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A1 pulley cutting potential and safety of three ultrasound-guided percutaneous A1 pulley release techniques for trigger finger: a cadaveric study

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Abstract

Background There is no consensus as to the best technique for percutaneous trigger finger release.

Methods This assessor-blinded study compared three ultrasound-guided percutaneous trigger finger release techniques using a needle (N), a needle-knife (NK), and a specially designed knife (K). Three physicians simulated A1 pulley release surgery on 56 fingers of 14 fresh-frozen hand cadaver body donors. Both the physicians and the fingers included were randomly selected.

Results The results of repeated-measures ANOVA revealed significantly longer cuts for the NK and K techniques, than for the N technique, both absolute (mean ± SD) (NK = 5.55 ± 3.07 mm, K = 6.29 ± 4.07 mm, and *N* = 2.02 ± 3.46 mm; N vs. NK $p = 0.015$, N vs. K $p = 0.002$, and NK vs. K $p = 1.000$), and cut percentage in relation to the total pulley length (NK = 51.61 ± 28.34%, K = 54.63 ± 33.72% and *N* = 18.24 ± 31.09%; N vs. NK $p = 0.008$, N vs. K $p = 0.003$, and NK vs. K $p = 1.000$). No neurovascular bundle injuries were found upon dissection. The overall complication rate was 11%, with no significant differences among the three techniques. Only one major tendon injury occurred in the NK group.

Conclusions In this cadaveric study, the NK and K techniques were more effective at releasing the A1 pulley than the N technique. All three techniques have emerged as equally safe.

Keywords Trigger finger, Minimally invasive surgery, Ultrasound-guided surgery, Cadaver

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Background

The trigger finger (TF) is a common condition that affects up to 3% of the general population [1]. Open TF release is among the most frequently performed interventions on the hand, with successful outcomes in a high percentage of cases [2–4]. However, a number of complications may be given when open surgery is performed [5]. To improve treatment efficiency, and reduce recovery time, infection risk and the costs of open surgery, numerous percutaneous TF release techniques have been described [3, 6–16].

Percutaneous blind release of TF has a number of complications that should not be underestimated [17]

so endoscopic techniques [17] or ultrasound (US)-guided procedures [6–8, 18] have been described without evidence yet on which is best. A number of recent systematic reviews and metanalysis found US-guided percutaneous A1 pulley release to be advantageous over open surgical release in terms of improved QDASH score in the first month, accounting for a quicker recovery from surgery, quicker return to normal activities, and an earlier discontinuation of oral analgesia [18, 19]. Long term conclusions such as recurrence rates, have been brought up in favor of US-guided techniques but still lack solid evidence [18, 20].

When using an US-guided technique, a wide range of cutting instruments, including conventional or modified needles, needle-knives and special knives, have been tested [6, 7, 9–13, 21–24]. There are also many uncertainties about the efficacy of pulley release and the safety of US-guided percutaneous approaches, especially because of the potential risk of tendon and/or neurovascular injury, as reported outcomes vary widely [14].

The main aim of this cadaveric study was to compare the cutting potential and safety, in terms of structural injury to surrounding neurovascular or tendinous structures, of US-guided percutaneous A1 pulley release via a needle, a needle knife, and a jawed knife specially designed for pulley release (Fig. 1).

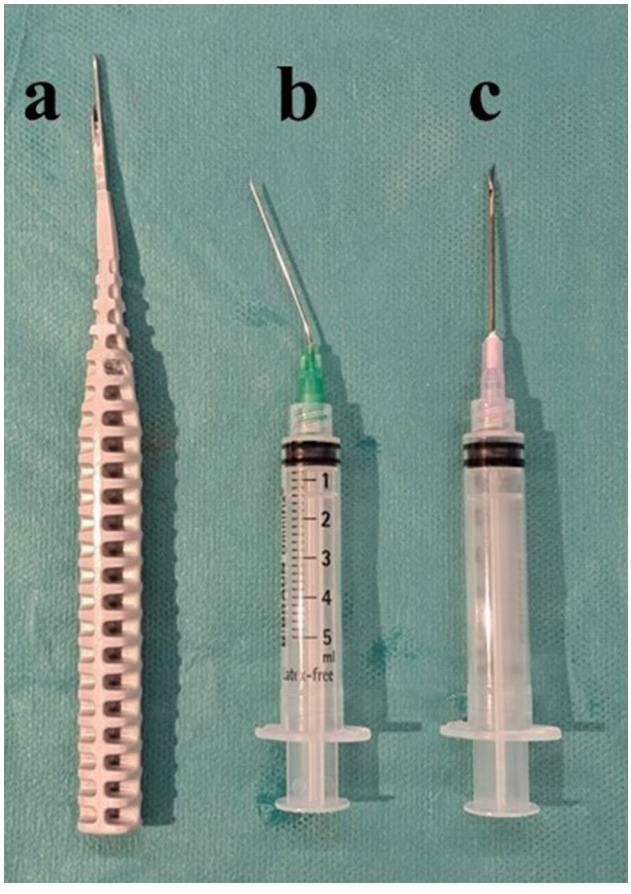

Fig. 1 Three instruments used for percutaneous trigger finger release: (**a**) Specially designed knife. (**b**) 21 G x 50 mm Needle curved at 140º with a lateral bevel. (**c**) 18 G Needle-knife

Methods

Design

Three surgical techniques were performed on 56 triphalangeal fingers from 14 cryopreserved body donor hands (9 females, 8 right), previously left to thaw at normal room temperature. Then they underwent further dissection. The anatomy and disposition of the thumb pulley system is much different from that of triphalangeal fingers and has some safety particularities that require different A1 pulley release techniques from those performed on triphalangeal fingers. For this reason, thumbs were not included in the present study. As no additional tissue preservation technique was used, cadaver specimen tissue consistency was preserved. Data were collected in two sessions, one in November and one in December 2022. Institutional review board approval was obtained prior to the study. The body donation program and use of cadaver tissue were in compliance with the current national legislation regarding ethics in research. None of the cadaver hands showed signs of trauma, deformities or surgical scars.

The cadaveric specimens were randomly distributed among three physicians with extensive experience (over 20 years) of US imaging and US-guided interventional procedures but without experience in the surgical techniques to be performed. This way we sought to analyze reproducibility of techniques already described in the indexed literature. Fingers were assigned to the three physicians via a code to indicate the hand and finger number. A statistician not involved in the study assigned a computer-generated randomization sequence to each physician, stratified by the finger and the technique. The physicians were unaware of the randomization sequence, which was concealed until the time of the simulated surgery. Another investigator, blinded to the technique and physician, performed anatomical dissection of the fingers after the procedure to assess surgical outcomes and complications.

Procedures and surgical techniques

Cadaveric limbs were placed in a supine position with the hands facing upwards on the table. All three procedures started with a US examination along the flexor tendon axes from proximal to distal. The same US device (APLIO i800; Canon Medical Systems, Tokyo, Japan) with a high-frequency hockey stick probe (18 MHz) was used for all US scans by all the physicians. In all the cases, the longitudinal axis of the tendon, and the proximal and distal edges of the A1 pulley were labeled on the skin via the

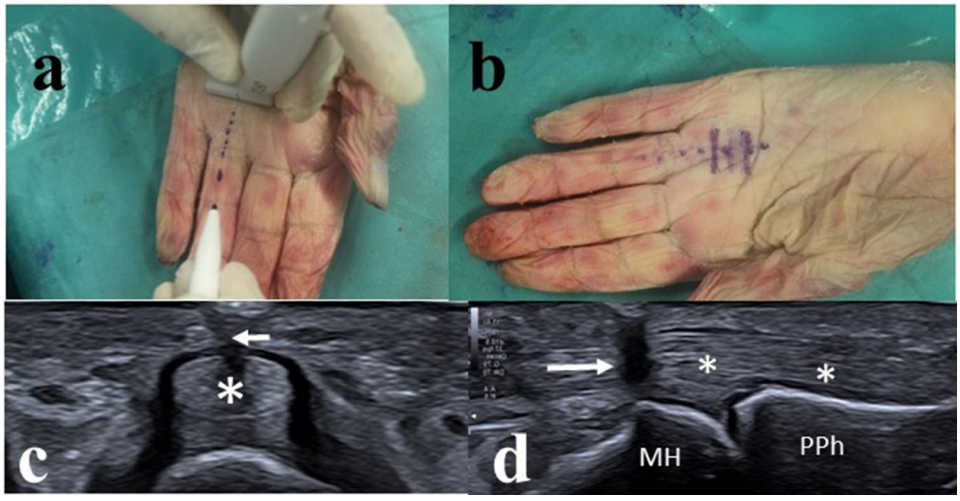

Fig. 2 Skin markings prior to the procedure via an ultrasound probe. (**a**) Longitudinal line of the flexor tendon. (**b**) Marking the distal and proximal margins of the A1 pulley. (**c**) Cross-sectional ultrasound image showing the needle shadow. (**d**) Longitudinal ultrasound image showing the needle shadow to mark the proximal and distal limits of the A1 pulley. The arrow indicate the needle reverberation. The asterisk indicate the flexor tendons. MH: metacarpal head. PPh: proximal phalanx

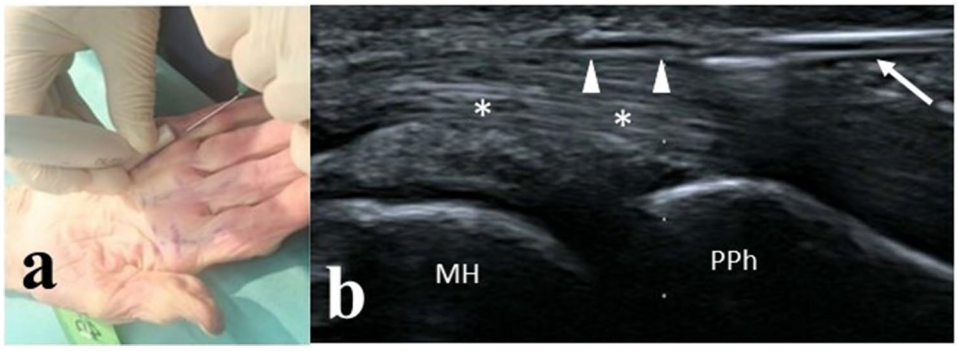

Fig. 3 Needle technique. (**a**) Inserting a 21 G needle under ultrasound guidance with a stick probe. (**b**) Ultrasound image identifying the needle penetrating the deepest most distal part of the A1 pulley. MH: metacarpal head. PPh: proximal phalanx. The arrowheads indicate the A1 pulley. The arrow indicates the needle. The asterisks indicate the flexor tendons

method described by Rojo-Manaute et al. [25]. These authors used a needle positioned between the transducer and skin to trace the long axis of the A1 pulley (Fig. 2a). The proximal edge of the pulley is defined by the metacarpal head-neck junction, and the distal edge is defined by the junction between the base and shaft of the proximal phalanx [25].

Once the marks were drawn on the skin (Fig. 2b), and with US guidance, the flexor tendons were visualized in the cross-sectional and longitudinal axes (Fig. 2c and d), the three physicians performed one of the three following techniques:

(1) *Needle technique.* This technique uses a 21 G x 50 mm needle with the tip curved at 140º and the bevel positioned laterally as a cutting instrument [10]. The US probe was placed on the long axis over the flexor tendon at the level of the metacarpophalangeal joint. The needle was introduced into the distal third of the proximal phalanx (Fig. 3a). Then, under US guidance, using both the long and short axis view, longitudinal incisions were made from distal to proximal, attempting to cut the pulley in ten similar moves (Fig. 3b).

(2) *Needle-knife technique.* This technique is based on an approach perpendicular to the skin surface, which generates a greater cutting force on the pulley. In contrast to the original description by Eastwood [15], a Nokor® (Becton Dickinson and Co., Franklin Lakes, New Jersey, USA) 18 G needle with a triangular scalpel blade at its tip was used, allowing for fewer cutting movements in a more linear way than with the beveled needle. After performing the corresponding A1 pulley skin markings, the needle-knife was introduced perpendicular to the palmar skin surface in the middle of the A1 pulley along

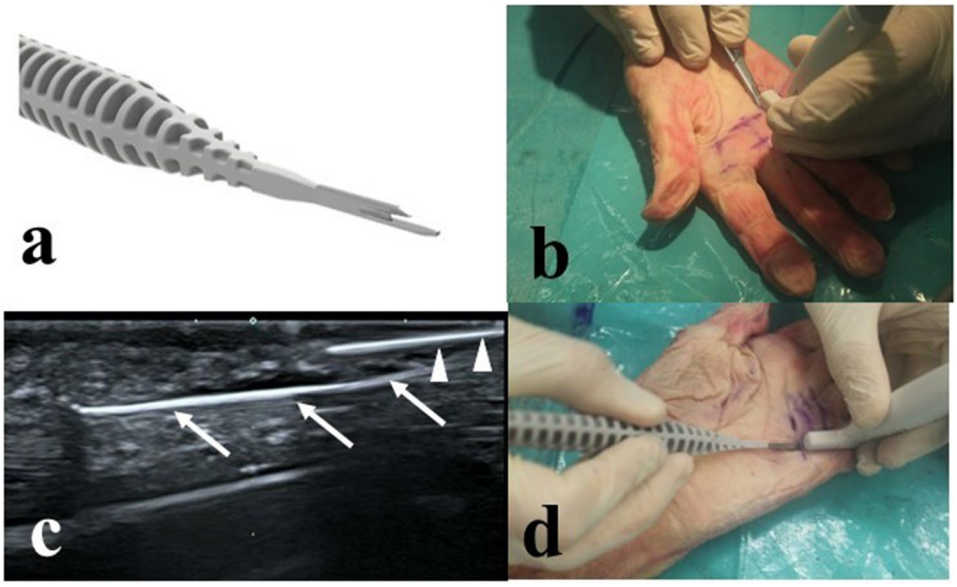

Fig. 4 Knife technique. (**a**) Close up of the tip of the knife showing the long and short prongs. (**b**) Enlarging the space via mosquito artery forceps. (**c** and **d**) The knife was introduced under ultrasound guidance to perform the release. The arrowheads indicate the shorter upper jaw of the knife. The arrow indicates the longer lower jaw of the knife

the longitudinal axis of the flexor tendon. Passive flexion and extension movements of the finger were used to ensure that the needle was not in contact with the flexor tendon. Six cutting movements were performed from distal to proximal with the needle-knife.

(3) *Knife technique.* For this technique, a specially designed jaw-bladed knife was used to section the A1 pulley (Kemis H1, Newclip Technics, Haute Goulaine, France). This cutting instrument has a 3 mm wide blade consisting of a shorter upper and longer lower prong (Fig. 4a). A 2 mm skin incision was made 1 cm proximal to the proximal edge of the A1 pulley. After expanding the space under the A1 pulley via curved mosquito artery forceps (Fig. 4b), the knife was introduced with the longer lower jaw under the pulley and over the tendon to cut the pulley under direct US guidance (Fig. 4c and d). A single cutting move was performed.

Anatomic dissection and outcomes

After the surgical procedure, an expert anatomist blinded to the technique performed the dissection of the samples and recorded the following outcomes for each digit: (1) complete release of the A1 pulley achieved or not, (2) digital nerve or vascular injury, (3) tendon injury noted as minor (minimal surface abrasion or excoriation affecting less than 10% of the tendon thickness) or major (visible laceration affecting more than 10% of the tendon thickness or potentially clinically relevant injury), (4) A2 pulley injury, (5) minimum transverse distance from the pulley incision to the digital collateral nerve, and (6) A1 pulley incision site determined by inspection during the anatomic dissection (midline, ulnar, radial, or oblique). The length of the incision on the A1 pulley was measured via a precision caliper (Qfun Ò digital caliper, 0–150 mm, CN, China) (Fig. 5). To assess the degree of A1 pulley division, the longitudinal length of the A1 pulley divided by the total length of the A1 pulley was compared and calculated as a percentage. A cut that accounted for the total length of the A1 pulley was considered a complete pulley release. A cut greater than 50% of the total length was considered substantial pulley release. Pulleys with no cuts were recorded as "intact".

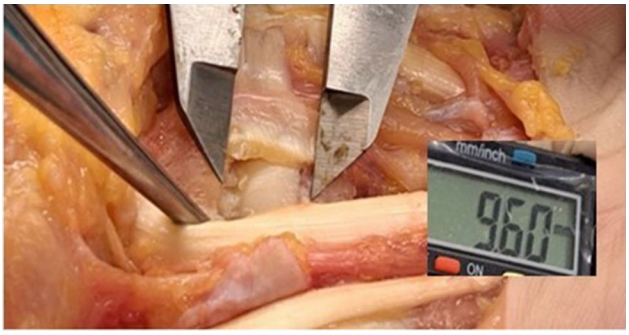

Fig. 5 Measuring the A1 pulley in the anatomical dissection with the precision caliper

Statistical analysis

Data was analyzed using Stata SE version 18 for Windows (Stata Corp LLC, TX; USA). The absolute and relative frequencies are described as percentages, and continuous variables are described as the means and standard

deviations. The chi-square test was used to compare categorical variables, and Fisher's exact F test was used when the value was less than 5 in at least one of the cells of the *n x m* contingency tables. Quantitative variables were analyzed via ANOVA to compare the mean data for each technique, with Bonferroni correction. Kruskal-Wallis tests were employed when appropriate. Significance was set at $p < 0.05$.

Results

The characteristics of the cadavers and fingers treated in this study are summarized in Table 1.

The length of the A1 pulley divided was significantly greater in the needle-knife and knife groups than in the needle group, both in absolute value, and in percentage value (Table 2). Although no significant differences were found between the techniques in terms of the number of complete releases, the needle-knife and knife techniques yielded greater numbers of substantially released pulleys and lower numbers of intact pulleys (Table 2). Although the differences were not statistically significant, there were more tendon and A2 pulley injuries in the NK group (Table 2). The minimum transverse distance between the pulley incision and the closest digital collateral nerve did not differ across the different techniques (Table 2).

The site of pulley release could be determined in 41 of the fingers. No significant differences were found in this variable among the three techniques (Table 3).

Discussion

In this assessor-blinded cadaveric study, our main finding was that when performing an A1 pulley release with US guidance or assistance, it was possible to achieve longer release of the A1 pulley via the needle-knife or knife technique than via the needle technique, whereas the number of structural injuries to surrounding neurovascular or tendinous structures was not statistically significant amongst techniques.

The needle technique has the lesser cutting potential. The aim is to progressively debilitate the A1 pulley with repetitive punctures until it is progressively torn. In the present study, we achieved A1 pulley cuts that were approximately one-third of the length obtained with the other two techniques. The high number of incomplete A1 pulley sections is in agreement with that obtained in previous cadaveric studies using 21G needles [10], which means that the technique is reproducible even for practitioners who are not familiar with it. Although the results in cadaveric samples might not seem very encouraging, in the two-part study by Lapègue et al. [10], TF symptoms were resolved in 82% of patients on the same day of surgery, and the percentage increased to 97% after a 6-month follow-up with additional steroid injections [10]. Thus, adjunct procedures such as US-guided

Table 1 Descriptive characteristics of the cadavers and fingers according to technique

	Technique		
	N (*n* = 18)	NK (*n* = 19)	K (*n* = 19)
Age (years)	91.76 ± 4.64	92.22 ± 4.57	91.29 ± 5.03
Female (*n*)	10	12	14
Male (*n*)	8	7	5
Right hand (*n*)	10	12	10
Left hand (*n*)	8	7	9
Index (*n*)	4	6	4
Middle (*n*)	6	3	5
Ring (*n*)	4	5	5
Little (*n*)	4	5	5

Data are expressed as *n*, unless age, which is expressed as the mean ± SD. K: knife technique; N: needle technique; NK: needle-knife technique

Table 2 Quality of A1 pulley release, complications, and minimal distance to the nearest collateral nerve

	Technique			
	N (*n* = 18)	NK (*n* = 19)	K (*n* = 19)	*p*
Percentage of the total longitudinal pulley length released (%)	18.24 ± 31.09	51.61 ± 28.34	54.63 ± 33.72	0.002[&]
Cut pulley length (mm)	2.02 ± 3.46	5.55 ± 3.07	6.29 ± 4.07	0.002[¥]
Complete pulley release (*n*)	1	1	3	0.602[#]
Cut pulley length greater than 50% (*n*)	3	11	11	0.016[#]
Intact pulley (*n*)	10	1	2	0.000[#]
Complications (*n*)				
Neurovascular	-	-	-	-
Minor tendon injury	-	2	1	0.766[#]
Major tendon injury	-	1	-	1.000[#]
A2 pulley injury	-	1	1	1.000[#]
Minimal transverse distance (mm)	4.40 (2.27)	2.96 (1.40)	3.46 (1.24)	0.129[&]

Continuous data are expressed as the means ± SDs, whereas discrete data are expressed as *n*. [&]: *p* for ANOVA. [#]: *p* for Fisher's exact F test. [¥]: *p* for Kruskal-Wallis test. K: knife technique; N: needle technique; NK: needle-knife technique

Table 3 Site of release of the A1 pulley according to technique

	Technique			
	N (*n* = 18)	NK (*n* = 19)	K (*n* = 19)	*p*
Midline (*n*)	4	11	15	0.002[#]
Ulnar (*n*)	-	1	-	1.000[#]
Radial (*n*)	2	5	1	0.193[#]
Oblique (*n*)	-	1	1	1.000[#]

Data are expressed as *n*. K: knife technique; N: needle technique; NK: needle-knife technique; [#]: *p* for Fisher's exact F test

corticoid injections should be considered when needle techniques are used.

As the degree of pulley release accounts for the percentage of cases that cannot be clinically solved by the needle technique, efforts have been made to develop techniques that have greater cutting potential and can achieve greater pulley sections, while maintaining a good safety profile. Adding a small knife to the tip of a needle to enable direct cutting motion instead of a repetitive puncture approach, can be achieved with modified needle-knives with excellent clinical results under US guidance [7]. Seemingly, in the present study, significantly greater sections were obtained compared with the needle technique, and no significant differences in terms of complications were observed.

Knife-based techniques have the greatest cutting potential and have obtained very good clinical and functional results in previous reports, with success rates in the treatment of TF between 94% and 100% [24], and a 90 to 98% rate of A1 pulley complete release in fresh frozen cadaver hands [16, 26]. However, injuries to the A2 pulley account for as many as 12% of the injuries to cadaver fingers [16]. To minimize A2 pulley sections and other potential complications, we used the Kemis H1 knife under US guidance. There were far fewer complete A1 pulley sections, and most of the A1 pulleys were sectioned for more than 50% of the total pulley length, with only one (1.79%) A2 pulley damaged. Further studies should corroborate whether percutaneous US-guided knife techniques achieve the best balance between the length of the pulley cut, the safety of the procedure and the clinical resolution of symptoms as well as how aggressively a surgeon must maintain this balance.

The most frequent complications described in cadaveric studies following percutaneous TF release are longitudinal injuries of the flexor tendons and partial digital artery lacerations [6, 27]. Our data confirm that percutaneous TF release is a safe procedure for the techniques here described. By marking the skin under US guidance, the risk of neurovascular bundle or A2 pulley lesions can be minimized regardless of the cutting instrument used, in contrast to percutaneous A1 pulley release without US guidance, which can lead to potential damage to the flexor tendons or adjacent neurovascular structures [7]. We had no neurovascular injuries in our study, three minor tendon injuries, one major tendon injury and two A2 pulley lacerations affecting less than 25% of the total pulley length. Although the difference was not significant, it should be noted that tendon injuries were three times more common with the needle-knife technique than with the knife technique. This percentage of tendon injuries is much lower than the 65% reported by Calleja et al. [28]. The closest transverse distance from the pulley cut to the neurovascular bundle highlighted the sufficient safety margin of all three techniques.

Further studies should aim to identify the most effective percutaneous A1 pulley sectioning technique by means of a well-designed randomized controlled clinical trial. However, only a cadaver study can determine the specific percentage of A1 pulley sections associated with a specific technique, thus, we believe that the results of the present study can contribute to the design of further research. In this way, the question is raised whether the original needle technique by Lapégue [10] could be compared in a cadaver lab setting to corroborate previous findings describing a similar technique with a thicker 14 G angiocath needle but with a greater achievement of complete releases [29]. However, with the results hereby obtained we favor more the needle-knife or knife techniques.

Additionally, the clinical significance of incomplete A1 pulley release requires further study with longer follow-up, considering recurrences and digit range of motion. In this way number of cutting movements should be analyzed in a more practical way other than standardizing a limited number as done in this study for the process of research methodology.

Finally, as this study was performed in cadaver specimens we could closely assess safety parameters between techniques, in terms of structural injury to nearby structures, and even though we did not obtain significant differences among them, we observed a tendency for the needle-knife technique (which is the only technique not performed under direct US guidance but under US assistance) to have more complications. Increasing the sample size could help to further determine if this difference remains statistically not significant.

Conclusions

The findings of this cadaveric study indicate that TF release via the US-assisted needle-knife or US-guided knife techniques hereby studied, can achieve greater A1 pulley release than the US-guided needle technique. The 21G US-guided needle technique here used, proved to be inefficient at achieving A1 cutting lengths greater than 50% of the A1 total pulley. A good safety profile was obtained in terms of structural injury to nearby neurovascular or tendinous structures, without significant differences in between techniques.

Abbreviations

A1	First annular
A2	Second annular
K	Knife technique
N	Needle technique
NK	Needle-knife technique
TF	Trigger finger
US	Ultrasound

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Author contributions
JF, RB and XS designed the study. FD did the literature search and review. JF, XS, AR, MB, and RB performed the experimental part and the anatomical dissection. FD collected the data. JF and MB analysed the data. MB and FD drafted the first manuscript. JF supervised the manuscript. MB finally revised the manuscript. All authors reviewed the final manuscript versión.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethical approval
Ethical approval for this study was obtained from the Institutional Review Board from the University of Barcelona, Faculty of Medicine and Health Sciences, in accordance with current Spanish legislation regarding ethics in cadaveric research.

Consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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