stopwatch. The timer was paused when the knots were grossly assessed to determine the mode of failure (knot breakage, knot unraveling, breakage of suture not adjacent to the knot, or suture slippage from the tensile mount).

Figure 2—Photograph depicting an Aberdeen knot with a 3 + 1 configuration. The knot is tied with braided rope, without appropriate tightening of the knots, to aid visibility.

Described for square knots. The time to complete each knot was recorded with a stopwatch. The timer was started once a participant began constructing the first throw and was stopped once the final throw or turn was fully tightened as judged by the evaluator (DAU).

After completion of each knot, the participants were asked to rate their confidence in the security of the knot on a 4-point Likert-type scale (1 = low, 2 = moderate, 3 = high, and 4 = very high). The number and type of errors (granny knots, slip knots, or loosely tied knots) believed to be present in each knot was recorded independently by the participant and the evaluator (DAU). After completing all knots, participants were asked to rate the difficulty of each of the 3 knot types by use of the same Likert-type scale.

Magnified visual examination and mechanical testing of knots

After each knot was removed from the test apparatus, suture connecting the SSK and ESK was cut to 3 mm as previously described.31 Sutures were looped 4 times around the cross bar of the second tensile mount and secured prior to extension, as previously described.27 The difference in methods for placement of these knots for testing was deemed necessary as the Aberdeen knot is a sliding knot and relies on tension along the load end of the suture for knot security.27 The Aberdeen knots were preloaded to 2.74 N prior to testing. During each test, a computer software program was used to capture and analyze the KHC of each suture strand, defined as the maximum tensile strength of the suture prior to breakage or slippage. After testing, the constructs were grossly assessed to determine the mode of failure (knot breakage, knot unraveling, breakage of suture not adjacent to the knot, or suture slippage from the tensile mount).

Statistical analysis

All statistical analyses were performed with a commercially available software package.8 Distribution of continuous data was assessed by the Kolmogorov-Smirnov test. Normally and nonnormally distributed data were reported as mean ± SD and median and range, respectively. Repeated-measures ANOVA with Newman-Keuls multiple comparisons post hoc testing was used to compare parametric data among the 3 knot types and among the first, second, and third knot of each type tied by each student. The total numbers of errors identified by the participant, by the evaluator during knot-tying, and by the evaluator through examination of the magnified photographs were compared by this method as well. The errors observed on the magnified photographs were used for statistical comparisons among knot types and among repetitions within a given knot type. Nonparametric data were compared by means of the Friedman test with Tukey multiple comparison post hoc testing. Median number of photographically detected errors for each knot type and mean KHC was determined across all participants and all repetitions. These values were compared between knot types by calculation of the Pearson correlation coefficient. The relationship between participants’ confidence score for security of each knot and the number of photographically detected errors was...
assessed by the same method. Effect size was calculated as the Cohen $d$. For all comparisons, values of $P < 0.05$ were considered significant.

Results

Sixteen second-year veterinary students participated in the study. All participants had practiced tying SSKs and ESKs over the previous 3 months in their surgical skills laboratory classes. Ten participants did not have any experience with square knots outside of the laboratory classes. Five participants had practiced tying square knots outside of the laboratory classes during the same 3-month period. One participant had 3 years of clinical experience and had occasionally tied square knots during that time; this individual did not have results that varied from the mean ± SD of the other participants for any variable assessed. None of the participants had any experience tying Aberdeen knots prior to enrollment in the study.

All participants completed 3 SSKs (4-throw), 3 ESKs (5-throw), and 3 Aberdeen knots (3 + 1 configuration), resulting in 144 total knots (48 of each type). Data for knot completion time were missing for 1 ESK and 1 Aberdeen knot, resulting in 142 knot completion times analyzed. Owing to technical difficulties, KHC data were not obtained for 1 of 48 SSKs and 3 of 48 ESKs, and mode-of-failure data were not obtained for the same 3 ESKs. Twenty-four of 48 Aberdeen knots did not have a long enough strand of suture at the load end for tensiometer mounting, resulting in absence of KHC and mode-of-failure data. These knots were not censored for analysis regarding other variables.

Figure 3—Photograph of the loading apparatus of a custom-built tensiometer used to assess KHC and mode of failure in SSKs, ESKs, and Aberdeen knots tied by study participants. The load cell is attached to the metal bar at the top of the figure. A—An SSK is loaded onto the apparatus prior to testing. The suture loop is secured around the shaft parts of both the upper and lower tensile mounts. B—An Aberdeen knot is loaded onto the materials testing device. The suture is placed around the lower tensile mount and the load end of the suture is looped 4 times around the crossbar of the upper tensile mount and secured prior to extension.
Participant ratings for confidence in the security of knots as well as the perceived difficulty level of each knot type were summarized (Table 1). Analysis revealed a significant (P = 0.023) difference among median difficulty ratings; post hoc analysis revealed the ratings for tying Aberdeen knots were significantly lower than the ratings for tying ESKs (Table 2); these ratings did not differ between Aberdeen knots and SSKs or between SSKs and ESKs. Median ratings for participant confidence in knot security did not differ among the 3 knot types. Analysis revealed a significant (P < 0.001) difference among mean completion times; post hoc analysis revealed the completion time for Aberdeen knots was significantly less than that for other knot types (effect size for comparison with the ESKs and SSKs, 1.686 and 1.325, respectively), and mean completion time for ESKs was significantly less than that for SSKs (effect size, 0.384).

Twelve of 48 (25%) SSKs were observed to have errors on photographic evaluation; 2 were deemed to be loose, 1 contained 1 granny knot, and 9 contained ≥1 slip knot (7 with 1 slip knot, 1 with 2 slip knots, and 1 with 3 slip knots). Forty of 48 (83%) ESKs were observed to have errors by this method (all slip knots; 10 included 1 slip knot, 14 had 2 slip knots, and 16 had 3 slip knots). Ten of 48 (21%) Aberdeen knots were noted to be loose on photographic evaluation; no other errors were noted for this knot type.

Analysis revealed a significant (P < 0.001) difference in the median number of errors per knot among knot types as assessed by photographic evaluation; post hoc analysis revealed the number of errors was significantly higher for ESKs, compared with results for the other 2 knot types (Table 2). These error rates did not differ significantly between SSKs and Aberdeen knots. Because of differences in the setup for mechanical testing of Aberdeen knots versus that used for SSKs and ESKs, KHCs were only compared between the 2 square knot types. Mean KHC was significantly (P < 0.001) lower for ESKs than for SSKs (effect size, 1.157).

Comparison of mean completion times among the first, second, and third repetitions of each knot type tied by each participant revealed that there was a significant (P = 0.001) difference among repetitions for Aberdeen knots; post hoc analysis revealed that the second and third Aberdeen knots were completed significantly faster than the first knot of this type (Table 3). There was no significant difference in mean KHC among repetitions for any knot type. The median participant rating for confidence in knot security was significantly (P < 0.001) higher for the third Aberdeen knot than for the first knot of this type. There was no significant difference in these ratings among repetitions for other knots, and there was no significant difference in the median number of errors between repetitions for any knots.

The number of photographically detected errors had a significant negative correlation with KHC for SSKs and ESKs (Table 4). Correlation between the median number of errors and KHC for the Aberdeen knots could not be calculated because of lack of varia-

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**Table 1**—Comparison of veterinary student confidence in knot security for surgical knots of 3 types (4-throw SSKs, 5-throw ESKs, and Aberdeen knots of 3 + 1 configuration) and perceived difficulty of tying each knot type for each participant.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Low (N)</th>
<th>Moderate (N)</th>
<th>High (N)</th>
<th>Very high (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Security (No. of knots)</td>
<td>SSK</td>
<td>ESK</td>
<td>Aberdeen knot</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>16</td>
<td>23</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>18</td>
<td>20</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>16</td>
<td>16</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Difficulty (No. of participants)</td>
<td>SSK</td>
<td>ESK</td>
<td>Aberdeen knot</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>7</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

All participants (n = 16) completed 3 knots of each type resulting in 144 total knots (48/type). Confidence in knot security was rated on a Likert-type scale from 1 (low) to 4 (very high) after tying each knot. Perceived difficulty of tying the knot was rated after completion of all knots of the same type.

**Table 2**—Comparison of completion time, KHC, number of photographically evaluated errors, and participants’ ratings for perceived difficulty and confidence in knot security for the surgical knots in Table 1.

<table>
<thead>
<tr>
<th>Variable</th>
<th>SSK</th>
<th>ESK</th>
<th>Aberdeen knot</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completion time (s)</td>
<td>38.9 ± 12.0*a</td>
<td>28.0 ± 6.3*b</td>
<td>20.3 ± 7.6*c</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>KHC (N)</td>
<td>57.06 ± 9.89*b</td>
<td>25.64 ± 21.05*b</td>
<td>46.46 ± 2.09*a</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>No. of errors</td>
<td>2 (0–3)</td>
<td>2 (0–3)</td>
<td>0 (0–1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>1.5 (1–4)</td>
<td>2 (1–3)</td>
<td>1 (1–3)</td>
<td>0.023</td>
</tr>
<tr>
<td>Confidence in knot security</td>
<td>3 (1–4)</td>
<td>2.5 (1–4)</td>
<td>2 (1–4)</td>
<td>0.206</td>
</tr>
</tbody>
</table>

Data are reported as mean ± SD or median (range). The number of errors represents the median number of errors detected per knot for all students. Data were analyzed by means of repeated-measures ANOVA with Newman-Keuls multiple comparisons post hoc testing (knot completion time, KHC) or the Friedman test with Tukey multiple comparisons post hoc testing (number of errors, student ratings). Knot completion times were not obtained for 1 ESK and 1 Aberdeen knot, and KHC was not determined for 1 SSK and 3 ESKs.

*a–cWithin a row, values with different superscript letters are significantly (P < 0.05) different on post hoc analysis.

See Table 1 for remainder of key.
The mode of failure for all 48 SSKs was breakage at the knot. Of the 45 ESKs, 42 (93%) failed by breakage at the knot, 2 (4%) failed by knot slippage, and 1 (2%) failed by breakage of suture at a site other than the knot. Of the 24 Aberdeen knots, 14 (58%) failed by breakage at the knot, 7 (29%) failed by knot slippage, and 3 (13%) failed by breakage at a site other than the knot. No knots failed by slipping out of the tensile mounts. No significant (P = 0.175) difference in the rate of failure by mode was found among knot types.

Discussion

In the present study, Aberdeen knots of 3 + 1 configuration were completed more rapidly than 4-throw SSKs and 5-throw ESKs by participating veterinary students. In addition, Aberdeen knots had significantly fewer errors and a lower perceived difficulty level than ESKs.

Knot-holding capacity is defined as the maximum force that can be applied to a knot before it breaks or slips.21 To the authors’ knowledge, the KHC necessary to withstand normal physiologic forces placed on typical surgical closures for abdominal incisions in dogs or cats is unknown. However, it is pertinent to note that, among our study sample of 16 second-year veterinary students, the mean KHC for ESKs was less than half that of SSKs, and the SD for ESKs was much greater (indicating a greater degree of variability among participants) than that for SSKs.

The KHCs of SSKs and ESKs were negatively correlated with the number of photographically detected errors per knot, and the median number of errors detected in ESKs was significantly higher than in Aberdeen knots or SSKs. It is likely that the lower KHC of ESKs, compared with SSKs, was attributable to multiple factors; however, it is the authors’ contention that the greater error rate was one of these factors, as previous reports13,17,18 have shown that slip knots, granny knots, and loosely tied square knots have less knot security than appropriately tied square knots. Because ESKs are typically used at the end of a con-
tinuous suture line, it is particularly important that they be tied securely because failure of the knot can lead to dehiscence of the entire suture line. A previous retrospective study performed to evaluate complications during ovariohysterectomies performed by veterinary students found that although there was a low rate of body wall dehiscence (15/513 [2.9%]), all cases in which the cause of dehiscence could be determined were attributable to failure of an ESK.

Participants could have been expected to have greater proficiency in tying surgical knots that they had some previous experience with (SSKs and ESKs), compared to one they had not performed prior to the study (the Aberdeen knot). However, the participants’ mean knot security confidence ratings did not differ significantly among the 3 knot types in the present study, and the mean difficulty level participants assigned to Aberdeen knots was similar to that for SSKs and significantly lower than that for ESKs. This likely reflected the simplicity of teaching and learning Aberdeen knots as well as the difficulty for novices learning to tie ESKs. All knots were completed in the same order; however, as no participants had performed Aberdeen knots before the study, we considered it unlikely that the order in which the various knots were tied affected the study results.

Despite the results indicating that confidence in knot security was similar for all knot types, the median number of photographically detected errors in ESKs was significantly higher than that in other knots. In fact, there was no correlation between participants’ knot security confidence ratings and the number of errors for any knot type. There were, however, significant differences in the number of errors detected photographically versus those detected by participants or the evaluator for ESKs and Aberdeen knots. Veterinary students and supervising faculty members may not always be able to recognize when a knot-tying error is occurring; in 1 study, 21 of 25 participants created slip knots when they were asked to perform square knots, and only 3 of 12 participants who were confident that they correctly tied 6 of 6 square knots had done so.

The apparatus used for knot tying in our study was not an accurate representation of in vivo suturing, and it was not similar to models that the study participants had previously used. There may have been a learning curve that affected the participants’ ability to use this device. However, when each of the participants’ 3 repetitions of each knot type were compared, we found no difference in mean KHC for any of the knot types and no difference in mean completion times for SSKs or ESKs. These comparisons revealed that the first Aberdeen knot completed by participants took significantly more time to tie than the second or third Aberdeen knots. Considering that the time difference was only observed for Aberdeen knots, it was most likely reflective of a learning curve for this knot. The participants’ previous experience with square knots may have allowed them to reach a steady level of proficiency that they had not had time to develop for Aberdeen knots. It was not the purpose of the present study to determine the learning curve for proficiency for tying these knot types, but the fact that there was no significant difference in mean time to complete the second and third Aberdeen knots and the increase in participants’ knot security confidence ratings between the first and third repetitions, may have suggested a relatively short learning curve. It was possible that participants’ perceived difficulty and knot security confidence ratings were influenced by the test apparatus and that these values could have been different if the knots were performed in vivo.

Our study had several other limitations. First, the knots were tied on the testing device and then removed from this device to be measured and mechanically tested, and this can result in knots that are more prone to slippage. In fact, 7 of 24 (29%) Aberdeen knots that could be mechanically tested had failure by knot slippage, and this rate was much higher than previously reported. This may have been attributable to the method of our testing (ie, removing the suture from the testing device) or to the lack of experience of our study participants in tying this knot. However, despite this finding, the mean value for KHC of Aberdeen knots in the present study (46.46 N) was comparable to findings in a prior study that involved use of the same suture and testing methods (40.82 N).

Results of previous studies also indicate that fat and other biological fluids may cause an increase or decrease in relative knot security. The present study was conducted with dry suture, and further testing will be needed to determine in vivo knot security of square knots and Aberdeen knots tied by veterinary students. We chose 2-0 polydioxanone as a test suture because it is a commonly used material for closure of the body wall during laparotomy procedures. Other suture materials have different handling characteristics that may result in different outcomes, and the results of the present study should not be extrapolated to other suture materials.

The largest limitation of the study reported here was the difference in the method used to mechanically test Aberdeen knots, compared with that used for the 2 square knot types. The testing methods used in the study were selected to better reflect in vivo conditions, in which the square knots would experience tension along the 2 strands apposing the tissue (ie, the strands distracted in our materials testing device) and the Aberdeen knot would only experience tension along the load strand. A previous study compared the loop method of mechanical testing used for ESKs and SSKs to the linear testing method used for Aberdeen knots. The investigators in that study found that the loop testing method identified KHCs that were 2.2 and 4.4 times that measured with the linear testing method, with lower values more common for monofilament sutures and securely tied knots. As a result, the KHC results for Aberdeen knots in the
present study could not be directly compared to the KHC results for the other 2 knots. However, on the basis of information in the aforementioned study,\textsuperscript{40} it would be expected that, if all 3 knots had equivalent KHCs, the different testing methods would have resulted in KHC measurements for the SSKs and ESKs that were twice that of Aberdeen knots, and subjective assessment indicated this was not the case.

Finally, data were lost for 24 Aberdeen knots performed by the first 8 participants because the loading strands of the suture were not long enough to be secured on the test apparatus. This led to only 24 Aberdeen knots being tested instead of the anticipated 48. Whereas this loss of data increased the likelihood of a type I or type II statistical error, the only data lost were related to KHC and mode of failure, and KHC was not statistically compared between Aberdeen and other knot types.

Our results indicated that after being given instructions and an opportunity to practice tying an SSK, an ESK, and an Aberdeen knot once on the test apparatus, second-year veterinary students were able to tie an Aberdeen knot more quickly than an SSK or ESK with 2-0 polydioxanone, and fewer errors were created in Aberdeen knots, even though they had previous training in the other 2 knot types. The ability to perform square knots is valuable to veterinary education; however, the authors suggest teaching the Aberdeen knot as well, owing to its relative ease and apparent security when performed by novices.

Acknowledgments

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Footnotes

a. Charlotte Pipe, Charlotte, NC.


c. PDs, Ethicon Inc., Somerville, NJ.

d. Canon PowerShot SX400, Canon Inc., Tokyo, Japan.

e. Ziploc, SC Johnson & Son Inc., Racine, Wis.

f. LabVIEW 2014 SP1, National Instruments, Austin, Tex.

g. WINK5, version 7.0.9, Texsoft, Cedar Hill, Tex.

References


From this month’s AJVR

Sedative and cardiorespiratory effects of intramuscular administration of alfaxalone and butorphanol combined with acepromazine, midazolam, or dexmedetomidine in dogs
Melissa A. Murdock et al

OBJECTIVE
To evaluate the sedative and cardiorespiratory effects of IM administration of alfaxalone and butorphanol combined with acepromazine, midazolam, or dexmedetomidine in dogs.

ANIMALS
6 young healthy mixed-breed hounds.

PROCEDURES
Dogs received each of 3 treatments (alfaxalone [2 mg/kg] and butorphanol [0.4 mg/kg] combined with acepromazine [0.02 mg/kg; AB-ace], midazolam [0.2 mg/kg; AB-mid], or dexmedetomidine [0.005 mg/kg; AB-dex], IM) in a blinded, randomized crossover-design study with a 1-week washout period between treatments. Sedation scores and cardiorespiratory variables were recorded at predetermined time points. Data were analyzed by use of mixed-model ANOVA and linear generalized estimating equations with post hoc adjustments.

RESULTS
All treatments resulted in moderate to deep sedation (median score, ≥15/21) ≤5 minutes after injection. Sedation scores did not differ among treatments until the 40-minute time point, when the score was higher for AB-dex than for other treatments. Administration of AB-dex resulted in median scores reflecting deep sedation until 130 minutes, versus 80 and 60 minutes for AB-ace and AB-mid, respectively, after injection. Heart rate, cardiac output, and oxygen delivery decreased significantly after AB-dex, but not AB-ace or AB-mid administration. Respiratory variables remained within clinically acceptable ranges after all treatments. Undesirable recovery characteristics were observed in 4 dogs after AB-mid treatment. Four dogs required atipamezole administration 180 minutes after AB-dex injection.

CONCLUSIONS AND CLINICAL RELEVANCE
All protocols produced reliable sedation. The results indicated that in young, healthy dogs, AB-mid may produce undesirable recovery characteristics; AB-dex treatment caused cardiovascular depression and should be used with caution. (Am J Vet Res 2020;81:65–76)