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The mechanical properties of six finger trap suture techniques

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1 Mechanical properties of finger trap sutures

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3 The mechanical properties of six finger trap suture techniques

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24 **The mechanical properties of six finger trap suture techniques**

26 **Abstract**

28 Objective:

29 To identify the most commonly tied finger trap sutures (FTS), determine whether these
30 patterns behave differently using mechanical testing, and ascertain which were most
31 secure. Secondly, to establish whether the number of repeats performed affected the
32 FTS behavior.

34 Study Design:

35 Questionnaire and experimental study.

37 Methods:

38 Six commonly used FTS methods (A-F) were identified from literature review and
39 questionnaire. Mechanical testing of patterns using 3 metric nylon suture and 18 French
40 polyurethane esophagostomy tubing was performed. The effect of altering the number of
41 repeats (2, 4 and 8 repeats) along the tube was investigated using 2 patterns (B and D).
42 Samples were loaded to failure under continuous distraction. Displacement and force data
43 were measured and failure mode was video recorded.

45 Results:

Patterns E and F were susceptible to slipping ($p<0.001$). Patterns A and D were stiffer than pattern E, and patterns A-D were stiffer than pattern F ($p=0.012$). Patterns A and B had less extension than pattern E and F, and patterns A-D had less extension than pattern F ($p=0.002$). 87.5% of FTS failed by breaking at the first suture knot. The number of repeats had no effect on FTS performance.

Conclusions:

The mechanical behavior of suture-tube constructs and failure mode is affected by the FTS pattern. Patterns E and F are not advocated due to suture slippage. The number of repeats may not affect the FTS performance. Overall, patterns B, C and D performed the best using this methodology. Further study using different tube and suture constructs is warranted.

Introduction

Finger trap sutures (FTS) are constructs that are commonly used to secure temporary tubes and catheters to the skin and prevent dislodgement.¹ They are designed to tighten as tension is applied, ideally providing security without constricting the tube lumen.² The FTS has also been referred to as the Chinese FTS,^{1, 2, 3, 4, 5, 6} Roman sandal suture^{7, 8, 9} or Roman garter suture.¹⁰ Alternative methods to secure tubes such as adhesive tape and circumferential sutures are less effective.¹

Multiple different techniques for tying FTS have been reported^{1, 2, 4, 6, 7} but these descriptions have been unclear and it is not known which is the most effective technique. It is self evident that secure tube placement is fundamentally important. Complications resulting from failure of tube fastening include premature displacement, tube kinking, obstruction and tube migration.^{2, 8, 11, 12, 13, 14} Gastrostomy, enterostomy or thoracostomy tube disruption can result in peritonitis¹² or pneumothorax respectively.¹³ One study reported thoracostomy tube complications in 22% of cases, including a dog with fatal pneumothorax.¹³ Replacing dislodged catheters and tubes increases patient morbidity, treatment cost, is time consuming¹ and often requires a general anaesthetic.¹⁴

FTS have been compared with other suture types, for example Song et al.² compared the failure mode of the Chinese FTS and 4 simple interrupted friction sutures. The FTS was quicker to place and had a longer mean displacement to failure compared to the friction suture when undergoing axial loading.² Ricker et al.¹⁵ reported no significant difference

92 between 3 patterns of FTS, using 2 different types of catheter material and 2 different
93 suture materials.¹⁵ The study suggested that the surface characteristics of a tube alters the
94 coefficient of friction between tube and suture, and the ability of the arms of the FTS to
95 slide over each other at suture intersections affected the ability of the suture to grip the
96 tube. However, there were no clear reasons to select the FTS patterns investigated and
97 multiple variables were altered making it challenging to draw firm conclusions. Finally
98 the materials used in the study were not materials commonly used in current clinical
99 practice (e.g. braided nylon and narrow 5 French diameter tubing).

100
101 The aims of this study were to determine which patterns are most frequently tied by
102 surgeons using a questionnaire, and then to determine whether a particular pattern
103 outperformed the others using distraction to failure mechanical testing to mimic the tube
104 being accidentally pulled or intentionally disrupted by the patient. We wished to design a
105 study comparing relevant materials commonly used in veterinary patients for the most
106 frequent indications to secure a tube. We hypothesised that some FTS patterns would
107 perform better than others (e.g. resist greater loads and resist slipping) and aimed to
108 publish clear guidelines for tying the best performing patterns.

Materials and methods

A questionnaire was circulated by the Association of Veterinary Soft Tissue Surgeons and the Veterinary Society of Surgical Oncology to member veterinary surgeons, including ECVS and ACVS diploma holders, asking them to describe their preferred method, uses of, and complications they have experienced with FTS (Appendix 1). The term ‘square knot’ was defined as a single throw, followed by a second throw in the opposite direction. ⁴ A ‘surgeons’ throw’ was defined as a double throw. The term ‘surgeons’ knot’ was defined as a double throw (or surgeons’ throw), followed by a single throw in the opposite direction. ⁴

Part 1: Comparison of suture patterns

The 6 most common FTS patterns were identified by literature review (Patterns A ¹, D ² and E ⁶) and questionnaire (Patterns B, C and F) (Appendix 2). Twelve sutures were tied for each of the 6 patterns using 3 metric nylon suture (Ethilon™; Ethicon, Johnson & Johnson Medical Limited, Wokingham, UK). All sutures were tied using a two-handed technique by the same investigator (KP). A suture loop was created around a 5mm diameter steel cylinder (representing the skin attachment of the FTS) and a square knot created leaving suture ends of equal length. The suture ends were then tied around a 20cm length, 18 French diameter dedicated esophagostomy polyurethane tubing (Esophagostomy tube E1380, MILA International, Inc., Erlanger, Kentucky). Each throw or knot was tightened to slightly indent the tube but not occlude the lumen. For all suture

patterns, there were a total of 6 repeats (number of throws or knots along the top surface of the tube).

Part 2: Comparison of number of repeats

Testing of patterns B and D using 2, 4 and 8 repeats was also performed (n=8 for 2, 4 and 8 repeats for each pattern; total = 48 constructs).

Samples were held between 2 mounted grips in a materials testing machine (Instron 3367; Instron, High Wycombe, UK). A 6cm section of the tubing was fixed in the clamp at the top of the machine and the suture loop beginning the FTS was secured to a grip at the bottom of the machine. A ruler was positioned adjacent to the suture construct. The distance between the 2 grips was adjusted to hold the suture construct taut with minimal force (Fig 1). The samples were loaded to failure through axial loading, with a continuous distraction force at a rate of 6mm/min. Experiments were video recorded for analysis. Displacement and force data was measured using computer and data acquisition software (Bluehill 3; Instron, High Wycombe, UK). Variables recorded were maximum load to failure (N), energy at failure (J) and extension at maximum load (mm). Suture slippage of the first knot of the FTS and failure mode was measured by analyzing the video recordings. Load extension graphs were plotted and stiffness was calculated using the gradient of the linear aspect of the graphs. Failure mode was recorded as suture slippage if the suture slid over the tube more than 40mm. The location of suture breakage was recorded.

Statistical analysis

Data was recorded as mean $\pm$ the standard error of the mean. Statistical analysis was performed using SPSS for Windows (version 21; IBM SPSS Statistics, Chicago). A one-way ANOVA was used to compare values of load at failure, energy at failure and extension at maximum load between the six methods with post-hoc least significance difference (LSD) analysis performed where $p < 0.05$. A two-way repeated measures ANOVA was used for part 2 (comparison of the number of repeats).

Results

Twenty-seven questionnaires were returned. The most common uses of FTS described were to secure feeding tubes (n=25), chest drains (n=22), abdominal drains (n=21) and wound drains (n=9). Other uses mentioned were to secure cystostomy tubes (n=2), nasal oxygen tubes (n=2) and urinary catheters (n=2). The most frequent complications reported are shown in Table 1, with the majority of surgeons being concerned about tube displacement or removal, suture breaking or loosening and infection at the tube entry site.

Nine methods of tying FTS were described (Table 2). One was discounted since it was not a self-constricting dynamic suture. Two methods were excluded because they were only described once. Six methods were investigated (Fig 2). The most popular methods were Pattern A (n=8/27) and Pattern D (n=7/27).

Part 1: Comparison of suture patterns

There was no difference between suture patterns for maximum load to failure (p=0.51) or energy at failure (p=0.052). Patterns A, B, C and D had less suture slippage than E and F (p<0.001, Fig 3). Patterns A and D were stiffer than pattern E. Patterns A, B, C and D were stiffer than F (p=0.012, Fig 4). Less extension was recorded for patterns A and B compared with pattern E and F. Pattern F had more extension than patterns A, B, C and D (p=0.002, Fig 5). The majority (87.5%) of FTS failed by breaking at the suture knot representing the skin attachment (n=63/72). The FTS slipped over the tube with patterns E (n=4/72) and F (n=5/72) (p=0.03).

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207 Part 2: Comparison of number of repeats

208 There was no significant effect of repeat number on the maximum load to failure (Fig 6),
209 energy at failure, suture slippage (Fig 7), extension or stiffness. Almost all (99%) of the
210 FTS failed by breaking of the suture at the first knot representing the skin suture,
211 (n=45/46); only Pattern B had one example where the suture slipped over the tube.

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Discussion

We were able to determine the FTS methods currently used by surgeons responding to our questionnaire and mechanically compare the most commonly used methods. Patterns A, B, C and D had similar experimental mechanical performance. Patterns E and F did not perform as well as the other patterns due to suture slippage and therefore increased extension. In the second experiment the number of repeats had no effect on the mechanical behavior of the 2 suture patterns tested. The majority of constructs failed by the suture breaking at the first knot rather than by slipping of the tube through the FTS. This implies that the chosen suture pattern may be less important than the material properties of the suture, except where the pattern is more susceptible to slipping (patterns E and F).

The optimal stiffness of a FTS construct is unknown and may be of limited clinical relevance. Ideally, suture materials should be flexible enough to facilitate placement and knot tying,¹⁶ but have a suitable stiffness to avoid stretching under physiological load.¹⁷

In a previous report,² the authors speculated that tube securing techniques with a high peak axial force or larger displacement to failure were more secure. Failure was defined as the first sign of suture slippage, suture breakage or tube breakage. Another study set a failure limit of 100mm distraction.¹⁵ The term displacement, distraction and/or extension refer to the amount a material is stretched when a load is applied during mechanical testing experiments. For a FTS pattern, this variable is quite complex as it is altered by a

combination of the suture material and tube material properties. There is no defined acceptable extension of a FTS construct and as such we felt that suture slippage would be a more appropriate variable to assess because slipping of a tube through an anchoring construct is undesirable. However, it is unclear how much tube displacement or slippage through a FTS might be considered practically relevant. We set a maximum suture slippage of 40mm before defining failure by suture slippage which is more stringent than previous reports since we felt it was more clinically applicable. Also, observation of the video footage showed that sutures failing to grip for 40mm all continued to slip until the entire length of the tube pulled through the FTS.

We found that as a consequence of the suture having throws on opposite sides of the tubes in patterns E and F, the suture did not lie adjacent to the tube wall and we suspect could not create adequate friction and grip the tube as it was pulled. We also found that when tying patterns E and F it was difficult to maintain tension along the entire pattern, and we speculate that this contributed to the inferior performance of patterns E and F. Whilst surgeon experience tying these constructs over several years could mitigate this problem, we should not dismiss these findings based on conjecture and instead rely on the objective mechanical performance results of this study. As such, we recommend that patterns E and F should not be used for securing indwelling tubes.

Patterns B and D were selected when comparing the effect of different numbers of repeats along the tubes on the mechanical behavior of the constructs because they had performed consistently well in the first part of the study. We found there was no

275 difference in the mean slippage of the patterns as a result of altering the number of
276 repeats. However, two of the constructs with 2 repeats failed by massive slippage and we
277 suggest that patterns with a minimum number of 4 repeats should be used for greater
278 reliability.

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280 We chose monofilament nylon as it is commonly used to suture skin incisions and secure
281 tubes. Investigation of absorbable multifilament materials to create FTS has been
282 performed¹⁵ but we did not feel that this would be useful. Multifilament materials
283 degrade, can wick fluid and bacteria, and monofilament non-absorbable suture is the
284 material of choice when placing extracorporeal anchoring constructs for tubes.^{1,2} Three
285 metric material was chosen as a commonly used clinical diameter.^{1,2,15} We used 18
286 French diameter custom manufactured polyurethane esophagostomy feeding tubes.
287 Polyurethane tubing is a commonly used material for indwelling tubes and the group of
288 surgeons that responded to our questionnaire frequently used FTS to secure feeding tubes.
289 In a previous investigation of suture anchoring techniques² tube diameters of 8 French
290 (jejunostomy), 20 French (gastrostomy) and 24 French (thoracostomy) tubing were used.
291 That study found that the smaller 8 French diameter tubing was more prone to tube
292 breakage than tube slippage or suture breakage. Ricker et al.¹⁵ tested infrequently used 5
293 French diameter tubing and found that all the polypropylene tubes failed by deformation
294 because the tube was too small.

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296 Most of our suture constructs failed by breaking at the first knot, which is similar to other
297 studies where sutures were anchored in the skin of cadavers² or leather pieces¹⁵ rather

than a direct attachment to the base of the materials testing machine. In those reports, none of the sutures pulled out of the skin or leather. Therefore we removed this additional variable to allow a more robust comparison between different suture patterns. When a suture material is knotted, it can be weakened by 10-40%¹⁸ due to shear stresses that exist at the point between the loop and the first throw of the knot.^{19,20} Logically, any pattern capable of resisting significant slipping of the tube through the FTS may therefore be an acceptable choice in a clinical environment if the first knot is the weak point. However, if no negative factors result from selecting the pattern that resists the greatest load to failure in mechanical tests, nothing is lost by choosing the strongest construct to maximize resistance to tube pullout. On analysis of the video recordings, the esophagostomy tubing occasionally kinked just prior to suture failure, but this did not lead to plastic deformation and luminal occlusion.

Forces other than axial distraction may be exerted on FTS in the clinical setting, but these have not been investigated. Axial loading represents a situation where a sudden force is applied to the tube. For example, the patient pulling on the tube or the tube getting caught on something. Cyclical loading, cadaveric or live animal studies may provide further information on the mechanism of suture failure.

There is no literature defining the optimal force when tightening a FTS to achieve slight indentation of the tube. One would expect this to vary depending on tube material and diameter. We did not use a uniform force when tightening the FTS throws and knots, which may have ensured greater consistency between our constructs. However, the same

board certified surgeon with several years of experience tying FTS was used to minimize variability between constructs. Further investigation would be necessary to determine differences between surgeons.

Our data cannot be extrapolated to consider different tube and sutures materials, diameters or clinical performance in vivo. Measures should always be taken to monitor indwelling tubes secured by FTS, and avoid patients from interfering with the system, such as Elizabethan collars, bandaging and tube care.

This study provides clear descriptions of how to tie several FTS patterns currently used by veterinary surgeons using clinically relevant suture and tubing materials. We are the first study to find that different FTS patterns affect the mechanical characteristics and failure mode of the constructs. We do not advocate using patterns E and F due to the risk of suture slipping. The number of repeats may not affect performance of a FTS. Overall, patterns B, C and D performed the best using this methodology. Further study using different tube and suture constructs is warranted. Surgeons should be aware that the method of tying FTS affects the mechanical behavior of the constructs and failure mode.

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Disclosure Statement

The authors declare no conflict of interest related to this report.

390 References

- 391
- 392 1. Smeak DD. The Chinese finger trap suture technique for fastening tubes and
393 catheters. *J Am Anim Hosp Assoc.* 1990;26:215-218.
- 394 2. Song EK, Mann FA and Wagner-Mann CC. Comparison of different tube
395 materials and use of Chinese finger trap or four friction suture technique for
396 securing gastrostomy, jejunostomy and thoracostomy tubes in dogs. *Vet Surg.*
397 2008;37:212-221.
- 398 3. Fossum TW. Surgery of the Lower Respiratory System: Pleural Cavity and
399 Diaphragm, in Fossum TW (ed): *Small Animal Surgery*. 3rd Edition. St. Louis,
400 MO, Mosby Inc., USA. 2007, pp 896-929.
- 401 4. Sissener T. Suture Patterns and Surgical Knots, in Baines S, Lipscomb V,
402 Hutchinson T (ed): *BSAVA Manual of Canine and Feline Surgical Principles, A*
403 *Foundation Manual*. 1st Edition. BSAVA, Gloucester, UK. 2012 p 277-292.
- 404 5. Krackow KA and Cohn BT. A new technique for passing tendon through bone. *J*
405 *Bone Joint Surg Am.* 1987;69(6):922-924.
- 406 6. Aspinall V. Suturing techniques and common surgical procedures, in Aspinall V
407 (ed): *Clinical Procedures in Small Animal Veterinary Practice*. 1st Edition. W.B.
408 Saunders Co, London, UK. 2013, pp 254-310.
- 409 7. Yool DA. Part 1 Basic Surgical Principles: Suture Patterns and Knots, in Yool DA
410 (ed): *Small Animal Soft Tissue Surgery*. 1st Edition. CABI Publishing,
411 Wallingford, UK. 2012, pp 39-53.

8. Marques AIDC, Tattersall J, Shaw DJ, et al. Retrospective analysis of the relationship between time of thoracostomy drain removal and discharge time. *J Small Anim Pract.* 2009;50:162-166.
9. Abbasi CO, Khraishi TA, Maestas A, et al. Modified Roman Sandal: a more effective and reliable surgical drain anchoring technique. *Int J Exp Comput Biochem.* 2015;3(2):102-120.
10. O'Flynn P, Akhtar S. Effective securing of a drain. *Ann R Coll Surg Engl.* 1999;81:418-419.
11. Cavanaugh RP, Kovak JR, Fischetti AJ et al. Evaluation of surgically placed gastrojejunostomy feeding tubes in critically ill dogs. *J Am Vet Med Assoc.* 2008;232(3):380-388.
12. Elliott DA, Riel DL, Rogers QR. Complications and outcomes associated with use of gastrostomy tubes for nutritional management of dogs with renal failure: 56 cases (1994-1999). *J Am Vet Med Assoc.* 2000;217(9):1337-1342.
13. Tattersall JA, Welsh E. Factors influencing the short-term outcome following thoracic surgery in 98 dogs. *J Small Anim Pract.* 2006;47:715-720.
14. Fossum TW. Postoperative Care of the Surgical Patient, in Fossum TW (ed): *Small Animal Surgery.* 3rd Edition. St. Louis, MO, Mosby Inc., USA. 2007, pp 90-110.
15. Ricker ZH, Rochat MC, Payton ME. Biomechanical evaluation of finger trap suture variants for securing catheters. *J Am Vet Med Assoc.* 2015;246(5):515-521.
16. Bezwada RS, Jamiolkowski DD, Lee IY et al. Monocryl suture, a new ultra-pliable absorbable monofilament suture. *Biomaterials.* 1995;16:1141-1148.

17. De La Puerta B, Parsons KJ, Draper ERC et al. In Vitro Comparison of Mechanical and Degradation Properties of Equivalent Absorbable Suture Materials from Two Different Manufacturers. *Vet Surg.* 2011;40:223-227.
18. Capperault I, Bucknall TE. Suture and dressings, in Bucknall TE, Ellis H (ed): *Wound healing for surgeons*. Bailliere Tindall, London, UK. 1984, pp 73-93.
19. Muffy TM, Boyce J, Kieweg SL, et al. Tensile strength of a surgeon's knot or square knot. *J Surg Educ.* 2010;67:222-226.
20. Campbell EJ, Bailey VJ. Mechanical properties of suture materials in vitro and after in vivo implantation in horses. *Vet Surg.* 1992;21:355-361.

Figure 1: Experimental apparatus. The sample is held in mounted grips on the Instron machine with a ruler adjacent to the construct.

Figure 2: Finger trap suture patterns A-F each with 6 repetitions. A full description of these patterns can be found in Appendix 2.

- = 2 x square knots
- = Surgeons knot
- = Criss cross
- = Single throw
- = Double throw
- = Tube

Figure 3: Suture slippage for the 6 finger trap suture patterns. Patterns with the same letter are not statistically different from one another ($p > 0.05$).

Figure 4: Stiffness for the 6 finger trap suture patterns. Patterns with the same letter are not statistically different from one another ($p > 0.05$).

Figure 5: Extension for the 6 finger trap suture patterns. Patterns with the same letter are not statistically different from one another ($p > 0.05$).

Figure 6: Maximum load to failure for the number of repeats for finger trap suture pattern B and D. No statistical difference found.

Figure 7: Suture slippage for the number of repeats for finger trap suture pattern B and D.

No statistical difference found.

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503 Table 1: Questionnaire results – complications

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Complication	Number
Infection at tube entry site	13
Gradual tube displacement	10
Suture loosening	10
Suture breaking	9
Premature tube removal	7
Patient interference	6
Tube blockage	5
Pneumothorax	2
Loss of seal at drain skin entry	1
Skin irritation at skin suture	1
None	1

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514 Table 2: Questionnaire results – methods

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Number (pattern)	Method	Total number
1 (D)	Double throw and criss-cross alternated	8
2 (A)	Knot and criss-cross alternated	7
3 (B)	Single throw and criss-cross alternated	3
4 (F)	Double throw and single throws alternated	2
5 (C)	Double throw, criss-cross, then single throw with criss-cross alternated	2
6 (E)	Single throw both sides	2
7	Square knot and single throw alternated	1
8	Surgeons knot and double throw alternated	1
9	Tape placed as butterfly around drain & sutured to skin	1
Total		27

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