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# Mini-open versus conventional open carpal tunnel release: A detailed comparison of efficacy, feasibility, and complications

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### *Abstract*

*Backgrounds:* In surgical treatment of carpal tunnel syndrome, both conventional open carpal tunnel release technique (COT) and mini-open technique with KnifeLight (MOT-K) are effective and safe. However, there is a need for a detailed study comparing outcome, feasibility, complications, and time to return to daily activities/work, supported by itemized electrophysiological evidence. *Methods:* Patients with carpal tunnel syndrome were enrolled into COT and MOT-K groups. Preoperative and postoperative characteristics such as Boston Symptom Severity Scale, Boston Functional Status Scale, patient global assessment, physical examination findings, grip strength, and electrophysiological findings were compared between groups. Groups were also compared in terms of duration of the procedure, incision length, time to return to daily activities and work, edema, scar tenderness, scar hypertrophy, pillar pain, and patient satisfaction. *Results*: There were no differences in demographics and baseline clinical and electrophysiological characteristics between patients undergoing COT or MOT-K procedures. Both groups showed significant postoperative improvements in terms of symptoms and functional scores. In terms of electrophysiological parameters, improvements in distal motor latency were observed in both groups and in sensory amplitudes only in the MOT-K group. The MOT-K group had a shorter operation time, a shorter incision length, and a faster return to daily activities and work. The incidence of oedema, scar tenderness, and scar hypertrophy was also lower in the MOT-K group. *Conclusions:* Although both COT and MOT-K have similar efficacy, MOT-K seems more advantageous in terms of minor complications and return to daily activities/work.

*Keywords:* Carpal tunnel syndrome, median nerve, minor surgical procedure, decompression, electrophysiology, minimally invasive surgery, knifelight

## INTRODUCTION

Carpal tunnel syndrome (CTS) is the most common peripheral entrapment neuropathy.[1] Diagnosis of CTS is based on the medical history and physical examination findings. In addition, electrodiagnostic tests are used for initial and differential diagnosis and for post-treatment follow-up.[2] Nerve conduction studies (NCS) can show the decrease in axonal conduction velocity in nerve fibres with focal demyelination due to nerve compression.[3] There is a wide treatment spectrum, but the main treatment for severe CTS is surgery. Conventional open carpal tunnel release (conventional open technique, COT) is the most commonly used surgical technique, it has been extensively studied, and its complications are well known.[4] However, complications such as hypertrophic tender scars, tightness and prolapse of the flexor tendons, and loss of work due to delayed return to daily activities and work, have led researchers to search for minimally invasive surgical methods.[5–8] Other surgical options include endoscopic surgery and device-assisted mini-open

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carpal tunnel release. They have been developed as alternative methods for patients at high risk of complications. For the mini-open technique, a device called KnifeLight has been developed (Stryker Instruments, Kalamazoo, Michigan, USA) and used successfully.[9]

In the clinical practice, COT requires a 3-5 cm incision, whereas endoscopic release and mini-open technique with KnifeLight (MOT-K) require smaller incisions. There are few trials comparing the effectiveness and complications of these 3 methods. They are binary comparisons and generally superficial in their effectiveness. The mini-open technique was considered superior in terms of avoiding the palmar cutaneous branch of the median nerve, according to anatomical studies.[10–14] Regarding the endoscopic technique, there are controversial results.[15–18] However, for the third method, MOT-K, previous studies are not detailed enough to guide surgeons.[9,19–22] Finally, there is a need for a study that includes detailed clinical and electrophysiological outcomes, feasibility, complications, and return to work that can establish a cause and effect relationship.

In this study, we aimed to compare the symptomatic, functional and electrophysiological efficacy between COT and MOT-K. We also aimed to compare feasibility, complications, and time to return to daily activities/work between these techniques.

## METHODS

We conducted a retrospective cohort at Dışkapı Yıldırım Beyazit Training and Research Hospital, Departments of Orthopaedics and Traumatology and Physical Medicine and Rehabilitation. It was approved by the ethics committee of our institution (number 40/23) and conducted in accordance with the Declaration of Helsinki.

In the KnifeLight cohort, which started in 2015, all patients with CTS underwent NCS testing, including measurement of bilateral median and ulnar nerve conduction tests. Physical examination findings, the Boston Symptom Severity and Functional Status Scale, and handgrip strength were also recorded. All patients from 2015 who underwent the MOT-K surgical technique described below were included in this study. Patients matched for age, sex, and baseline electrophysiological severity were included in the control group.

The study included patients between the ages of 18 and 75 who were diagnosed with clinically severe CTS for which surgery was indicated. Patients with a history of CTR surgery, other concomitant peripheral entrapment neuropathy of the upper extremity, cervical disc herniation, and a history of fracture or anomaly of the upper extremity were excluded from the study. All patients enrolled in the study were informed of the surgical procedures to be performed and all signed written informed consent.

### *Preoperative assessment*

Before surgery, demographics, patient global assessment by visual analogue scale (VAS), Boston Symptom Severity Scale, Boston Functional Status Scale, thenar atrophy, sensory deficit, Tinel's test, Phalen's test and handgrip strength tests were recorded.[23,24] Hand grip strength was assessed using a hand dynamometer (Grip Saehan Corporation, Korea). Patients were asked to squeeze the dynamometer with the affected hand 3 times with maximum effort while sitting, and the highest value was recorded.

All patients underwent preoperative NCS. Median nerve antidromic sensory action potential amplitude (μV) and sensory conduction velocity (m/s) in the second finger, median nerve distal motor latency at the level of the wrist (ms), compound muscle action potential amplitude (mV) and motor conduction velocity (m/s) were assessed during electrophysiological evaluation. Absent or low sensory and/or motor amplitudes, prolonged distal motor latency, and slow sensory and/or motor conduction velocity were considered NCS findings suggestive of CTS.

### *Operative techniques*

All procedures were performed by the same surgeon who was trained in the techniques. Both procedures were performed under local anaesthesia induced by injection of 5-10 ml of 2% prilocaine (with a 1:100000 concentration of adrenaline) without the use of a tourniquet. KnifeLight is a disposable CTR device. The cutter blade lies between 2 blunt transparent plastic skids. The device has a battery-operated light source located inside the longer plastic skid under the knife blade. In the technique used in this study, a longitudinal skin incision of a length of approximately 15 mm centered the intersection between the oblique line drawn from the ulnar side of the thumb in the abduction and the line drawn along the longitudinal axis of the forearm from the 3rd web (Figure 1). The distal end of the transverse carpal ligament was accessed by passing the subcutaneous adipose tissue and

palmar fascia. A curved clamp was placed under the transverse carpal ligament to protect the median nerve, and a 2-3 mm incision was made over the clamp from the distal to the proximal end of the ligament. The longer lower skid of KnifeLight was placed below the transverse carpal ligament and the shorter upper skid was placed above the transverse carpal ligament to keep the cutter blade at the distal end of the transverse carpal ligament corresponding to the location of the incision made. The light on the device was switched on and the lights in the operating room were switched off. The wrist was extended 15°-20° and supported by placing a pad underneath. The transverse carpal ligament was cut after the device was positioned and moved proximally, and the light emitted from the device disappeared as the light source in the longer lower runner remained under the ligament. The resistance felt when the ligament was cut decreased at the wrist level and the light emitted from the device became visible again, indicating that the ligament had been completely released. The incision was closed with non-absorbable sutures after haemostasis was achieved.[19]

In the COT, a longitudinal skin incision of approximately 4 cm was made from the intersection between the oblique line drawn from the ulnar side of the thumb in the abduction and the 3rd web to the distal wrist crease. Subcutaneous tissue was passed, then the palmar fascia was opened and the transverse carpal ligament was reached. A curved clamp was placed under the transverse carpal ligament to protect the median nerve, and an incision of approximately 5 mm was made over the clamp from the distal to the proximal end of the ligament. After supporting the wrist by placing a pad underneath to extend it 15°-20°, the transverse carpal ligament was cut with blunt tissue scissors. The incision was closed with non-absorbable sutures after haemostasis was achieved.

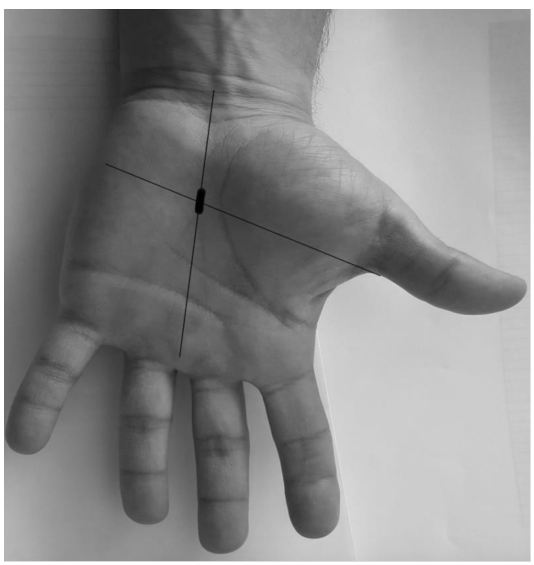

Figure 1. Where to cut using the mini-open technique with KnifeLight

Patients' operative notes (including length of incision and duration of procedure) were recorded.

*Postoperative assessment*

Patients were followed every other day after surgery. Sutures were removed on postoperative days 12-14. Patients with wound discomfort were also followed every other day after suture removal and satisfactory wound healing time was recorded.

At 10 weeks after surgery, patients were assessed for wound healing time, time to return to daily activities and work, wound oedema, scar tenderness, scar pain and scar hypertrophy. As the main objectives of this study were to assess return to work/daily activities and related scar complications and electrophysiological results, a short but electrophysiologically tolerable period was chosen for postoperative evaluation. Choosing an evaluation period months after surgery might have resulted in a lack of recall of data on pain and return to work. Therefore, a period of 10 weeks (the days after return to work) was chosen. At the end of 10 weeks, patients were reassessed for global clinical status, handgrip strength, Boston Symptom Severity Scale and Boston Functional Status Scale scores, and electrophysiological status. Patient satisfaction was assessed using a Likert scale.

*Statistical analysis*

IBM Statistical Package for Social Sciences version 24 was used for analysis. Values with a normal distribution were expressed as mean (standard deviation) and those without a normal distribution were expressed as median (minimum, maximum). Student's t-test or Mann-Whitney U test was used to assess differences between independent groups, and paired sample t-test or paired sample Wilcoxon test was used to assess differences between dependent groups. A p-value of $<0.05$ was considered statistically significant. The minimum sample size required was calculated to be 16 to achieve significant recovery on the Boston Symptom Severity Scale according to a previous similar study.[25] The sample size was

also calculated for electrophysiological sensory amplitude and 12 patients were required to achieve a significant recovery (alpha-value set at 0.05 and the power of at least 80%, calculated in GPower 3.0).

## RESULTS

According to the eligibility criteria, a total of 29 patients were included in the study, of whom 25 were women and 4 were men. The demographic and clinical data of the patients and their distribution according to surgical technique are shown in Table 1.

All patients underwent a neurological examination immediately after procedure, including loss of thumb function. No patients in either group experienced neurological deficits, including all thumb functions.

Changes in clinical and electrophysiological parameters in the two groups before and after surgery and their statistical significance are shown in Table 2. They were also tested to see if these changed according to group.

The comparison of the 2 surgical techniques in terms of length of incision, duration of surgery, early results and complications is shown in Table 3. Incision length, duration of surgery, wound healing time, time to return to daily activities and work, oedema rate, scar tenderness and scar hypertrophy rates were significantly different between the groups in favour of MOT-K ($p < 0.05$). There was no significant difference between the groups in terms of pillar pain and patient satisfaction.

## DISCUSSION

Our cohort shows that both COT and MOT-K offer practical improvements in the surgical treatment of

**Table 1: Distribution of patients to the COT and MOT-K groups, their demographic and clinical data, and statistical significance of the difference between the groups***

| Demographic and clinical data | COT | MOT-K | p |
|---|---|---|---|
| n (with pre- and post-operative assessments) | 15 | 14 | |
| Age, years (SD) | 56.13 (11.16) | 50.57 (8.38) | 0.14 |
| Ratio of females | 93.3% | 76.8% | 0.33 |
| Ratio of employed patients | 33.3% | 42.9% | 0.71 |
| Rate of right-hand dominance | 87.5% | 100% | 0.48 |
| Duration of complaints, months (min, max) | 24 (1, 66) | 12 (1, 120) | 0.16 |
| Patient global assessment, VAS (SD) | 7.68 (1.85) | 7.47 (1.77) | 0.84 |
| Tinel's test positivity rate | 80% | 71.4% | 0.68 |
| Phalen's test positivity rate | 86.7% | 92.9% | 0.96 |
| Presence of thenar atrophy | 46.7% | 57.1% | 0.57 |
| Rate of sensory deficit positivity | 73.3% | 42.9% | 0.14 |
| Handgrip strength, kg (min, max) | 12 (1, 28) | 17 (7, 54) | 0.20 |
| Boston Symptom Severity Scale (SD) | 2.97 (0.62) | 2.55 (0.85) | 0.14 |
| Boston Functional Status Scale (SD) | 3.05 (0.69) | 2.40 (0.87) | 0.03 |
| Severe CTS on NCS | 46.7% | 42.9% | 0.83 |
| Sensory AP amplitude, $\mu$V (min, max) | 7.3 (0, 37.5) | 6.5 (0, 25.5) | 0.75 |
| Sensory conduction velocity, m/s (min, max) | 28.1 (0, 49) | 29.8 (0, 40.5) | 0.96 |
| Distal motor latency, ms (SD) | 4.82 (1.83) | 5.98 (2.07) | 0.12 |
| Motor CMAP amplitude, mV (min, max) | 6.4 (0, 28) | 8.55 (0.5, 24.3) | 0.48 |
| Motor conduction velocity, m/s (min, max) | 51 (0, 59.5) | 51.7 (39.6, 55.9) | 0.44 |

*The values are presented as percentage (%), median (min, max) or mean (SD). COT = conventional open technique, MOT-K = mini-open technique with KnifeLight, SD = standard deviation, VAS = visual analog scale, CTS = carpal tunnel syndrome, NCS = nerve conduction study, AP = action potential, and CMAP = compound muscle action potential

**Table 2: Comparison of the clinical and electrophysiological parameters before and after surgery between patients undergoing surgery with the COT and those undergoing surgery with the MOT-K***

| Parameter | Group | | Mean (SD) | Median (min, max) | 95% CI | p | $p^{\alpha}$ |
|---|---|---|---|---|---|---|---|
| BSSS score | COT | Preop | 2.97 (0.62) | 3.04 (1.45, 4.09) | 2.65-3.29 | ***<0.01*** | 0.78 |
| | | Postop | 1.88 (0.85) | 1.67 (1.09, 3.63) | 1.44-2.32 | | |
| | MOT-K | Preop | 2.55 (0.85) | 2.54 (1.54, 3.82) | 2.10-3.01 | ***<0.01*** | |
| | | Postop | 1.36 (0.58) | 1.09 (1, 3.18) | 1.04-1.66 | | |
| BFSS score | COT | Preop | 3.05 (0.69) | 3.06 (1.6, 4.33) | 2.69-3.40 | ***<0.01*** | 0.74 |
| | | Postop | 1.77 (0.88) | 1.55 (1, 3.87) | 1.31-2.22 | | |
| | MOT-K | Preop | 2.40 (0.87) | 2.5 (1, 4.12) | 1.94-2.87 | ***<0.01*** | |
| | | Postop | 1.25 (0.37) | 1.12 (1, 2.12) | 1.05-1.45 | | |
| PGA, VAS | COT | Preop | 7.67 (1.85) | 7 (4, 8) | 6.70-8.67 | ***<0.01*** | 0.45 |
| | | Postop | 2.94 (2.59) | 3 (0, 8) | 1.55-4.32 | | |
| | MOT-K | Preop | 7.47 (1.77) | 7 (5, 8) | 6.49-8.44 | ***<0.01*** | |
| | | Postop | 2.00 (2.00) | 2 (0, 7) | 0.89-3.11 | | |
| Handgrip strength, kg | COT | Preop | 13.27 (7.71) | 11.5 (1, 28) | 9.14-17.11 | 0.65 | 0.79 |
| | | Postop | 14.07 (6.02) | 13.5 (7, 30) | 10.96-17.16 | | |
| | MOT-K | Preop | 18.57 (10.99) | 17 (7, 54) | 12.19-24.07 | 0.46 | |
| | | Postop | 20.07 (16.08) | 14 (10, 74) | 11.48-28.65 | | |
| Sensory AP amplitude, $\mu$V | COT | Preop | 9.51 (11.29) | 7.3 (0, 37.5) | 3.50-15.53 | 0.24 | 0.47 |
| | | Postop | 18.42 (26.94) | 4.1 (0, 77.9) | 4.07-32.78 | | |
| | MOT-K | Preop | 7.93 (8.33) | 6.5 (0, 25.5) | 3.31-12.54 | ***0.03*** | |
| | | Postop | 17.47 (2.92) | 13.95 (0, 77.9) | 4.77-30.16 | | |
| Sensory conduction velocity, m/s | COT | Preop | 18.95 (17.94) | 28.1 (0, 49) | 9.39-28.51 | 0.88 | 0.39 |
| | | Postop | 19.56 (16.87) | 29 (0, 41.4) | 10.57-28.55 | | |
| | MOT-K | Preop | 19.27 (16.49) | 29.8 (0, 40.5) | 10.13-28.40 | 0.13 | |
| | | Postop | 24.41 (16.79) | 29.9 (0, 50) | 15.11-33.71 | | |
| Distal motor latency, ms | COT | Preop | 4.82 (1.83) | 5.15 (0, 7.56) | 3.92-5.80 | ***0.04*** | 0.14 |
| | | Postop | 4.22 (1.94) | 4.31 (0, 9.74) | 3.22-5.22 | | |
| | MOT-K | Preop | 5.98 (2.07) | 5.58 (3.62, 10.6) | 4.84-7.05 | ***<0.01*** | |
| | | Postop | 3.87 (1.79) | 4.47 (0, 5.99) | 2.97-4.90 | | |
| CMAP amplitude, mV | COT | Preop | 6.90 (6.75) | 6.4 (0, 28) | 3.31-10.50 | **0.03** | 0.65 |
| | | Postop | 4.29 (3.21) | 4.6 (0, 9) | 2.57-6.00 | | |
| | MOT-K | Preop | 7.93 (6.54) | 8.55 (0.5, 24.34) | 4.31-11.56 | ***<0.01*** | |
| | | Postop | 5.58 (5.65) | 3.45 (0, 19.83) | 2.44-8.71 | | |
| Motor conduction velocity, m/s | COT | Preop | 45.10 (14.11) | 51 (0, 59.5) | 37.58-52.62 | 0.95 | 0.67 |
| | | Postop | 46.02 (15.36) | 50 (0, 67) | 37.84-54.21 | | |
| | MOT-K | Preop | 49.25 (5.38) | 51.7 (39.6, 55.9) | 46.27-52.23 | 0.97 | |
| | | Postop | 43.34 (20.83) | 50.50 (0, 64) | 31.80-54.88 | | |

* $p^{\alpha}$ = Statistical significance of the difference between the mean changes in the groups before and after surgery. COT = conventional open technique, MOT-K = mini-open technique with KnifeLight, SD = standard deviation, BSSS = Boston Symptom Severity Scale, BFSS = Boston Functional Status Scale, PGA = patient global assessment, VAS = visual analog scale, AP = action potential, and CMAP = compound muscle action potential

**Table 3: Postoperative assessment data of patients operated using the COT and those undergoing surgery using MOT-K***

| Parameters assessed after surgery | COT | MOT-K | p |
|---|---|---|---|
| Incision length, mm (min, max) | 38 (33, 45) | 14 (12, 20) | ***<0.01*** |
| Duration of the procedure, minutes (SD) | 14.87 (3.18) | 6.861 (1.93) | ***<0.01*** |
| Wound healing time, days (min, max) | 20 (14, 39) | 14 (12, 15) | ***<0.01*** |
| Time to return to daily activities, days (min, max) | 9 (3, 30) | 2.5 (2, 7) | ***<0.01*** |
| Time to return to work for employed patients, days (min, max) | 30 (15, 44) (n=6) | 19 (13, 21) (n=7) | ***0.03*** |
| Rate of edema | 66.7% | 14.3% | ***0.01*** |
| Rate of scar tenderness | 60% | 7.1% | ***<0.01*** |
| Rate of pillar pain | 46.7% | 14.3% | *0.11* |
| Rate of scar hypertrophy | 33.3% | 0% | ***0.04*** |
| Satisfaction on a Likert-type scale | | | |
| Dissatisfied | 20% | 7.1% | 0.72 |
| A Bit Dissatisfied | 6.7% | 0% | |
| Satisfied | 6.7% | 7.1% | |
| Very Satisfied | 66.7% | 85.7% | |

*The values are given as percentage (%), median (min, max) or mean ± SD. COT = conventional open technique, MOT-K = mini-open technique with KnifeLight, SD = standard deviation

CTS. Symptoms, functional scores, grip strength and a large number of electrophysiological results were similar in the two groups. Exceptionally, MOT-K was slightly superior in terms of the improvement in sensory amplitudes. In addition, duration of surgery, incision length, time to return to daily activities and rates of perioperative oedema, scar tenderness and scar hypertrophy were lower in the MOT-K group.

In the MOT-K procedure, the transverse carpal ligament is cut blindly through a small incision under the guidance of a light source. Tendons and neurovascular structures are preserved during surgery due to the design of the device.[19,20] In our study, the palmar region rather than the wrist was preferred as the site for the incision because of the potential risk of injury to the superficial palmar arch.[26] In a cadaver study involving histological examination of the palmar area corresponding to the second web, third finger axis, third web and fourth finger axis, Ruch *et al*. found that nerve structures were least dense in the third web.[27]

Therefore, a mini-incision was made in the direction of the third web in the mid-palmar area, which is a designated safe area for performing the technique using KnifeLight.

The rate of scar tenderness following COT ranges from 19% to 61%.[28] In a study using the same incision as the MOT-K group, Klein *et al*. found a scar tenderness rate of 2.88%.[29] In the studies by Bhattacharya *et al*. and Helm and Vaziri comparing COT and the KnifeLight technique using the same incisions, scar tenderness was significantly more common in the COT group than in the MOT-K group.[21,22] In our study, the rate of scar tenderness was 60% in the COT group and 7.1% in the MOT-K group, and the difference was statistically significant. These results are consistent with those reported in the literature. In addition, the rate of scar hypertrophy was 33.3% in the COT group and 0% in the MOT-K group, a statistically significant difference.

Subcutaneous nerves in the pillar region are at risk of injury during COT.[12–14,30] This is associated with postoperative pillar pain. Serra *et al*. reported pillar pain at 3 months postoperatively in 15 of 112 patients (13%) who underwent surgery via a mini-incision in the mid-palmar region, and pillar pain persisted in only 6 patients at 12 months.[8] The rate of pillar pain was found to be 46.7% in the COT group and 14.3% in the MOT-K group, with no statistically significant difference between the groups. Despite a numerical difference in the rate of pillar pain between the groups in our study, the lack of a statistically significant difference supports the notion that pillar pain may be independent of the surgical technique used, as noted by DaSilva *et al*.[12]

We compared the results in terms of symptom relief and functional effectiveness; COT and the

KnifeLight technique were found to be effective with no significant difference between the groups. In addition, evaluation of the functional status in both groups before and after surgery using the Boston Functional Status Scale showed significant functional improvement after surgery, with no significant difference between the groups. Similarly, Bhattacharya *et al*. and Helm and Vaziri reported that both techniques were effective in providing symptomatic relief, with no difference reported between groups.[21,22] According to these data, both techniques are effective in providing symptomatic relief and there is no difference between these 2 techniques.

One of the strengths of the present study is that it included a detailed electrophysiological assessment. With regard to electrophysiological status, each parameter such as median nerve sensory action potential amplitude, sensory conduction velocity, distal motor latency, compound muscle action potential and motor conduction velocity was assessed individually. Although there was evidence of improvement in the distal motor latency in both groups, there was no significant improvement in the motor conduction velocity and amplitude. The reason for this finding could be that the NCS was performed in the early period and the distal motor latency is more sensitive than the other parameters.[3] Although there was an improvement in the sensory amplitude in both groups, only the improvement in the MOT-K group was statistically significant. The lack of significant improvement in terms of the sensory amplitude in the COT group can be explained by the fact that the surgical technique may have caused further injury to the sensory nerves.

The time to return to daily activities and work was shorter in the MOT-K group, and the difference between the two groups was statistically significant in our study. A previous study of KnifeLight was reported that the mean time to return to personal care and work after surgery was 3 and 23 days, respectively.[20] In the study by Helm and Vaziri, the mean time to return to work was 28 days in the COT group and 20 days in the MOT-K group, with a statistically significant difference between the groups.[22]

This study concludes that CTS surgery using the KnifeLight mini-incision provides surgical outcomes that are comparable to conventional incision in terms of symptom relief, functional outcomes, and electrophysiological outcomes. On the other hand, the use of KnifeLight in CTS surgery has been shown to be beneficial, with a shorter time to return to daily activities and work and lower rates of minor complications. Our results suggest that the surgical treatment of CTS using KnifeLight is successful, and we recommend the use of this surgical technique in the surgical treatment of CTS.

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## DISCLOSURE

Availability of data: The datasets used are available from the corresponding author upon reasonable request.

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Conflict of interests: None

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