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ORIGINAL RESEARCH

Comparative Analysis of a New Device-Assisted Mini-Incision Versus Conventional Surgery for Carpal Tunnel Syndrome: A Retrospective Study of 109 Cases

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Study Design: A retrospective cohort study.
Objective: This study aimed to compare the effectiveness and safety of the new device-assisted mini-incision approach for carpal tunnel release (CTR) with the conventional method.
Methods: A total of 109 patients diagnosed with primary carpal tunnel syndrome confirmed clinically were retrospectively included and divided into two groups based on the surgical approach: Group A (n=54) underwent surgery using a new device-assisted mini-incision, and Group B (n=55) received conventional surgery. Clinical outcomes, including pinch strength, grip strength, Visual Analog Scale (VAS) score, two-point discrimination (2-PD), Disabilities of the Arm, Shoulder, and Hand (DASH) score, and Boston Carpal Tunnel Questionnaire (BCTQ), were evaluated at 1, 3, and 6 months postoperatively. Additionally, operative time, incision length, wound pain, pillar pain, and the interval until return-to-work were compared between the two groups.
Results: At the 6-month follow-up, all patients in both groups had recovered. There were no significant differences between the two groups in postoperative pinch strength ($P = 0.665$), grip strength ($P = 0.803$), 2-point discrimination (2-PD) ($P = 0.347$), Visual Analogue Scale (VAS) score ($P = 0.143$), Disabilities of the Arm, Shoulder and Hand (DASH) score ($P = 0.524$), and Boston Carpal Tunnel Questionnaire (BCTQ) (SSS: $P = 0.195$; FSS: $P = 0.103$). Statistically significant differences were observed between the two groups in operation time ($P < 0.001$), incision length ($P < 0.001$), and return to work time ($P < 0.001$). Although at 6-month follow-up, there was no significant difference in the incidence of wound pain and pillar pain between the two groups. But the incidence of wound pain and pillar pain was lower in Group A (wound pain: 0%; pillar pain:0%) compared to Group B (wound pain: 5.5%; pillar pain:7.3%).
Conclusion: The device-assisted mini-incision technique provided comparable functional results to the conventional approach, with reduced complications and smaller incisions, supporting its use as a viable alternative in appropriate cases.
Keywords: carpal tunnel syndrome, carpal tunnel release, mini-incision approach, conventional approach

Introduction

Carpal tunnel syndrome (CTS) is the most common kind of nerve compression condition affecting upper limbs. Carpal tunnel release (CTR) is a surgical treatment that is widely recognized as an effective means of addressing CTS.[1–3] Symptoms of the disease often include pain and numbness in the fingers, as well as signs of muscle atrophy.[4] The conventional approach is an "S"-shaped cut in the skin from the center of the palm to the crease of the wrist. This incision has the advantage of fully exposing the transverse carpal ligament and preventing incomplete release. However, it often leads to problems such as pain at the site of the incision, flexor tendon compression, sensitivity in the scar tissue, and thenar as well as hypothenar pain (pillar pain).[5,6]

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The first endoscopic release of the transverse carpal ligament was carried out in 1989 by Okutsu et al. The operation is carried out on the distal forearm utilizing a versatile subcutaneous endoscopic method.[7] However, the limited range of view during subcutaneous endoscopic treatments may result in insufficient transverse carpal ligament release. And the requirement of expensive apparatus and special skills restrict its extensive application. Kaleff et al also described a transverse skin incision for CTR. However, in two of the twenty-eight patients, the release was insufficient.[8] Hwang, P.Y., Yong-Suk Leeet al used a knifelight and a hook knife, respectively, to execute transverse carpal ligament release through a tiny wrist incision.[9,10] None of their methods allow doctors to visually see the release of the median nerve. And the presence of scarring on the wrist can lead to discomfort while patients engage in common tasks like typing on a keyboard or using a mouse. Blind or limited-vision techniques may risk incomplete ligament release or injury to nerve branches. In summary, existing minimally invasive approaches for CTS each have limitations, such as suboptimal visualization or technical difficulty.

The study by Donati, D. et al believes that ECTR provides an effective alternative for CTS treatment, with advantages in terms of faster functional recovery, reduced postoperative discomfort, and faster return to work.[11] The results of the study by Rajapandian, R. et al showed that the results of ECTR were comparable or better than those of OCTR, especially in terms of postoperative discomfort, functional recovery, grip strength, return to work, and patient satisfaction. In addition, the levels of scar sensitivity, pillar pain, and wound-related complications were lower with ECTR than with OCTR. However, ECTR has a higher risk of reversible nerve injury.[12] The rationale for developing our new device-assisted mini-incision technique stems from the need to enhance safety and accessibility while maintaining cost-effectiveness and ease of use compared to existing methods. Our approach uses a single small (1.5–2 cm) longitudinal incision in the palm, through which a custom-designed device is introduced to safely dissect and divide the transverse carpal ligament under direct video visualization. This device was designed by our team and consists of four components: a special metal guide, a U-shaped push knife, a blunt dissection tool, and a miniature visualization camera. The design of the device emphasizes anatomical safety – the push knife has blunt tipped prongs and travels along the guide, shielding the median nerve and surrounding structures during the cut. The integrated camera allows the surgeon to see inside the carpal tunnel to confirm complete release of the ligament and inspect the median nerve. By minimizing incision size while maintaining direct visualization, this technique is intended to reduce incision-related morbidity without compromising surgical completeness. Presenting and assessing the new device and method's safety and efficacy in comparison to the conventional surgery is the aim of this study.

Materials and Methods

Ethical Statement

The study was approved by the Institutional Review Board Hebei Medical University Third Hospital in compliance with the Helsinki and an exemption from the informed consent was obtained (W2021-046-1).

All data were anonymized before the analysis to safeguard patient privacy.

Participants and Research Design

This retrospective research included patients diagnosed with CTS and surgically treated in our hospital from January 2022 to July 2023. The conventional approach was employed for patients treated before August 2022, while the new device-assisted mini-incision approach was utilized for those treated thereafter. To ensure comparability between groups, we applied consecutive sampling to include all eligible patients who met the inclusion criteria within the specified time frames (pre- vs post-August 2022). The inclusion criteria for this study are: ① Patients diagnosed with CTS based on medical history, physical signs, physical examination, neuroelectrophysiological examination, and imaging examination. ② Have not received conservative treatment with steroid injection. ③ Aged between 18 and 70 years. ④ Patients with unilateral CTS planning to undergo surgical treatment. ⑤ Not accompanied by other nerve entrapment diseases. The exclusion criteria for this study are: ① Individuals with systemic diseases such as hypertension, diabetes, and malignant tumors that may impact treatment. ② People who are pregnant, have central nervous system lesions or mental disorders. ③ People with fractures or surgery on the affected side ④ The carpal tunnel has a lesion that occupies space. ⑤ Patients with severe heart, kidney, lung and other organ dysfunction. ⑥ Follow-up data is incomplete. Both Group A and B were operated on by the same senior surgeon.

Surgical Procedure

Conventional Surgical Procedure

For the surgery, each patient is given local anesthetic while lying supine on the surgical table Each patient had an upper arm tourniquet applied throughout the procedure. In the conventional approach, an S-shaped incision 5 mm ulnar side of the thenar crease and parallel to the thenar crease is used. After separating the subcutaneous tissue, identify and protect the median nerve and palmar cutaneous branches, and then open the carpal tunnel from proximal to distal end. Then suture the wound.

The New Device-Assisted Mini-Incision Surgical Procedure

In this study, we designed a new device to assist in treating CTS through mini-incisions. This device consists of four parts: a special metal guide with a groove, a push knife, a dissection device, and a visualization device (Figure 1). The push knife features a U-shaped blade with two blunt tips at its top and bottom, designed to enhance safety during the

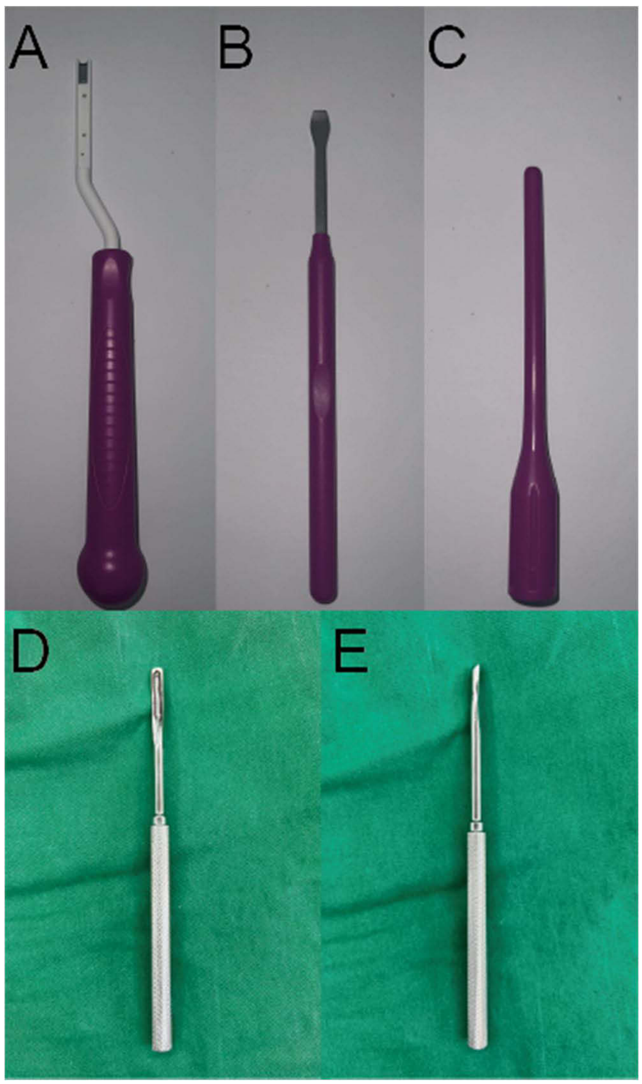

Figure 1 The new surgical device.(**A**) The push knife. (**B**) The dissection device. (**C**) The visualization device. (**D** and **E**) The metal guide.

procedure. The metal guide, in conjunction with the blunt tips of the push knife, provides protection for the median nerve and other critical structures. Additionally, the distal end of the guide is closed, ensuring complete dissection of the transverse carpal ligament while minimizing the risk of injury to adjacent proximal tissues. The visualization apparatus serves not only to confirm complete release of the carpal tunnel but also allows direct observation of the median nerve and surrounding tissues, enabling tailored treatment based on the extent and nature of the compression.

The incision is made at the intersection of the radial border of the ring finger and Kaplan's cardinal line, extending 1.5–2.0 cm proximally. The subcutaneous tissue is carefully dissected, ensuring identification and protection of the superficial palmar arch to prevent vascular injury. The procedure begins with blunt dissection using a separator, which gently detaches the transverse carpal ligament (TCL) from the surrounding tissues, creating a safe working space. Once adequate separation is achieved, a guiding plate is inserted beneath the TCL, positioned toward the ulnar side of the carpal tunnel to avoid critical neurovascular structures. The visualization device is then connected to a smartphone or tablet via a USB cable, providing real-time intraoperative imaging. Using this imaging system, the surgeon verifies that there are no important structures obstructing the surgical pathway before proceeding with the ligament release. Next, a push knife is introduced along the groove of the guiding plate, ensuring controlled and precise cutting. As the push knife advances proximally, the blunt tip of the knife secures the TCL, while the blade safely incises the ligament without harming adjacent structures. After releasing the median nerve, a direct endoscopic inspection is performed using the visualization tool to confirm complete decompression of the carpal tunnel. The surgeon carefully assesses for any residual compression and inspects for potential nerve, tendon, vascular, or soft tissue injury before concluding the procedure. Finally, the wound is sutured, and sterile dressings are applied (Figures 2–4).

Both groups of patients were operated on by the same experienced surgeon to reduce the variability of results caused by the operator. All surgeries were conducted following a standardized protocol, with a uniform device setup, incision placement, and ligament release technique. All patients are encouraged to resume light activity as tolerated on the same postoperative day.

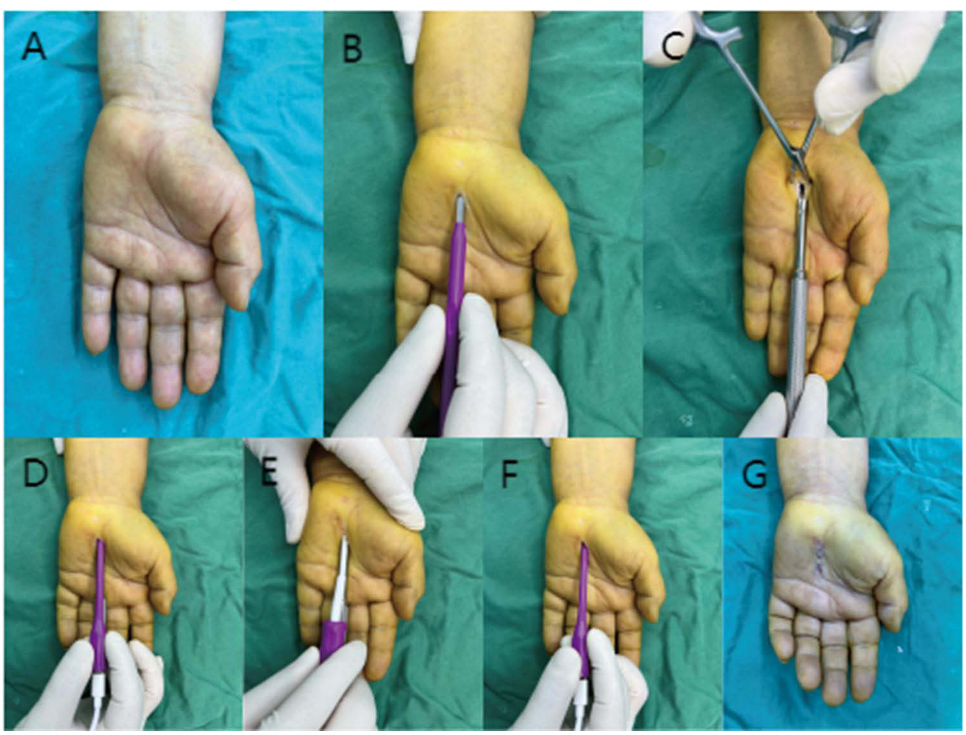

Figure 2 Intraoperative pictures.(**A**) Before surgery. (**B**) Inserting the dissection device into the carpal tunnel. (**C**) Inserting the metal guide into the carpal tunnel. (**D**) Examination of carpal tunnel using the visualisation device. (**E**) Incision of the transverse carpal ligament guided by the visualisation device. (**F**) Re-examination of the carpal tunnel using the visualisation device (**G**) Stitch up the wound.

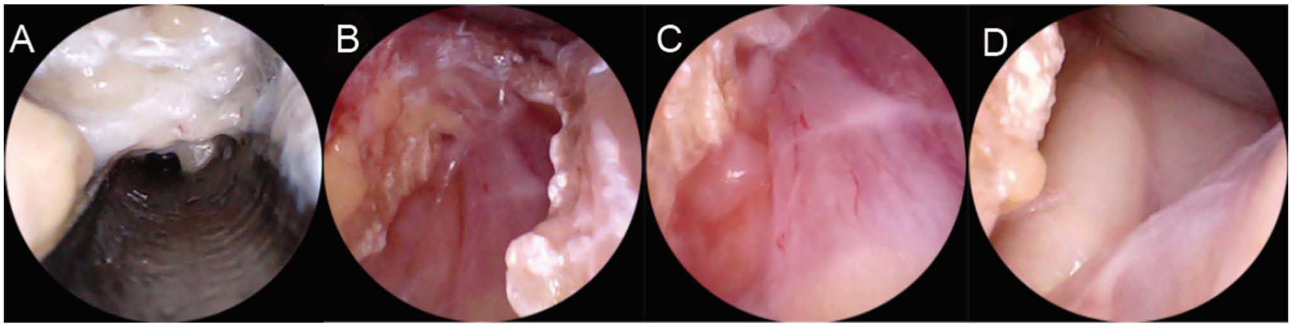

Figure 3 Intraoperative pictures taken with the visualization device. (**A**) Ensure no vital tissues between guide and transverse carpal ligament.(**B**) This image shows the transverse carpal ligament that has been cut. (**C**) The median nerve is completely released. (**D**) The tissues surrounding the median nerve are intact.

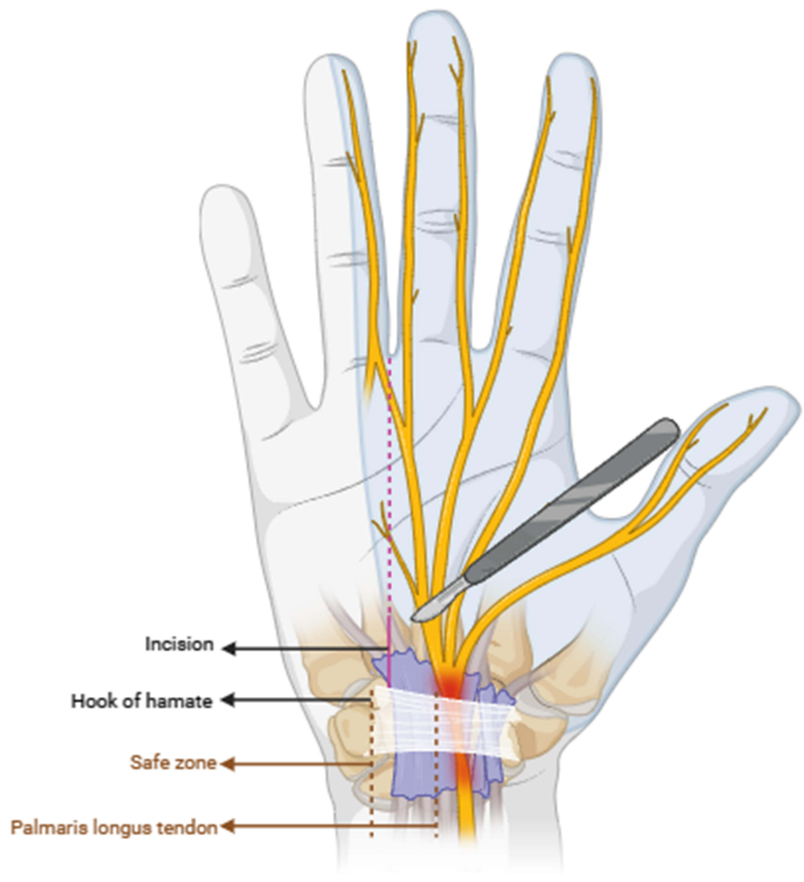

Figure 4 Incision and safe zone.

Outcome Evaluation

After surgery, patients were followed up at 1 month, 3 months, and 6 months. The following outcomes were evaluated: the pinch and grip strength, the 2-point discrimination (2-PD), the Visual Analogue Scale (VAS), the Disabilities of the Arm, Shoulder and Hand (DASH) score and the Boston Carpal Tunnel Questionnaire (BCTQ). 2-PD refers to a person's ability to accurately discern the distance between two points during a tactile test, where the patient performs the test with eyes closed. The DASH score is a scale used to assess upper limb function and is widely used in research and clinical practice, especially in the field of hand surgery and rehabilitation, with scores ranging from 0 to 100.[13,14] The Symptom Severity Scale (SSS) and Functional Status Scale (FSS) are components of the BCTQ. The SSS includes 11 items assessing pain, paresthesia, numbness, weakness, nocturnal symptoms, and overall functional status, while the FSS comprises 8 items evaluating hand function during common daily activities. Each item is scored on a 5-point scale (1–5), ranging from 1 (no symptoms) to 5 (the worst symptoms) for SSS and from 1 (no difficulty) to 5 (cannot perform the activity at all) for FSS. The average of the two subscales is calculated separately.[14,15] The presence of wound pain and pillar pain, two common complications of the procedure, was assessed. Wound pain was defined as pain centrally located directly over the scar, while pillar pain was characterized as a deep-seated ache or discomfort over the thenar or hypothenar regions, or both. Both types of pain were evaluated using the VAS score, with a score greater than 3 indicating the presence of pain. We also recorded the operation time, incision length, and return-to-work time for both patient groups.

Statistical Analyses

To assess normality, we conducted the Shapiro–Wilk test for both groups. Results indicated that the data did not significantly deviate from normality ($p > 0.05$). Given our sample size ($n > 50$ per group), parametric tests remain robust under the Central Limit Theorem. In descriptive analysis, means and standard deviations (SD) were used for continuous variables and frequencies as well as percentages were used for categorical variables. SPSS version 27.0 software (IBM, Chicago, IL, USA) was used for statistical analysis. The distinction between groups was assessed utilizing either Fisher exact tests or independent-sample t-tests. $P < 0.05$ was deemed to signify a statistically meaningful discrepancy.

Results

Preoperative Information

The research involved 109 participants from our medical center, the group consisted of 33 men and 76 women. Each individual in the study had received a diagnosis of carpal tunnel syndrome through the use of electromyography and ultrasonography testing. Symptoms such as pain, tingling, numbness, and hypoesthesia occur in the distribution area of the median nerve in the hand. A total of 54 patients underwent CTR using the new device-assisted mini-incision approach (Group A), while 55 patients received the conventional CTR approach (Group B). The ages of patients in Group A and Group B were 49.3±8.2 and 50.5±7.8 years, respectively. The duration of symptoms in the two groups was 8.9±4.2 and 8.1±4.4 months, respectively. No significant differences were observed in baseline characteristics between the two groups, including pinch strength, grip strength, VAS score, 2-PD, DASH score, and BCTQ (Table 1).

Table 1 Baseline Characteristics of Patients with New Device-Assisted Mini-Incision Approach (Group A) and Conventional Approach (Group B)

	Group A(n=54)	Group B(n=55)	P value
Age(year)	49.3±8.2	50.5±7.8	0.435
Gender			
Male	17	16	0.786
Female	37	39	
Course of disease (months)	8.9±4.2	8.1±4.4	0.334
Pinch strength (g/mm^2)	8.4±2.0	8.2±2.3	0.629
Grip strength (g/mm^2)	17.3±7.8	16.9±8.3	0.796
2-PD(mm)	7.2±1.5	7.4±1.7	0.517
VAS score	4.5±1.3	4.8±1.1	0.196
DASH score	55.3±20.1	53.8±19.1	0.690
BCTQ			
SSS	3.6±0.6	3.5±0.8	0.463
FSS	2.1±0.5	2.2±0.6	0.347

Abbreviations: 2-PD, two-point discrimination; VAS, Visual analogue scale; DASH, Disabilities of the arm, shoulder and hand; BCTQ, Boston carpal tunnel questionnaire; SSS, Symptom Severity Scale; FSS, Symptom Severity Scale.

Intraoperative Information and Postoperative Results

Table 2 indicates a significant difference in operation time between Group A (11.3±2.1 minutes) and Group B (20.5 ±4.3 minutes), with statistical significance (P<0.001). The incision lengths in Group A (16.3±2.1mm) and Group B (47.3 ±5.9mm) show a significant difference (P<0.001). There is a significant difference in return-to-work time between Group A (11.6±2.7 days) and Group B (14.2±3.1 days), which is statistically significant (P<0.001). Follow-up at 1, 3, and 6 months showed improvement in grip strength, pinch strength, and 2-PD for both groups. Postoperatively, the VAS score, DASH score, and BCTQ score were significantly lower. There were no significant differences in postoperative metrics between the two groups (P>0.05). Notably, Group A had fewer instances of wound pain and pillar pain during follow-up. By the sixth month, wound pain and pillar pain had completely disappeared in Group A, while Group B still had 5.5% and 7.3% cases of wound pain and pillar pain, respectively (Table 3).

Table 2 Comparison of Outcomes in Patients with Mini-Incision Approach (Group A) and Conventional Approach (Group B)

	Group A (n=54)	Group B (n=55)	P value
Operation time (min)	11.3±2.1	20.5±4.3	<0.001
Incision length (mm)	16.3±2.1	47.3±5.9	<0.001
Return to work (day)	11.6±2.7	14.2±3.1	<0.001

Note: Operation time, from the skin incision to closure.

Table 3 Comparison of Outcomes in Group A and Group B

	1 Month			3 Months			6 Months		
	Group A (n=54)	Group B (n=55)	P value	Group A (n=54)	Group B (n=55)	P value	Group A (n=54)	Group B (n=55)	P value
Wound pain									
Yes	4(7.4%)	10(18.2%)	0.093	1(1.9%)	6(10.9%)	0.124	0(0%)	3(5.5%)	0.248
No	50	45		53	49		54	52	
Pillar pain									
Yes	6(11.1%)	12(21.8%)	0.132	3(5.6%)	7(15.6%)	0.335	0(0%)	4(7.3%)	0.131
No	48	43		51	48		54	51	
Pinch strength (g/mm2)	9.3±1.9	9.0±2.1	0.436	10.5±2.0	10.4±2.1	0.800	11.7±2.3	11.5±2.5	0.665
Gripping strength (g/mm2)	19.8±5.8	18.8±6.1	0.383	21.6±6.2	21.4±6.4	0.869	23.1±6.3	22.8±6.2	0.803
2-PD(mm)	4.7±1.1	4.9±1.2	0.367	3.8±0.7	3.9±0.8	0.489	3.5±0.5	3.6±0.6	0.347
VAS Score	2.2±0.5	2.4±0.6	0.062	1.5±0.6	1.6±0.4	0.307	0.7±0.3	0.8±0.4	0.143
DASH Score	32.8±10.6	34.8±11.6	0.350	21.2±7.1	22.6±8.1	0.340	13.8±5.3	14.5±6.1	0.524
BCTQ									
SSS	2.5±0.7	2.5±0.8	1.000	1.7±0.6	1.8±0.8	0.463	1.3±0.4	1.4±0.4	0.195
FSS	1.6±0.6	1.7±0.7	0.425	1.3±0.3	1.4±0.5	0.209	1.2±0.2	1.3±0.4	0.103

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Complications

No patients required secondary surgery, and no instances of wound infection or dehiscence occurred. The procedure did not cause any harm to the median nerve, tendons, or artery.

Discussion

The median nerve can become compressed in the carpal tunnel due to prolonged incorrect wrist posture and constant bending, resulting in the frequent occurrence of CTS. The majority of patients affected are females aged 40–50.[16,17] Patients experiencing mild symptoms or short-term conditions can benefit from conservative medical management.[18] However, if conservative treatment is extended or if symptoms become severe, it could exacerbate the damage to the median nerve, resulting in decreased function and disability. Hence, it is advised by healthcare professionals for individuals with moderate to severe CTS to promptly undergo surgery in order to expedite the restoration of wrist function.[19] This study evaluated a new device-assisted mini-incision CTR technique in comparison with the conventional CTR for carpal tunnel syndrome. Overall, our findings demonstrate that the new mini-incision approach can achieve therapeutic outcomes equivalent to the conventional open procedure, while offering advantages in terms of operative efficiency and postoperative recovery. At 6 months postoperatively, there were no significant differences between the groups in grip or pinch strength, wound pain, pillar pain, sensation (2-PD), or patient-reported scores (DASH, BCTQ), indicating that the degree of median nerve decompression and functional restoration was comparable with either technique. This is an important point, as it suggests that the minimally invasive nature of the mini-incision approach did not compromise the completeness of carpal tunnel release or the overall surgical efficacy.

During the conventional CTR procedure, a curvilinear incision is created 5 mm on the ulnar side of the thenar crease, running parallel and proximal to it, in order to completely visualize the transverse carpal ligament. Benefits of conventional CTR include complete and reliable release, clear vision of the operative field, and simple surgical techniques. However, the occurrence of complications during surgery can be heightened with larger incisions, resulting in extended postoperative healing, pillar pain, and sensitivity at the scar location. Furthermore, there exists the potential for damage to the palmar cutaneous branch of the median nerve. Palm mini-incision CTR do not pass directly through the wrist, which can protect the skin and subcutaneous tissue of the wrist and reduce mechanical damage to the nerve tissue of the wrist, thereby reducing the occurrence of postoperative wound pain and pillar pain. Our new device minimizes incision length, which in turn reduce the incidence of incision-related complications.

Currently, there exist numerous methods of mini-incision surgery. Calleja et al employed two small incisions on the palm and wrist for carpal tunnel release. Despite satisfactory DASH score and Levine score results among postoperative patients, the authors noted a postoperative scar tenderness incidence of 15.6%.[20] Kaleff et al utilized a proximal mini-transverse incision approach for treating CTS on the wrist. Nevertheless, wrist scars may cause inconvenience to patients during daily activities, such as typing or using a mouse, where the wrist scars frequently come into contact with other objects.[8] Moreover, if the surgical approach needs to be changed to the conventional approach for some reasons during the operation, the transverse incision is difficult to change. Therefore, we use the palmar longitudinal mini-incision approach to treat CTS.

There are several details that need to be noted during our surgery. Firstly, prior to entering the carpal tunnel at the forearm's distal end, the median nerve emits its palmar cutaneous branch about 4 to 7 cm from the tunnel's entrance. Running alongside the primary trunk of the median nerve on the inner side of the flexor carpi radialis muscle, this branch extends towards the lower end before dividing when it reaches the surface of the transverse carpal ligament. It controls sensation in the thenar, wrists, and parts of the palms.[21] Following its descent to the palmar aponeurosis, the primary stem of the palmar cutaneous branch of the median nerve branches off into multiple smaller nerves. Most of these nerve branches govern the sensory functions of the skin and underlying tissue in the thenar and midpalm regions, with a minority branching out into the palmar aponeurosis to regulate its sensory capabilities. Some research have indicated the existence of differences in the palmar cutaneous branch of the median nerve. The recurrent branch from the palmar cutaneous branch of the median nerve may anastomose with the anterior branch of the lateral cutaneous nerve of the forearm. Furthermore, a connection may exist between the ulnar branch of the median nerve's palmar cutaneous branch and the palmar cutaneous branch of the ulnar nerve in the hypothenar region.[22,23] The palmar cutaneous branch of the

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ulnar nerve is not consistent, and when present, arises at variable levels from the ulnar nerve in the distal forearm, and innervates the skin of the medial palm.[24–32] The purpose of our special longitudinal incision is to reduce potential harm to the palmar cutaneous branches of both the ulnar and median nerves during surgery. Secondly, after incising the skin, bluntly separate the subcutaneous tissue and pay attention to the position of the superficial arterial arch. After locating the superficial arterial arch, the dissection tool can be cautiously inserted into the ulnar side of the palmaris longus tendon to avoid harm to any vital structures.[33] Thirdly, it is crucial to prevent any further harm when making an incision in the transverse carpal ligament during surgery. To enhance the safety of the mini-incision carpal tunnel release (CTR) procedure, we followed the safe zone principle, as described in our previous research.[34] The safe zone is defined as the area between the axis of the palmaris longus tendon and a vertical line extending from the hook of the hamate. This ensures that the incision and dissection are performed without endangering critical nerves or blood vessels. The guide was inserted within this safe zone (Figure 4), providing a controlled and secure pathway for dividing the transverse carpal ligament while minimizing iatrogenic injury risks. Some researches have documented considerable differences in the anatomy of the thenar motor branch of the median nerve.[35–37] In our study using the mini-incision technique, we did not observe variation in the thenar motor branch of the median nerve. However, if the incision is kept within the designated safe area, it is unlikely to result in any harm to the volar motor branch. These key points assure the safety and efficiency of this mini-incision procedure.

We believe that using a limited incision in the palm helps reduce the risk of wound pain and pillar pain, and our results support this, as no patients in the mini-incision group had persistent pillar pain at 6 months, whereas a few cases occurred in the open group. Wound pain is believed to result from the formation of small neuromas in the subcutaneous tissue caused by the severing of fine nerve branches. The precise mechanism and cause of pillar pain remain elusive and controversial [38,39] However, most scholars now believe that the cause is injury to the palmar cutaneous branch of the median nerve. In contrast, a palm-based incision is anatomically further from the main PCB trunk. Even if inadvertent injury occurs, it would likely involve only small distal branches, which are less clinically significant. Previous studies have demonstrated that mini-incision carpal tunnel release performed in the palm is associated with lower rates of pillar pain and related complications compared to traditional wrist-based incisions.[40]

The incision site plays a significant role in the development of postoperative scar tenderness. Wrist-based incisions are typically placed across the transverse wrist crease—a high-mobility, multi-axial joint region that undergoes frequent flexion-extension (130–160°) and radial-ulnar deviation (50–60°) during daily activities such as lifting, pushing, or bracing. These repetitive movements subject the overlying skin to mechanical stress, folding, and friction, increasing the risk of sensitive or painful scarring. In contrast, the palm—particularly the central palmar area where the mini-incision in this study was placed—is a biomechanically stable region. It does not span a joint, exhibits minimal motion, and is structurally supported by dense subcutaneous fat pads. This reduces the likelihood of shear stress and skin tension at the incision site. Additionally, the incision aligns with relaxed skin tension lines (Langer's lines),[41] which may further promote optimal healing and reduce the incidence of scar-related complications.

Effective management of wound and pillar pain is crucial for improving patient recovery and quality of life. Our results show that the mini-incision technique significantly reduces postoperative wound pain and pillar pain compared to the conventional approach. This reduction contributes to faster functional recovery and a shorter return-to-work interval, which is a key factor in patient satisfaction and overall surgical success. Given that pillar pain is a common concern after carpal tunnel release, minimizing this complication can lead to better long-term outcomes. The smaller incision and reduced tissue trauma in our approach likely contribute to this benefit. Future studies could further explore the long-term effects on pain resolution and functional recovery to reinforce these findings.

Beyond clinical effectiveness, the practicality of adopting this novel device is crucial. Surgeons familiar with conventional open CTR can adapt quickly with minimal additional training, unlike ECTR, which has a steeper learning curve. Additionally, ECTR requires specialized endoscopic equipment, which can cost tens or even hundreds of thousands of dollars, making it less accessible in resource-limited settings. In contrast, our mini-incision device is highly affordable, with a production cost of only a few dollars, and it is compatible with widely available digital tools like smartphones or tablets. These advantages make the mini-incision technique a cost-effective and feasible alternative,

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particularly for hospitals with budget constraints. Future studies should further explore its economic impact in different healthcare environments.

Our study is not without its constraints. First, though all data were collected prospectively, this study was retrospective in nature, and future research should prioritize prospective randomized controlled trials to ensure accuracy and validity of findings. Secondly, this study only compared the results of mini-incision approach with the conventional approach. Further comparison with other transverse carpal ligament release procedures is needed before this approach can be widely recommended. Thirdly, the mini-incision approach for carpal tunnel syndrome treatment is contraindicated for patients with space-occupying lesions in the carpal tunnel, including tophi deposition, bony space-occupying carpal tunnel, malunion after carpal fracture, wrist swelling, and other conditions. For the above situations, conventional CTR are still needed to release the carpal tunnel. Additionally, as this study was conducted at a single center, its generalizability may be limited. Future multicenter studies are needed to validate these findings in diverse settings. Lastly, while our study provides valuable short-term outcomes, longer follow-up is necessary to assess the durability of symptom relief and long-term functional recovery.

Conclusion

We introduced a new device-assisted mini-incision technique for the treatment of carpal tunnel syndrome and compared its surgical outcomes with those of the conventional approach. The results showed that the mini-incision technique yielded comparable functional outcomes, with lower rates of postoperative complications and smaller incisions, suggesting the new device-assisted mini-incision technique may be a feasible alternative in selected cases.

Ethical Statement

The study was approved by the Institutional Review Board Hebei Medical University Third Hospital in compliance with the Helsinki and an exemption from the informed consent was obtained (W2021-046-1).

All data were anonymized before the analysis to safeguard patient privacy.

Acknowledgments

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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The authors report no competing interests in this work.

References

1. Vasiliadis HS, Georgoulas P, Shrier I, Salanti G, Scholten RJ. Endoscopic release for carpal tunnel syndrome. *Cochrane Database Syst Rev*. 2014;2014(1):Cd008265. doi:10.1002/14651858.CD008265.pub2
2. Atroshi I, Gummesson C, Johnsson R, et al. Prevalence of carpal tunnel syndrome in a general population. *JAMA*. 1999;282(2):153–158. doi:10.1001/jama.282.2.153
3. Padua L, Coraci D, Erra C, et al. Carpal tunnel syndrome: clinical features, diagnosis, and management. *Lancet Neurol*. 2016;15(12):1273–1284. doi:10.1016/S1474-4422(16)30231-9

4. Doughty CT, Bowley MP. Entrapment Neuropathies of the Upper Extremity. *Med Clin North Am*. 2019;103(2):357–370. doi:10.1016/j.mcna.2018.10.012
5. Karl JW, Gancarczyk SM, Strauch RJ. Complications of carpal tunnel release. *Orthop Clin North Am*. 2016;47(2):425–433. doi:10.1016/j.ocl.2015.09.015
6. Tarallo M, Fino P, Sorvillo V, Parisi P, Scuderi N. Comparative analysis between minimal access versus traditional accesses in carpal tunnel syndrome: a perspective randomised study. *J Plast Reconstr Aesthet Surg*. 2014;67(2):237–243. doi:10.1016/j.bjps.2013.10.033
7. Okutsu I, Ninomiya S, Takatori Y, Ugawa Y. Endoscopic management of carpal tunnel syndrome. *Arthroscopy*. 1989;5(1):11–18. doi:10.1016/0749-8063(89)90084-4
8. Kaleff PR, Lima MSXD, Fernandes YB, et al. Carpal tunnel syndrome: treatment with small transverse incision. *Arq Neuropsiquiatr*. 2010;68(1):93–97. doi:10.1590/s0004-282x2010000100020
9. Hwang PY, Ho CL. Minimally invasive carpal tunnel decompression using the KnifeLight. *Neurosurgery*. 2007;60(2 Suppl 1):ONS162–168. doi:10.1227/01.Neu.0000249249.33052.7e
10. Lee YS, Youn H, Shin SH, Chung YG. Minimally invasive carpal tunnel release using a hook knife through a small transverse carpal incision: technique and outcome. *Clin Orthop Surg*. 2023;15(2):318–326. doi:10.4055/cios22223
11. Donati D, Goretti C, Tedeschi R, et al. Comparing endoscopic and conventional surgery techniques for carpal tunnel syndrome: a retrospective study. *JPRAS Open*. 2024;41:80–87. doi:10.1016/j.jpra.2024.05.003
12. Rajapandian R, Moti Wala S, Aledani EM, et al. Endoscopic versus open carpal tunnel release: a systematic review of outcomes and complications. *Cureus*. 2024;16(7):e64991. doi:10.7759/cureus.64991
13. Gummesson C, Atroshi I, Ekdahl C. The disabilities of the arm, shoulder and hand (DASH) outcome questionnaire: longitudinal construct validity and measuring self-rated health change after surgery. *BMC Musculoskelet Disord*. 2003;4(1):11. doi:10.1186/1471-2474-4-11
14. Chen S, Qian Y, Sun Z, et al. Effectiveness of therapeutic ultrasound for the treatment of carpal tunnel syndrome (the USTINCTS trial): study protocol for a three-arm, prospective, multicentre, randomised controlled trial. *BMJ Open*. 2022;12(4):e057541. doi:10.1136/bmjopen-2021-057541
15. Lue YJ, Lu YM, Lin GT, Liu YF. Validation of the Chinese version of the Boston carpal tunnel questionnaire. *J Occup Rehabil*. 2014;24(1):139–145. doi:10.1007/s10926-013-9438-9
16. Currie KB, Tadisina KK, Mackinnon SE. Common hand conditions: a review. *JAMA*. 2022;327(24):2434–2445. doi:10.1001/jama.2022.8481
17. Walter K. What is carpal tunnel syndrome? *JAMA*. 2022;328(6):593. doi:10.1001/jama.2022.10522
18. Donati D, Boccolari P, Tedeschi R. Manual therapy vs. surgery: which is best for carpal tunnel syndrome relief? *Life*. 2024;14(10):1286. doi:10.3390/life14101286
19. Georgeto SM, Picharski GL, Andraus RAC, et al. Outcomes of bilateral carpal tunnel syndrome treatment - A systematic review and meta-analysis. *J Plast Reconstr Aesthet Surg*. 2022;75(9):3250–3259. doi:10.1016/j.bjps.2022.06.070
20. Calleja H, Tsai TM, Kaufman C. Carpal tunnel release using the radial sided approach compared with the two-incision approach. *Hand Surg*. 2014;19(03):375–380. doi:10.1142/s0218810414500300
21. Smith JL, Ebraheim NA. Anatomy of the palmar cutaneous branch of the median nerve: a review. *J Orthop*. 2019;16(6):576–579. doi:10.1016/j.jor.2019.06.010
22. Taleisnik J. The palmar cutaneous branch of the median nerve and the approach to the carpal tunnel. *Anatomical Study J Bone Joint Surg Am*. 1973;55(6):1212–1217. doi:10.2106/00004623-197355060-00008
23. Bezerra AJ, Carvalho VC, Nucci A. An anatomical study of the palmar cutaneous branch of the median nerve. *Surg Radiol Anat*. 1986;8(3):183–188. doi:10.1007/bf02427847
24. Vasiliadis HS, Tokis AV, Andrikoula SI, et al. Microsurgical dissection of the carpal tunnel with respect to neurovascular structures at risk during endoscopic carpal tunnel release. *Arthroscopy*. 2006;22(8):807–812. doi:10.1016/j.arthro.2006.03.021
25. Sacks JM, Kuo YR, McLean K, Wollstein R, Lee WPA. Anatomical relationships among the median nerve thenar branch, superficial palmar arch, and transverse carpal ligament. *Plast Reconstr Surg*. 2007;120(3):713–718. doi:10.1097/01.prs.0000270305.37677.e7
26. Tubbs RS, Rogers JM, Loukas M, et al. Anatomy of the palmar branch of the ulnar nerve: application to ulnar and median nerve decompressive surgery. *J Neurosurg*. 2011;114(1):263–267. doi:10.3171/2010.3.Jns091249
27. Sulaiman S, Soames R, Lamb C. An anatomical study of the superficial palmar communicating branch between the median and ulnar nerves. *J Hand Surg Eur Vol*. 2016;41(2):191–197. doi:10.1177/1753193415576460
28. Loukas M, Louis RG, Stewart L, et al. The surgical anatomy of ulnar and median nerve communications in the palmar surface of the hand. *J Neurosurg*. 2007;106(5):887–893. doi:10.3171/jns.2007.106.5.887
29. Punja R, Kini G, Hosapatna M. Unexplored parameters of ulnar nerve in the palm and its clinical implications; A cadaveric study. *Ann Med Surg Lond*. 2022;74:103259. doi:10.1016/j.amsu.2022.103259
30. Sulaiman S, Soames R, Lamb C. Ulnar nerve cutaneous distribution in the palm: application to surgery of the hand. *Clin Anat*. 2015;28(8):1022–1028. doi:10.1002/ca.22626
31. Neumann M, Suchomlinov A. Pilot cadaveric study of anatomical variations of the median nerve at the wrist in the Lithuanian population. *Cureus*. 2023;15(5):e39282. doi:10.7759/cureus.39282
32. Theofilopoulou S, Katouni K, Papadopoulos V, et al. Variations of the median nerve and carpal tunnel syndrome: a systematic review of the literature. *Maedica*. 2023;18(4):699–704. doi:10.26574/maedica.2023.18.4.699
33. Simić M, Bumbaširević M, Jović D, et al. Persistent median artery and communicating branch related to the superficial palmar arch. *Sci Rep*. 2024;14(1):222. doi:10.1038/s41598-023-50935-2
34. Bai J, Kong L, Zhao H, et al. Carpal tunnel release with a new mini-incision approach versus a conventional approach, a retrospective cohort study. *Int J Surg*. 2018;52:105–109. doi:10.1016/j.ijsu.2018.02.033
35. Al-Qattan MM. Variations in the course of the thenar motor branch of the median nerve and their relationship to the hypertrophic muscle overlying the transverse carpal ligament. *J Hand Surg Am*. 2010;35(11):1820–1824. doi:10.1016/j.jhsa.2010.08.011
36. Lindley SG, Kleinert JM. Prevalence of anatomic variations encountered in elective carpal tunnel release. *J Hand Surg Am*. 2003;28(5):849–855. doi:10.1016/s0363-5023(03)00365-4
37. Lutsky KF, Jones CM, Kim N, et al. Frequency of incidental median thenar motor nerve branch visualization during mini-open and endoscopic carpal tunnel release. *Hand*. 2017;12(1):60–63. doi:10.1177/1558944716643095

38. Ludlow KS, Merla JL, Cox JA, Hurst LN. Pillar pain as a postoperative complication of carpal tunnel release: a review of the literature. *J Hand Ther*. 1997;10(4):277–282. doi:10.1016/s0894-1130(97)80042-7
39. Yung PS, Hung LK, Tong CW, Ho PC. Carpal tunnel release with a limited palmar incision: clinical results and pillar pain at 18 months follow-up. *Hand Surg*. 2005;10(01):29–35. doi:10.1142/s0218810405002413
40. Bal E, Pişkin A, Ada S, et al. Comparison between two mini incision techniques utilized in carpal tunnel release. *Acta Orthop Traumatol Turc*. 2008;42(4):234–237. doi:10.3944/aott.2008.234
41. Rosicka K, Hill M, Wdowski MM. Skin anisotropy: finding the optimal incision line for volar forearm in males and females. *J Mech Behav Biomed Mater*. 2021;124:104805. doi:10.1016/j.jmbbm.2021.104805