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A cadaveric study of ultrasound guided nonincisional trigger finger release with newly developed threads

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This study investigated the effectiveness and safety of ultrasound-guided non-incisional thread trigger finger release on cadavers using a newly developed domestic thread (Smartwire-01). Ultrasound-guided non-incisional thread trigger finger release was performed on 12 fresh cadaveric hands, including 12 thumbs and 48 long fingers. Two experts, experienced in an ultrasound-guided thread transecting technique, performed the procedures independently. The distal-to-proximal and proximal-to-distal approaches were performed in 6 hands each to determine which is safer and more effective. After the procedure, anatomical analyses were conducted by a blinded anatomist. The presence of a dissected A1 pulley and any damage to adjacent structures were assessed. Among the 60 cadaveric digits, 52 (86.7%) showed complete transection of the A1 pulley. The success rate for the thumb (66.7%) was relatively lower than that of the other fingers (91.7%). The distal-to-proximal approach showed a higher success rate (96.7%) compared to the proximal-to-distal approach (76.7%), with a near-significant difference ($p = 0.052$). Anatomical analysis revealed clear and sharp incisional margins of the transected A1 pulley, with only 1 minor flexor tendon injury observed, which occurred with the proximal-to-distal approach. Ultrasound-guided non-incisional thread trigger finger release using Smartwire-01 is a safe and effective procedure when performed with the distal-to-proximal approach, particularly in long fingers.

Keywords Trigger finger disorder, Tenotomy, Ultrasonography, Minimally invasive surgical procedures, Cadaver

The first annular (A1) pulley physiologically maintains the flexor tendon's alignment close to the phalanges and ensures smooth tendon excursion. In trigger finger, pathological thickening of the flexor tendon or the A1 pulley leads to a size mismatch between the two structures, resulting in painful triggering, crepitus, or the presence of a palpable tender nodule along the tendon[1–3]. The first-line treatment of trigger finger is conservative care, including activity modification (e.g., minimizing repetitive gripping or pinching), finger splinting, and nonsteroidal anti-inflammatory medications[4,5]. Additionally, corticosteroid injection in the palm at the first annular pulley level of the affected digit is safe and effective for relieving signs and symptoms but is also associated with a high recurrence rate[6,7]. If these measures are ineffective, surgical release of the annular pulley is recommended[8].

Open release of the A1 pulley is considered the standard surgical technique to treat trigger finger[4]. The success rates of open A1 pulley release are between 90% and 100%, with a complication rate between 5% and 12%[9,10]. Several minimally invasive percutaneous approaches have emerged as an alternative to open surgery

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with studies suggesting these approaches may result in improved outcomes and have an efficacy similar to that of open release[11–16]. These techniques may save time and are associated with a smaller incision, potentially lowering the risk of infection. Some studies have reported percutaneous release to produce less postoperative pain and faster return to activity compared to the classical surgical treatment[14,15]. Although the non-image-guided percutaneous approach is reported to be safe[11–13,15,16]it solely relies on anatomic landmarks to avoid injuring adjacent anatomical structures. Using high-resolution ultrasound guidance for percutaneous release allows accurate identification of the thickened annular pulley while simultaneously identifying the digital neurovascular structures and the flexor tendons. A variety of cutting devices has been used for ultrasound-guided percutaneous release of trigger finger, including different size needles[17,18]blades[19]specially designed hooked knives[20,21]and thread[22].

The thread transecting technique, first proposed by Guo et al.[23]divides only structures inside the loop of thread and does not require a skin incision, leaving only two needle punctures. It also has the advantages of not using a sharp dividing instrument, not requiring repetitive cutting motions, and reducing the risk of iatrogenic injury under continuous sonographic visualization[24]. Guo et al. first applied this technique to carpal tunnel release and demonstrated in a cadaver study[23] that it is a feasible method capable of completely transecting the transverse carpal ligament without injuring vital neural or vascular structures. The clinical effectiveness and safety of non-incisional carpal tunnel release were reported by our previous studies with newly developed domestic thread (Smartwire-01) and by other groups[25–30]. In contrast, few cadaveric studies[31,32] have evaluated the efficacy and safety of non-incisional trigger finger release, and to date, only 1 clinical trial has been performed[22].

The present study is to determine the efficacy and safety of ultrasound-guided non-incisional thread trigger finger release on cadavers using a newly developed domestic thread (Smartwire-01). The procedure can be performed using either the distal-to-proximal approach or the proximal-to-distal approach. The secondary aim of the study is to determine the safety and efficacy of each approach.

Results

For all 60 digits (12 thumbs and 48 long fingers), the complete transection rate was 86.7% (52 of 60), while 6 were partially transected, and 2 experienced failure, defined as an intact A1 pulley (Table 1). Among the thumbs, 8 of 12 underwent complete transection, whereas 3 cases involved incomplete transection, and 1 demonstrated failure. For the long fingers, 44 of 48 achieved complete release, with 3 cases of incomplete transection and 1 case of failure. The success rate for the thumb (66.7%) was lower than that of the other fingers (91.7%). There was no difference in the incomplete/failure rate or procedure time between the two experts. Excluding instrument preparation, the procedure time ranged from 5 to 10 min under cadaveric conditions and decreased further with operator experience.

In the distal-to-proximal approach, only 1 thumb showed partial release. The overall complete A1 pulley transection rate was 96.7%, with 83.3% for the thumb and 100% for the long fingers. With the proximal-to-distal approach, the overall success rate was 76.7% (23 of 30), with 50.0% for the thumb and 83.3% for the long fingers. Partial transection was found in 5 cases (2 thumbs and 3 long fingers), and failure occurred in 2 cases (1 thumb and 1 long finger). The distal-to-proximal group showed a higher complete transection rate (96.7%) than the proximal-to-distal group (76.7%), with a near-significant difference ($p = 0.052$, Fisher's exact test), as determined using SPSS software (version 29.0; IBM Corp., Armonk, NY, USA).

A gross anatomical evaluation of the transection transected A1 pulley was performed by a blinded anatomist. Figure 3 presents the gross findings of the successfully dissected A1 pulley on the cadaveric hands. The incisional margins of all transected A1 pulleys were sharp and clear. No injuries to the digital nerves were observed in any of the 12 thumbs or 48 long fingers with either approach. However, 1 minor partial injury to the flexor tendon was noted in the left fourth finger with the proximal-to-distal approach (Table 1).

Discussion

Percutaneous methods of A1 pulley release under sonographic guidance have been introduced for the management of trigger finger[17–22]. The procedural technique, including the direction of approach, selection of cutting instruments, and other related factors, varies considerably depending on the operator and facility.

	Distal-to-proximal approach	Proximal-to-distal approach
A1 pulley, Thumbs ($N = 12$)		
Complete transection (N (%))	5 (83.3%)	3 (50.0%)
Incomplete transection (N (%))	1 (16.7%)	2 (33.3%)
Failure to transection (N (%))	0 (0.0%)	1 (16.7%)
A1 pulley, Long fingers ($N = 48$)		
Complete transection (N (%))	24 (100.0%)	20 (80.3%)
Incomplete transection (N (%))	0 (0.0%)	3 (12.5%)
Failure to transection (N (%))	0 (0.0%)	1 (4.2%)
Damaged structure (All fingers, $N = 60$)		
Digital nerve (N (%))	0 (0.0%)	0 (0.0%)
Flexor tendon (N (%))	0 (0.0%)	1 (3.3%)

Table 1. Results of A1 pulley transection and damage to nearby structures.

Although it is generally regarded as a safe and effective procedure, no randomized studies have yet established the most optimal approach or device. Among various cutting instruments, the use of a thread offers notable advantages. The transection occurs precisely along the targeted anatomical structure and is mechanically confined within the thread loop, with negligible influence on adjacent nontargeted tissue[22]. Smartwire-01, used as a cutting device in our study, was developed for the percutaneous dissection thread technique with higher cutting force, better visibility on ultrasound, and easier handling due to an additional coating of thin titanium nitride[28,33]. Particularly in the thumb, A1 pulley release has been reported to be technically more challenging than in the long fingers, with one case of incomplete release in the cadaveric study[34] and one case of failed release in the clinical study[18]. This has been explained by the unique anatomical characteristics of the thumb, which tends to move more easily during the procedure and cannot be positioned fully flat on its dorsal side. Caution has also been advised regarding the risk of radial digital nerve injury, due to the reduced safety margin in the thumb compared to the long fingers[35]. The clinical investigation reported transient radial digital nerve numbness in three thumbs immediately following the procedure, all of which resolved spontaneously within two weeks[20].

To our knowledge, there are only 3 studies on ultrasound-guided non-incisional thread trigger finger release, comprising 2 cadaver studies[31,32] and 1 preliminary clinical report[22]. Guo et al. tested the efficacy and safety of this procedure on 14 fingers and 4 thumbs of 4 cadaveric hands[32]. They reported nearly perfect results, with all digits demonstrating complete A1 pulley release without injury to nearby structures. In the study of Jengojan et al.[31]thread trigger finger release was performed on 20 cadaveric fingers, excluding the thumb. Complete release was achieved in 85% of cases, with slight flexor tendon injuries observed in 5 cases, and no neurovascular damage reported. Both cadaveric studies demonstrated that ultrasound-guided thread release for trigger finger is effective and safe. Our study achieved comparable results. Guo et al.[22] evaluated the clinical feasibility and effectiveness of 34 digits (11 thumbs and 23 long fingers) in 24 patients. They reported resolution of triggering and locking, and complete flexion and extension immediately following the release with no complications.

Regarding the direction of the procedure, the cadaveric study of Guo et al.[32] utilized both approaches for the fingers and found no differences. For the thumbs, only the proximal-to-distal approach was used, as the other approach suffered from difficulty in removing the needle. These findings differ from ours, which showed that the distal-to-proximal approach had a higher success rate for the long fingers (100% vs. 80.3%) and for the thumbs (83.3% vs. 50.0%). Also, our study was performed by 2 experts, with similar outcomes. The difference in these results may be associated with various factors, such as the condition of cadaveric hands, variations in procedural settings, and operator preferences. Guo et al. used the proximal-to-distal approach in a preliminary clinical study[22]. In contrast, Jengojan et al.[31] employed the distal-to-proximal approach in their cadaveric study. Many studies on percutaneous release of trigger finger using various devices have also utilized the distal-to-proximal approach[12,17,19–21,36]. Our results comparing the 2 approaches showed that the distal-to-proximal approach had a higher complete transection rate (96.7% vs. 76.7%, $p = 0.052$), potentially due to easier needle manipulation and improved procedural accuracy. Although the difference did not reach conventional statistical significance, these findings support the preferential consideration of the distal-to-proximal approach. This approach may be particularly advantageous for long fingers, in which a 100% success rate was achieved.

Incomplete transection occurred in some cases of each approach. Although real-time ultrasound guidance played an important role in ensuring a successful and safe procedure, it cannot confirm complete release of the A1 pulley. It is challenging to accurately delineate the proximal and distal boundaries of the pulley based solely on echogenicity in the ultrasound image[20,21,35]. Nevertheless, the determination of the limits of division on the A1 pulley is critical for successful release. Many researchers have used the topographic bone landmarks of the metacarpal head-neck junction and the phalangeal base-shaft junction as references for the proximal and distal boundaries of the pulley, respectively[37,38]. However, the specific extent of release based on these landmarks has varied among studies. Rojo-Manaute et al.[21] defined the proximal cutting margin as 5 mm proximal to the metacarpal head-neck junction and the distal margin as 3 mm distal to the base-shaft junction of the proximal phalanx, whereas Jou and Chern et al.[20] defined both margins at 5 mm from the respective landmarks. In a cadaveric study, Smith et al.[35] set the release extent from 1 to 2 mm proximal to the metacarpal head-neck junction to 1–2 mm distal to the base-shaft junction of the proximal phalanx. Also, anatomical studies demonstrated that the length of the A1 pulley varies among digits, correlates with finger length, and differs across ethnic groups[38–41]. This indicates that the security margin should not be a constant but adjusted for each patient.

Even partial transection could lead to sufficient mechanical decompression of the flexor tendon and immediate symptom relief in patients. This was demonstrated by Lapegue et al.[18]whose full transection of the A1 pulley was not successful in a cadaver study, while the same technique led to complete symptom relief in 96.8% of patients within 6 months. Similarly, Rojo-Manaute et al.[21] noted limited visualization in the cadaveric setting, particularly in the thumb, and recommended conversion to open surgery when sonographic guidance was inadequate. However, in their clinical study, ultrasound visualization was excellent, and no conversions were required. These observations suggest that technical limitations encountered in cadaveric models may not pose significant challenges in clinical practice. These findings also highlight a limitation of the present study, which was conducted using cadaveric specimens. Therefore, a follow-up clinical study is warranted to confirm the efficacy and safety of ultrasound-guided non-incisional thread trigger finger release using Smartwire-01. As the thread transection technique is highly dependent on the operator's proficiency in both ultrasound guidance and procedural skill, the level of expertise plays a critical role in ensuring safety and accuracy. In the present study, both operators had been performing ultrasound-guided thread procedures since 2020 and had clinical experience with over 100 cases of carpal tunnel release using this technique[29].

Conclusion

We demonstrated in this cadaveric study that ultrasound-guided non-incisional thread trigger finger release with Smartwire-01 was safe and effective for fingers other than the thumb, especially with the distal-to-proximal approach. Based on these promising findings, future clinical studies are recommended to assess the feasibility and safety of the thread transecting technique for trigger finger treatment.

Materials and methods

Materials

Cadaveric hands with no evidence of previous surgery or trauma history were included in the study. Twelve fresh cadaveric hands with 12 thumbs and 48 long fingers were used for this study. The mean age of the cadavers was 80.9 ± 7.2 years (one male and five females). The newly developed thread Smartwire-01 (Smart Wire Co., Ltd., Goyang-si, South Korea) was used as the cutting thread.

Non-incisional trigger finger release

Non-incisional trigger finger release is a percutaneous technique for A1 pulley transection using a transecting thread without skin incision. All procedures were performed using a Samsung RS85 Prestige US system (Samsung Medison, Seoul, South Korea) equipped with a linear US probe (L3–12 A). Prior to the procedure, ultrasound was used to assess the A1 pulley and common flexor tendon. The real-time ultrasound system was used to monitor the thread loop during the procedure. Non-incisional trigger finger release with Smartwire and a 20G Tuohy needle was performed on 12 fresh cadaveric hands (12 thumbs and 48 long fingers) by two experts in ultrasound-guided thread transecting technique. The distal-to-proximal approach and the proximal-to-distal approach were each performed in 6 hands to determine which is safer and more effective in non-incisional trigger finger release (Fig. 1).

A schematic drawing illustrating the procedure is shown in Fig. 2. The cadaveric hands were placed in supination (palms facing upward). The entire A1 pulley and the flexor tendon were identified using ultrasound. A 20G Tuohy needle was bent at the distal shaft and connected to a syringe containing 5 mL of normal saline. Under longitudinal ultrasound guidance, the needle was inserted into the palm at a location beyond the A1 pulley, allowing for easier needle manipulation. The needle was advanced toward the A1 pulley, and upon reaching its end, a small amount of normal saline was injected to separate the surrounding tissues. The needle passed under the A1 pulley while simultaneously hydrodissecting its margins and then exited the skin beyond the full length of the A1 pulley. The Smartwire-01 was passed through the needle, which was then removed, leaving the Smartwire-01 in place beneath the A1 pulley. Another needle was inserted at the same entry point, passed above the A1 pulley, and exited at the same exit point. Then, the tip of the pre-inserted Smartwire-01 was passed through the needle tip to create a looped configuration that was positioned at the A1 pulley after withdrawing the needle. Prior to cutting, ultrasound was used to verify that the thread adequately encircled

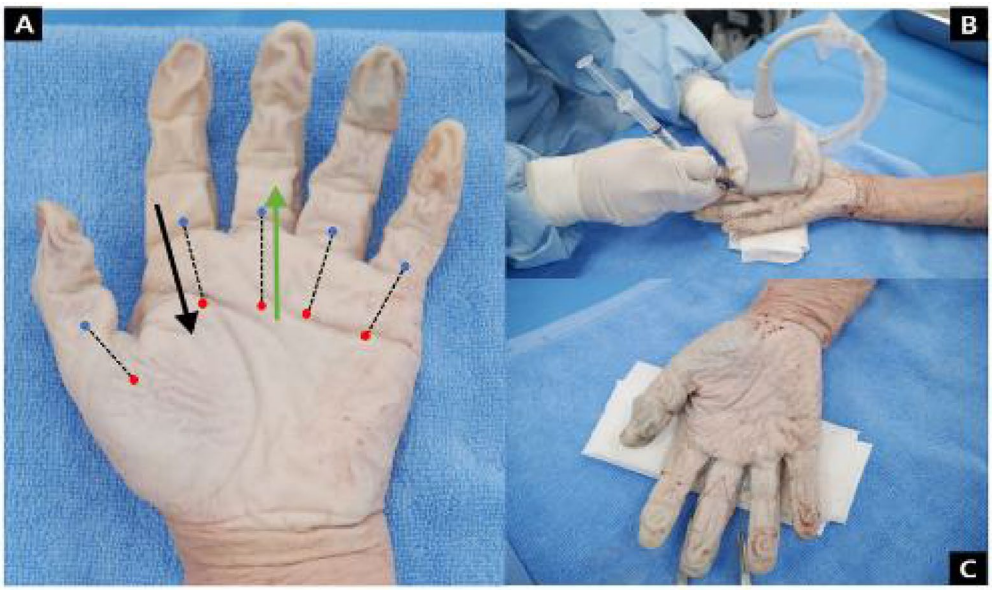

Fig. 1. Two methods of non-incisional trigger finger release. **A**: Needle puncture sites and direction of the procedure (blue points indicate distal puncture sites, red points indicate proximal puncture sites, dotted lines indicate needle pathway under the skin, black arrow indicates the direction of the distal-to-proximal approach, and green arrow indicates the direction of the proximal-to-distal approach). **B**: The distal-to-proximal approach of non-incisional trigger finger release with ultrasound guidance. **C**: Looped Smartwire-01 with the distal-to-proximal approach before transecting the first annular pulley.

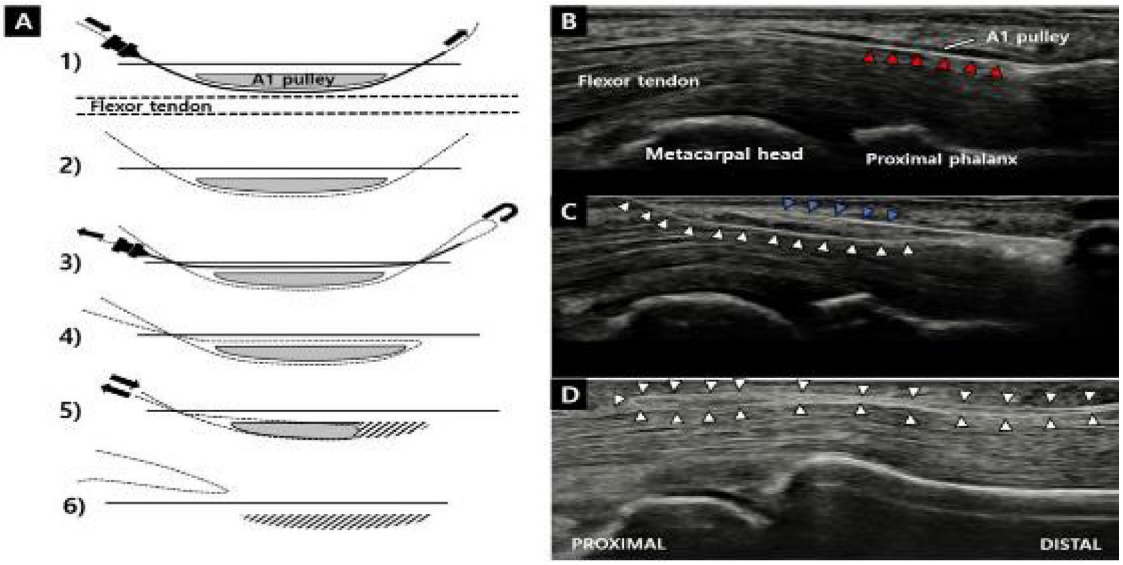

Fig. 2. Schematic drawing illustrating the non-incisional trigger finger release procedure, and corresponding ultrasound images obtained during the distal-to-proximal approach. **A**: (1) A bent 20G Tuohy needle was inserted into the palm at a point beyond the A1 pulley and advanced toward A1 pulley. Upon reaching the end of the A1 pulley, a small amount of normal saline was injected to separate the surrounding tissues. The needle was advanced beneath the A1 pulley with hydrodissection and exited the skin beyond the full length of the pulley. (2) Smartwire-01 was passed through the needle and positioned beneath the A1 pulley, after which the needle was removed. (3) A second needle was inserted at the same entry point, passed above the A1 pulley, and exited at the same exit point. (4) The tip of the pre-inserted Smartwire-01 was passed through the second needle to form a looped configuration around the A1 pulley. The needle was then withdrawn, leaving the thread looped in place. (5) The pulley was transected using a reciprocal motion of the Smartwire-01 under continuous ultrasound monitoring. (6) The thread was subsequently removed. **B**: Red arrowheads indicate the needle positioned beneath the A1 pulley. **C**: Blue arrowheads indicate the needle positioned above the A1 pulley, and white arrowheads indicate the Smartwire-01 beneath the A1 pulley. **D**: White arrowheads indicate the looped Smartwire-01 prior to transection of the A1 pulley.

the entire A1 pulley. The A1 pulley was manually transected using a reciprocal motion of the thread under continuous ultrasound visualization, and the thread was subsequently removed.

After trigger finger release, anatomical dissection was performed by a single blinded anatomist to visually assess the cut sites and to evaluate procedural efficacy and safety. Efficacy was defined as complete transection of the A1 pulley, and safety was assessed by identifying any injury to adjacent structures, including the digital neurovascular bundle or flexor tendon (Fig. 3).

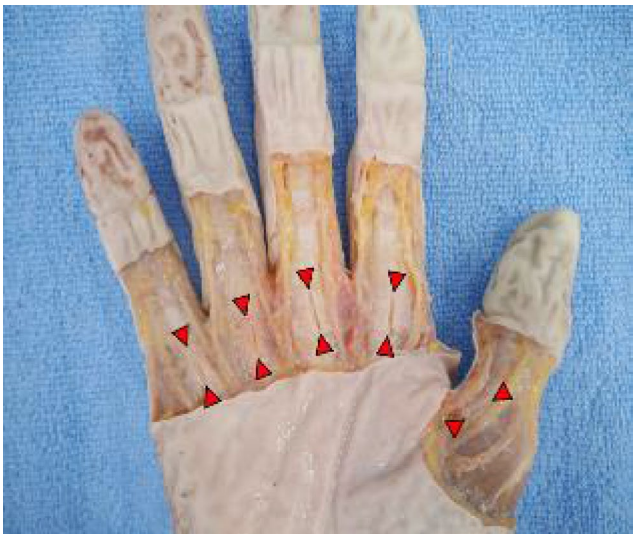

Fig. 3. Gross findings of the transected A1 pulley after non-incisional trigger finger release with the distal-to-proximal approach. There were no injuries to digital nerves or flexor tendons. The red arrowheads indicate the completely transected A1 pulley in the thumb and long fingers.

Data availability

The dataset generated and analyzed during this study is available from the corresponding author upon reasonable request.

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Author contributions

J.M.K., I.J.K., and U.Y.L. contributed to the conceptualization and methodology. J.M.K. and I.J.K. conducted the formal analysis. J.M.K., I.J.K., H.Y.P., and S.H.K. carried out the investigation. K.E.N. and J.M.K. wrote the original draft of the manuscript. All authors reviewed and approval of the final manuscript.

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Declarations

Competing interests

The authors declare no competing interests.

Ethics statement

The cadaveric specimens in this study were legally donated to the university-affiliated institute for applied anatomy. Informed consent was obtained from all the participants. The Institutional Review Board of the Catholic University of Korea approved this study. (Protocol number: MC22EISI0127) All experiments were performed in accordance with relevant guidelines and regulations.

Additional information

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