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Post Surgical Outcomes Following Limited-Open Carpal Tunnel Release or Endoscopic Carpal Tunnel Release

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POST SURGICAL OUTCOMES FOLOWING LIMITED-OPEN CARPAL TUNNEL RELEASE OR ENDOSCOPIC CARPAL TUNNEL RELEASE

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BY

KEELEY SHAYE SMITH

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ABSTRACT

Carpal Tunnel Syndrome is a neurological condition that may contribute to decreased grip strength, sensory function, activities of daily living, and many other negative impacts on an individual's life. The purpose of this study was to assess whether patients who received endoscopic carpal tunnel release had better patient reported outcomes than patients who received limited-open carpal tunnel release. This study prospectively assessed patient reported outcomes such as pain, Patient-Specific Functional Score, Quick Disabilities of the Arm Shoulder and Hand Score, two-point discrimination, and hand grip-strength. This study demonstrated that there were significant differences within all subjective data measures ($p \leq 0.017$) from the preoperative time-period to most recent follow up for all subjects despite the surgical technique, however; there was no significant difference within the objective measures. There was no significant difference when comparing subjective or objective measures between the two operative techniques. These findings suggest that in both surgical techniques, patients feel that they are getting better when asked to rate their symptoms in a subjective manner. In other words, both surgical techniques improve patient perceived pain, function, and disability outcomes.

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I. Introduction

In 1854, Carpal tunnel syndrome (CTS) was described by Paget as a mononeuropathy due to a compressive force distorting the carpal tunnel.[1] The American Academy of Orthopaedic Surgeons (AAOS) has adopted the modern day definition of CTS as a symptomatic compression neuropathy of the median nerve at the level of the wrist.[2] CTS has been represented in the literature as the most common entrapment neuropathy, attributing to 90% of all cases.[2]

The prevalence of CTS ranges in general populations due to differences in case definitions, study designs, inclusion criteria, and geographic location.[3] In a pooled cohort study, a prevalence of 7.8% among 4,321 working individuals in the United States was found. This cohort also found an incidence of 9.3 per 100 person-years.[3] Yet, another more comprehensive study in southern Sweden found a prevalence of 4% in the general population of 170,000. This study also showed the condition to be more prevalent in females, with a male-to-female ratio of 1.0:1.4.[4]

A general population study in Sienna, Italy was done over an eight-year period. The study found that 3,142 cases were identified, with 80% of cases in females and 20% in males.[5] An incidence rate of 276 per 100,000 exposures was shown with sex-specific incidences at 139 for men and 506 for women.[5] Another study found that 1 per 1000 individuals of the general population in England will be diagnosed with CTS each year.[6] Individuals in the age range of 40- 60 are most commonly affected.[7] To date, CTS is the most common form of median-nerve entrapment.[7]

In order for the orthopedic surgeon to determine the best route of treatment for each individual, factors such as the patient's job, relationship to work, co-morbidities, and personal factors must be considered. [2] Non-occupational risk-factors include pregnancy, advancing age, female gender, strong family history, and some medical disorders.[2] Many clinical cases of CTS will have no identifiable etiology or co-morbidity, and this should be taken into consideration by the diagnosing physician or orthopedic surgeon.[2]

Treatment strategies such as wrist splinting and physical therapy may be useful if the condition is mild or temporary (e.g. extremity effusion in pregnancy). In such cases, the treatment protocol likely will not exceed 6 weeks before the orthopedic surgeon suggests a different route of treatment. For cases that require more extensive treatment, surgical decompression may be necessary. There are currently three methods for carpal tunnel release, open, limited-open, and endoscopic.[14] Each decompression method has lent to positive post-surgical outcomes, with variations on the methods lying in the orthopedic surgeons training techniques.[29-35]

Although it has been established that patients receiving carpal tunnel release will likely have positive results[29-35], it is not well known if patient-reported outcomes are improved similarly between two common decompression strategies. Two well-established techniques include a single-port endoscopic carpal tunnel release, and limited-open carpal tunnel release. There are many studies in which assess the usefulness of pain scores, functional scores, disability ratings, and even objective patient function in response to various CTR methods.[9-10,24-25,30, 39-50] However, with

improvements in technology, and therefore decreases in invasiveness of procedures, modern day carpal tunnel release methods need to be compared. Concrete evidence of how patients are responding to treatment through subjective surveys may help diffuse any current speculation. More data measures on objective measures, however, may help to prove or disprove the effectiveness of these strategies, when comparing them to how the patient is subjectively rating their pain, dysfunction, and disability.

Since a gap exists in the literature comparing endoscopic carpal tunnel release (ECTR) with limited-open carpal tunnel release (LOCTR), by use of pain scores, Patient-Specific Functional Scores, Quick Disabilities of the Arm Shoulder and Hand Score, two-point discrimination, and hand grip strength, the purpose of the present research was to assess the differences in these metrics between patients undergoing either procedure.

II. Literature Review

Background

In 1854, Carpal tunnel syndrome (CTS) was described by Paget as a mononeuropathy due to a compressive force distorting the carpal tunnel.[1] The American Academy of Orthopaedic Surgeons (AAOS) has adopted the modern day definition of CTS as a symptomatic compression neuropathy of the median nerve at the level of the wrist.[2] CTS has been represented in the literature as the most common entrapment neuropathy, attributing to 90% of all cases.[3] In the working population of the United states, CTS has an incidence of 7.8% among 4,321 individuals.[3] This can be compared to another finding in southern Sweden, where CTS has an incidence of 4% in the general population of 170,000.[4] In an eight year period, 3,142 cases were identified, with 80% of cases in females and 20% in males.[4] An incidence rate of 276 per 100,000 exposures was shown with sex-specific incidences at 139 for men and 506 for women.[4] Another study found that 1 per 1000 individuals of the general population of England will be diagnosed with CTS each year.[6] Individuals in the age range of 40- 60 are most commonly affected.[7]

Clinical Presentation

Common symptoms of CTS include hand pain, tingling pain and numbness that is described as unpleasant along the median nerve distribution route,[8] grip strength weakness along with general weakness and decreased functional capacity of the affected hand,[9] night time worsening of symptoms, and clumsiness with activities requiring wrist flexion. [10] Many patients also describe 'flick sign' as a way of relieving

their symptoms. This involves the patient actively whipping the wrist into flexion and/or extension (flicking) in order to provide temporary relief.[11]

LeBlanc and Cestia[12] describe the symptoms of carpal tunnel as mild, moderate and severe. Mild symptoms present for less than one year, have a normal two-point discrimination reading, no sign of weakness, no sign of atrophy, no denervation, and no to mild nerve velocity decrease. Moderate symptoms present for less or more than one year, possible abnormal two-point discrimination test, minimal presence of weakness, minimal presence of atrophy, none to mild denervation, and none to mild nerve velocity decrease. Severe symptoms present longer than one year, and include abnormal two-point discrimination, obvious presence of muscle weakness, obvious presence of muscle atrophy, notable denervation, and severe nerve velocity decrease.[12] Patients who have a mild form of CTS may benefit from attempting conservative treatments before undergoing a surgical operation. An acceptable range of conservative treatment trials before progressing to surgical routes is six weeks to three months. [13]

Etiologies in approximate order of commonality for CTS include: repetitive maneuvers, obesity, pregnancy, arthritis, hypothyroidism, diabetes mellitus, trauma, mass lesions, amyloidosis, and multiple myeloma.[12] Repetitive maneuvers include office work, factory line work, and any other consistent movements when the wrist is in slight or full extension for an extended period of time. Motions with the wrist in slight or full extension place the transverse carpal ligament in a taut position, therefore compressing all underlying structures. Obesity may increase the likelihood of

having CTS because being overweight will exacerbate the compressive forces on the carpal tunnel, therefore increasing the risk of the area becoming inflamed, or the median nerve compressed.[12] Pregnancy may increase the risk of CTS due to the common side effect of fluid retention, which may increase the pressure within the carpal tunnel, therefore irritating the median nerve. [14] Arthritis may cause inflammation of the joint space, and the underlying soft tissue and nerves, which may result in compression of these structures. This compression within the carpal tunnel joint space may cause compression of the median nerve. Hypothyroidism is characterized by uncontrolled inflammation of the synovial membrane surrounding the carpal tunnel, and may cause compression of the underlying structures due to increased pressure on the median nerve.[15] Diabetes mellitus often presents with glycation of the connective tissue along with diabetic neuropathy, and therefore may contribute to CTS.[16] Trauma causing wrist fractures or dislocations can alter the space within the carpal tunnel, therefore placing pressure on the median nerve.[14] Mass lesions may introduce space occupying lesions which may decrease the size of the carpal tunnel, and increase the pressure on the median nerve within the joint space. [17] CTS frequents in patients with amyloidosis due to the progressive infiltration of amyloid fibrils in the flexor tendon retinaculum and synovial tissue. A frequency rate of up to 13% has been indicated, according to clinicaltrials.gov. [18] Multiple myeloma may increase CTS incidence due to amyloid deposition according to the International Myeloma Foundation.[19]

There are some challenges regarding clinical evaluation to determine the exact etiology of CTS. Patients ages 40-60 are at the highest risk of developing CTS, however there is no set reasoning for why each patient has developed this syndrome. CTS often has an insidious onset, making it hard to pinpoint one specific cause. It is speculated whether poor ergonomics of the working-aged individual may be of causation. Occupation seems to be a common hypothesis, specifically in which ergonomics include repetitive wrist movements, gripping, resisting, or isometrically holding the wrist in extension. However, there is a vast array of patient occupations, making it hard to pinpoint one in specific.

Innervation of the Carpal Tunnel

The median nerve extends distally along the forearm, reaching and innervating the hand. It arises from the medial and lateral cords of the brachial plexus, which unite at the level of the axillary artery. The fibers of the median nerve are derived from the sixth, seventh, and eight cervical as well as the first thoracic nerves. The nerve passes the distal branches of the brachial artery in the area of the coracobrachialis muscle to extend along the medial aspect of the forearm. The nerve is situated behind the lacertus fibrosus (bicipital fascia) and is separated from the elbow joint by the brachialis muscle. At the forearm level, the median nerve runs between both heads of the pronator teres to cross the ulnar artery. It continues distally under the flexor digitorum superficialis, lying on the flexor digitorum profundus, within 5 centimeters of the transverse carpal ligament (TCL). At this point in the median nerve pathway, it becomes superficially situated between the tendons of the flexor digitorum sublimis

and the flexor carpi radialis. In the wrist, the median nerve lies deep and radial to the palmaris longus and is covered by the skin and palmar fascia. The nerve lies deep to the TCL, continuing into the palmar region of the hand to innervate the phalanges. The median nerve innervates the 1st, 2nd, 3rd, and radial half of the 4th phalanges.[20]

Structural Changes to the Carpal Tunnel

The carpal tunnel is an osteofibrous canal at the volar wrist, and is comprised of many bones, ligaments and nerves which all track into the hand. The TCL extends from the hook of the hamate and the triquetrum to the scaphoid and trapezium in an ulnar to radial direction. It serves as a protective covering for all underlying structures. The nine tendinous structures of the carpal tunnel include: Flexor pollicis longus, Flexor digitorum superficialis of the 1st, 2nd, 3rd, and 4th phalanges, Flexor digitorum profundus tendons of 1st, 2nd, 3rd, and 4th phalanges. The median nerve also runs through the carpal tunnel and is the symptomatic factor in CTS.[21]

Momose et al.[22] assessed the anatomical construct of the carpal tunnel joint space pre- and post-carpal tunnel release (CTR) in order to determine what structural changes occurred. Patients underwent magnetic resonance imaging (MRI) to detect the changes within the joint space. The following structures were assessed: Flexor pollicis longus (FPL), Flexor digitorum profundus (FDP) of the 2nd, 3rd and 4th phalanx, Flexor digitorum superficialis (FDS) of the 2nd, 3rd, and 4th phalanx, transverse carpal ligament, and the median nerve. Pre-operatively, the carpal tunnel region at the level of the hamate was smaller than that of the pisiform level, however, after CTR the expansion level of the hamate was significantly larger than that of the pisiform. In

post-operative patients, the median nerve, FDS and FDP of all fingers shifted significantly in a palmar direction at the level of the pisiform and hook of the hamate. The TCL showed a continuous linear area of low signal intensity compared to no delineation of the ligament in the postoperative carpal tunnels. The median nerve embellished larger and rounder after CTR at the level of the hamate. These shifts support the suggestions that by releasing the TCL, the underlying structures will have the ability to modify their positions, presuming the inflammation of the joint space has decreased.[22]

The intra-carpal tunnel pressure in a healthy individual with the wrist in a neutral position is approximately 3-5 mmHg.[23,24] Intra-carpal tunnel pressure has shown to increase to pressures as high as 63 mmHg when the wrist is in 40 degrees of extension, with 0 degrees of metacarpophalangeal flexion.[25] Keir, Bach, and Rempel found that when the hand is in slight extension (e.g. using a computer mouse) the intra-carpal tunnel pressure increases to 16-21 mmHg. Furthermore, if an individual clicks or points with the mouse, the intra-carpal tunnel pressure increases to 28-33 mmHg.[26] Increased pressure within the carpal tunnel decreases the area within the joint space. This decrease in available joint space causes the soft tissue structures within the carpal tunnel to become compressed. This may result in compression or damage of the median nerve.[23-26]

Oh et al. used ultrasound to measure morphological changes in the median nerve in patients who had undergone either mini-open or endoscopic CTR procedures.[27] The notion being patients would have morphological changes of the

median nerve at each level of the carpal tunnel, and that these changes would be correlated with improvements in the patient outcomes. The patients reported significant improvement ($p<0.001$) in outcome scores when assessed by the Boston Carpal Tunnel Questionnaire (BCTQ) and the Disabilities of the Arm Shoulder and Hand score (DASH). The cross-sectional area of the median nerve was significantly increased at the middle outlet of the carpal tunnel. Changes at each level of the carpal tunnel were similar in both groups, suggesting that the mini-open and endoscopic CTR methods are both useful for increasing cross sectional area of the carpal tunnel.[27] These results are consistent with similar research assessing the flattening ratio of the median nerve in the carpal tunnel before and after mini-open CTR.[28-30]

Physiological Assessment of Carpal Tunnel Syndrome

Activities of daily living (ADLs) are crucial in every individuals' life. In order for individuals to perform normal ADLs such as locking the front door, preparing meals, holding objects, and a multitude of other tasks, grip strength is imperative. Within the occupational population, grip strength is no less important. Without adequate grip strength, the individual may drop items, or have difficulty picking up heavy or small items. This inability to grip items is due to the median nerve compression caused by CTS. When the median nerve is compressed, the musculature within the thenar eminence have altered sensory and motor function, leading to a loss of sensation or function.[14]

Simpson states that grip strength is useful to evaluate outcomes post-operation in patients who have undergone CTR.[31] Hand grip strength is most commonly assessed

by use of a hand dynamometer. This method is useful for gathering pre-operative outcomes to compare with post-operative outcomes throughout the duration of the patient's treatment. Grip strength may be assessed as early as two weeks post-operation, however, Simpson cautions testing too early in the post-operative stage when the assessment causes any pain in patients or the tissues have not completely healed. Simpson does not define the parameters for early strength testing, however, which is one limitation to the research.[31] Early grip strength testing has an expected decrease in the patients mean strength score. This decrease is likely due to scar pain, scar tenderness, and muscle pain of the intrinsic musculature of the thenar eminence causing tension at the now healing TCL. Ludlow et al. mentions that the decrease in postoperative grip strength may be linked to the pressure placed on the healing scar from the handle of the dynamometer device.[32] Taking these factors into consideration, it is advisable that the clinician set a baseline protocol for patient strength testing that allows enough time for tissue healing. Based on previous literature, grip strength testing should be performed no earlier than two weeks post-operation in order to ensure the results are not influenced by scar pain, scar tenderness, or muscle pain.[32]

Grip strength does not use the muscles involved in CTS exclusively. There may be compensation patterns of the synergistic muscles such as the FDS and FDP noted in the 4th and 5th phalanx. This compensatory pattern may mask weakness of the abductor pollicis brevis (APB) or opponens pollicus (OP).[33-35] The APB is one muscle comprising the thenar eminence, which is responsible for the opposition motion of the thumb. The APB is also utilized for abduction, extension, and opposition of the

thumb.[36] The OP is responsible for flexion and opposition of the thumb, as well as rotation to allow cupping of the hand. These muscles are important in CTS due to their innervation by the median nerve.[37] In cases where the innervation of these muscles is lacking, malfunction or atrophy may occur, which may decrease the patient's grip strength. Power grip requires synergistic function of intrinsic and extrinsic muscles of the hand. Most of the hand musculature is supplied by the median nerve proximal to the carpal tunnel.[38]

Thenar atrophy is a diagnostic tool utilized by some practitioners to determine the severity of CTS. Presence or absence of thenar atrophy has not been standardized and is typically recorded as a dichotomous outcome or by use of a mild, moderate, severe grading scale.[39] Due to the lack of standardization of thenar atrophy, this method of assessment should be used cautiously. Many studies caution the use of thenar atrophy, as it is not an easily measurable outcome. Thenar atrophy is not a standardized testing measure due to the variation in assessment strategy and questionable outcomes.[39]

Two-Point discrimination (TPD) is a diagnostic tool used to assess sensory function of the skin. This is a handheld, octagonal-shaped device with two prongs on each of the eight sides (Figure 1). The prongs are set at 2-8, 15, and 25 mm apart. The clinician will ask the patient to close their eyes, and place the prongs set at 5mm apart on the tip of the patient's finger. The patient must then verbally identify whether they feel one prong or two. The ability to feel two prongs at 5mm distance apart or lower is a normative value for the TPD. If the value exceeds 5mm and the patient identifies one

prong, the clinician will increase the distance by 1mm by turning the device to the 6mm side and repeat the prong on the finger. Readings of 15mm or greater are abnormal and have associated health risks such as loss of sensation. [45]

Conservative Treatment

The common route of CTS treatment may begin with conservative treatment, such as a wrist splint, medications, injections, or rehabilitation. The decision about which mechanism of treatment will depend on the discussion between the patient and doctor. In cases where CTS is deemed temporary, such as with fluid retention in pregnancy, wrist splinting is the preferred method of treatment. Splinting may also be a preferred treatment option in patients who have mild to moderate symptoms due to the lower cost and tolerability.[46] A review by Page, Massey, and O'Connor found effectiveness in nocturnal wrist splinting, with patients reporting an overall improvement in symptoms after four weeks, regardless of the splint design.[46] Burke, Burke, Stewart, and Cambre found that neutral-position splints relieved patient symptoms two-times more often than splints in extension splints.[47]

Another conservative treatment is in the well-known form of non-steroidal anti-inflammatory drugs (NSAIDs). NSAIDs are a relatively low-cost treatment modality that many individuals have access to. A prospective study done by Taylor-Gjevre et al. assessed various treatment routes, with a focus on wrist splinting and NSAIDs. The researchers assessed the symptom severity of 211 patients before and after treatment by use of a survey. A nerve conduction study was also performed in order to obtain an objective measure for each patient. The efficacy of wrist splinting and NSAIDs on 70

and 82 patients respectively was also assessed. The researchers found that wrist splinting was effective in 54 of the 70 patients (78%) while. NSAIDs were found to be effective in 61 of the 82 patients (74%) of patient cases. However, when the researchers performed a second nerve conduction study on the patients, there was no improvement in the median nerve conduction. These results give notion to the fact that patients perceive their overall symptoms as having greater value than the objective measures of the median nerve conduction.[48]

Physical therapy techniques such as nerve glides, carpal bone mobilization, and therapeutic ultrasound have minimal efficacy for treatment of CTS. Physical therapy may be prescribed by the diagnosing orthopedic surgeon; however, the patients insurance coverage, co-pays, and severity of symptoms may affect the prescription. However, due to the ease of treatment in many respects, physical therapy may be beneficial to try.[49.50] Physical therapy techniques may also include exercises to strengthen the intrinsic musculature of the hand. These exercises include movements such as making a fist, spreading the fingers wide, touching the tips of each finger to the thumb, and other fine motor movements. The goal of physical therapy is to improve motor function of the hand musculature in order to improve the individual's ability to perform ADLs.[51-52]

Corticosteroid injections are a common route of treatment for CTS. According to Atroshi, Flondell, Hofer, and Ranstam, corticosteroid injections are effective in reducing the amount of inflammation within the connective tissues comprising the carpal tunnel. This decrease in inflammation may aid in relieving pressure on the

median nerve, and therefore decrease the symptoms of CTS.[53] There is some debate, however, about the use of corticosteroid injections for long-term treatment in the CTS patient. There is evidence that using a corticosteroid injection for treatment prior to surgery may exacerbate the symptoms post-operatively. Vahi, Kals, Koiv, and Braschinsky[54] state that the occurrence of complaints was higher for patients who received local steroid injections pre-operatively, as compared to those who did not receive injections.

Surgical Outcomes

Aslani et al. composed a prospective research study design to assess treatment of CTR utilizing three different techniques. CTS was clinically diagnosed by the presence of three or more of the following: history of recurrent or persistent paresthesias along the median nerve distribution, exacerbation of symptoms with use of the hand, nocturnal awakening with paresthesias, and a positive Tinel's sign and/ or Phalen's sign. 105 patients with confirmed CTS were randomly assigned into one of three surgical groups. Thirty-six patients were in the open incision, twenty-eight in the limited-open incision, and thirty-two in the endoscopic group The results of this study concluded that positive outcomes in symptom improvement, as reported by the patient, occurred in 95% of cases, across all routes of surgery. The level of pain and satisfaction was decreased at four months post-operation in all three groups, however, in the limited-open and endoscopic groups this decrease is noted 8-15 days sooner. The size and location of the scar in each group varies, the ECTR in this study is smaller than the open CTR. The incision site and size of the ECTR are less disruptive to the

underlying tissues, which may allude to the decrease in scar pain and higher scar appearance satisfaction.[41]

Orak et al.[42] compared short-term patient outcomes between open CTR and endoscopic CTR. Twenty-eight patients underwent the open procedure, and twenty-two underwent the endoscopic. Inclusion criteria in this study included: complaints of CTS for a minimum of three months with no response to conservative management, electrophysiological findings of intermediate or advanced median nerve involvement, motor deficit, no previous cervical disc pathologies, no previous history of metabolic issues causing neuropathy, no previous history of upper extremity injury or surgery, and no restrictions in range of motion at the wrist and hand. The patients were evaluated using the visual analog scale for pain at one, two, four, and twenty-four hours post-operation. The study found that patients who underwent ECTR had significantly less postoperative pain. The authors note that this is likely due to the smaller scar and incision used in this technique.[42] Although there was less pain with the ECTR, pain assessments did not extend beyond the 24-hour period. Therefore, it is unknown if overall recovery was equitable between procedures.

Wipperman and Goerl found that CTR provides positive lasting results in 70-90% of surgical cases.[12,43] However, the authors do not state how long 'lasting' results are in these surgical cases. The authors established that CTR is considered the treatment of choice in patients who suffer from severe median nerve damage. The extent of median nerve damage is determined by permanent sensory or motor loss, or ongoing axonal loss or denervation on electrodiagnostic studies.[43-44] The authors found

that the patient outcomes are positive in each surgical intervention, however, patients who undergo ECTR return to work on average eight days earlier than those who receive the OCTR.[36] The authors also state that splinting of the wrist does not provide any benefits to the patients level of pain or return to work time. Splinting post-operation may increase stiffness and adhesions at the wrist, therefore decreasing the patient's mobility after the procedure.[2, 43]

Due to the vast array of patient outcome gathering methods, researchers can determine the overall satisfaction, strength, neurological function, and level of pain for each patient. Each research study performed can decide how many patient outcomes they would like to assess, depending on what the goal of the study is. Strength assessment studies may choose to use the hand dynamometer test, whereas patient satisfaction studies may use patient reported outcome surveys. However, combining assessments is likely more appropriate considering patient recovery is a multi-factorial process and a single metric will often produce incomplete results and interpretations about patient function.

A gap in research exists in the comparison of ECTR and LOCTR. No current studies exist that compare the two procedures as a route of treatment and assess both subjective patient outcomes such as the Patient-specific Functional Score (PSFS), Disabilities of the Arm Shoulder and Hand score (QuickDASH), and objective patient outcomes such as grip strength by hand dynamometer, and neurological function by TPD. Both of these surgical methods are increasing in popularity, as they have shown to have decreased severity of symptoms post-operation, and even a faster return to

work time.[44-46] More research needs to be conducted comparing these methods directly in order to aid in establishing a patient-oriented level of care.

Conclusion

CTS is a common neuropathy that has many etiologies such as repetitive movements at the wrist, obesity, diabetes, arthritis, trauma, and many others. Due to the large number of etiologies, it is important to develop an effective route of treatment. In some cases, a lifestyle change may be simple solution, whereas in other cases, surgical intervention is the necessary route of treatment. It is important to know and understand the many etiologies of CTS in order to improve treatments for patients who develop the disease.

There a multitude of symptoms that are very common to CTS. These include, but are not limited to, numbness or tingling in the hand or fingers, decreased ability to grasp objects, loss of strength, and increase night pain or weakness. Patients may fall anywhere on the mild, moderate, or severe spectrum. Therefore, it is important to have an understanding of which routes of treatment work best for the specific symptom the present patient is undergoing. Depending on the patient, their symptoms, and the physician, conservative management strategies may prove a viable option in patient healthcare. However, given the high success rate of CTR, it is not uncommon or uncalled for to choose this intervention for patients in any category of pain.

Due to the tightly bound joint space comprising the carpal tunnel, CTS is a very common disease. Educating patients on ways to avoid CTS may be the first step in

prevention. With proper ergonomics, some patients may be able to avoid CTS all together. However, education on CTS will not prevent all cases from occurring.

CTR procedures have become less invasive as technology has improved. In order to assess the effectiveness of the modernistic approaches to surgery, more research needs to be conducted. The two methods in question for this research include ECTR and LOCTR. In order to assess the effectiveness of these two procedures, it is imperative to gather subjective and objective patient data after each CTR method. The subjective methods to be used include the PSFS and QuickDASH surveys, and the objective measures are hand dynamometer, and TPD. In order to provide transparent outcome results to future CTR patients, it is important to establish if one method of CTR has better results.

Factors such as location of physician training, insurance costs, and anesthesia method necessary may need to be considered by the patient. Based on cost estimates provided by an orthopedic clinic located in central Kentucky, the estimated cost of an endoscopic carpal tunnel release is $1,800. A limited-open carpal tunnel release has an estimated cost of $1,200. Depending on the insurance coverage the patient has, the cost of procedure may play a role in his or her decision making. Another factor to consider is the administration route of anesthesia. In the endoscopic procedure performed at the same clinic, general anesthesia is utilized, whereas localized anesthesia (at the wrist) is used in the limited-open procedure. General anesthesia comes at a greater expense due to the inherent overhead such as the requirement of having an anesthesiologist, certified registered nurse anesthetist, and automatic

equipment. In order to provide optimal patient care, it is of utmost importance that the clinician realizes the many factors that play a role in the patient's decision to undergo CTR.

III. Research Methods

Hypothesis

The ECTR method of surgical decompression is less invasive, involves a smaller incision and has an optimal scar location. Therefore, the researcher hypothesized that patients undergoing ECTR would have significantly increased results in subjective and objective patient-reported outcomes compared to the LOCTR procedure.

Participants

The current study originally included 38 patients, however three patients were removed from the final analysis due to incomplete data, or failure to attend follow-up appointments. The final data analysis included 35 patients ranging from 31-85 years of age, receiving carpal tunnel release. 20 patients received ECTR, while the remaining 15 received LOCTR. Inclusion criteria included minimum age of 18 and diagnosed with isolated CTS with no previous surgical decompression. Patients with concurrent injury to the involved extremity were excluded, along with patients who had previous history or surgery on the involved extremity. Patients who could not read or write in English were also excluded.

Methods

The present study was conducted at an orthopedic sports-medicine clinic in central Kentucky. Two board certified orthopedic surgeons, who specialize in hand surgery, participated in this study. Using information gathered during the initial visit for each patient, each orthopedic surgeon performed one surgical technique, either ECTR or LOCTR. Each surgeon had his own method for CTS diagnosis criteria.

Endoscopic Carpal Tunnel Release

ECTR was performed by one surgeon involved in this study, who specialized in this technique. The procedure involved one incision of about 1-1.5 cm along the proximal wrist crease, between the flexor carpi ulnaris and the palmaris longus in the transverse plane. The dissection of the soft tissue began at the radial aspect of the incision, and went to the antebrachial fascia, where it was swept in an ulnar direction to mobilize the Guyon's canal structures. After the Guyon's canal structures and subcutaneous fat were mobilized, a blunt retractor was used to pull the structures in an ulnar direction. The surgeon then entered the carpal tunnel by dividing the antebrachial fascia along the same line as the first incision. The TCL was then elevated by use of a skin retractor along the ligaments leading edge.

Two Hagar Dilators were used to dilate the carpal tunnel and create a path for the Centerline™ tool utilized by the surgeon. The Dilators passed distally, along the ulnar side of the carpal tunnel near the hook of the hamate. This movement proceeded in a distal direction towards the ring finger, until the tip of the Dilator surpassed the carpal tunnel. The Centerline™ blade was then inserted, and followed the same path previously created by the Dilators.

The surgeon then advanced the device towards the ring finger, remaining close to the hook of the hamate, while also pressing the viewing window of the device snugly against the deep side of the TCL. Multiple passes in a proximal/ distal direction were necessary in order to clearly define the ulnar "strip" of the TCL. Once the ulnar strip was defined, the surgeon was able to see the transverse fibers of the TCL. In

order to establish the distal portion of the TCL, the surgeon palpated the area between the fat pad and distal end of the ligament and used this region as the alignment for the entry markers.

After the clear pathway for the Centerline™ blade was established, and the distal endpoint of the TCL confirmed via palpation, the ligament was divided by use of the Centerline™ blade, pulled in a proximal direction along the previously established pathway. Next, the Centerline™ blade was rotated to retract the blade, which allowed the surgeon to assess the TCL and ensure all fibers have been thoroughly separated. When the Centerline™ device was pushed along the pathway after the TCL separation, the surgeon should have felt a noticeable difference in the ease of advancement of the device.

Once the procedure was complete, the incision site was closed with subcuticular sutures in order to mitigate the scarring and have a positive cosmetic appeal for the patient. An injection of Marcaine into the carpal tunnel was performed in order to prevent immediate post-operative pain.

Limited-Open Carpal Tunnel Release

LOCTR was performed by the other surgeon involved in this study. This procedure involved a longitudinal incision in line with the radial aspect of the ring finger. The incision extended over the distal aspect of the TCL by approximately 1cm. The skin and the underlying dermis were dissected with this incision. Next, the palmar fascia was divided distally in order to identify the distal portion of the TCL. A self-

retaining retractor was inserted into the dissected area to hold it open for the surgeon to have unobstructed access to the carpal tunnel.

A No. 15 blade was then used to further open the plane of dissection between the longitudinal and the superficial palmar fascia, as well as the deeper TCL. The NO. 15 blade released the distal portion of the TCL. A short blunt dissector was then used to create a free plane of dissection deep to the TCL. A #2 Biomet stripper was used to dissect above and below the TCL, and a #3 Double Pilot was used to isolate the TCL from the nerve and superficial tissue. The Biomet security clip was then inserted, while the obturator was removed to allow the security blade to divide the proximal aspect of the TCL. Complete dissection was carried up to 2cm proximal to the wrist flexion crease.

All instruments were then removed from the carpal tunnel. The surgeon ensured there was a complete release of the TCL by use of direct visualization and palpation with a freer elevator. Once it was determined that there are no distal remaining fibers of the TCL present, the carpal tunnel prepared for closure using 4-0 prolene skin sutures in a routine fashion, and the patient's circulation was assessed by capillary refill.

Subjective Data Measures

To assess patient self-reported physical function, two established outcome forms were used. The Patient- Specific Functional Scale (PSFS)[56] and the Disabilities of the Arm, Shoulder, and Hand score (QuickDASH)[57]. The PSFS allows patients to list 3-5 specific activities they have difficulty performing due to their CTS. The activities were

listed by the patient and rated on a scale of 0-10 (high level of difficulty to no difficulty) therefore; each form was unique to each patient. The PSFS has a variability of error caused by measurement strategies, or standard error of measurement (SEM), of 0.43. The PSFS minimal detectable change (MDC) value has been reported to be 2.4 points at the 95% confidence level.[55] The QuickDASH contains 11 questions that allowed the patient to self-report the level of wrist/hand disability using a 1-5 scale (low level of disability to high level of disability). The QuickDASH asks the patient about his or her symptoms, experiences, and function within the past week. The SEM of the QuickDASH is 7.38, and the MDC is 17.18.[58]

Objective Data Measures

Two- point discrimination (TPD) is another diagnostic tool used to assess sensory function of the skin. (Figure 1) The TPD allows a clinician to assess whether a patient can distinguish between detecting 1 prong of the device touching the skin versus 2 prongs. TPD was performed with the patient seated across from the surgeon, with the dorsal aspect of the hand resting on the exam table. The patient was asked to close his or her eyes while the surgeon placed the TPD device on the tips of each finger of the involved and non-involved hand of the patient. The surgeon decided at random whether to use one prong or two, and the patient had to distinguish how many prongs were felt. Patients with no nerve compromise should be able to differentiate one prong from two in measurements as low as 5mm apart, with a lower limit of 5mm and an upper limit of 15mm.[10] Cases where the patient states feeling one prong when in fact two were used (and vice versa) are considered abnormal. The patient's TPD

readings were documented in his or her electronic chart. TPD is an objective measure that is useful in tracking patient improvement throughout the duration of the treatment process. Since the measurements are recorded in millimeters, even small improvements in the TPD readings may bring a patient from an abnormal to normal classification.

Handgrip strength (HGS) was assessed by use of a hand dynamometer at the pre- operation appointment, and at all follow-up visits. (Figure 2) The patient was seated with the involved hand grasping the hand dynamometer and the elbow at 90 degrees flexion with wrist in a neutral position. The arm was resting on the chair arm rest, with the dynamometer set at the second position, closest to the hand. The second position of the hand dynamometer was pre-determined by the surgeons in this study as the best position for testing the grip strength of the involved hand, based on previous measurement attempts. The patient was told to actively squeeze the device, generating a force output reading. The hand surgeon recorded the amount force generated by the patient. The patient repeated this process at each follow-up in order to track the progression of strength throughout the treatment process. The patient's grip strength was documented in the patient's chart.

Patients were assigned to groups based on which orthopedic surgeon was operating on their wrist. All ECTR procedures were performed by one surgeon, and all LOCTR were performed by another. Each patient provided written consent for inclusion in this study. The research assistant and/ or orthopedic technician reviewed all parameters of this study with the patient and gave the patient a copy of the

consent form. Any concerns and/ or questions the patient had were addressed at this time, and the patient was given a phone number to call if any further questions needed to be addressed.

The PSFS and QuickDASH surveys were attached to the consent form to be completed at the time of patient enrollment to assess baseline patient function and disability, respectively. During the initial visit with the orthopedic surgeon, baseline HGS and neurological function were gathered using the hand dynamometer and TPD, respectively.

The patients were scheduled to return to the clinic at 2, 4, and 6 weeks post-operation to assess healing and function. At each follow-up visit, the patient was provided the PSFS and QuickDASH surveys to be completed with their current level of function and disability. The PSFS was filled in with the patient response on the baseline survey, if activities were noted initially.

The orthopedic technicians obtained an overall pain score from the patient at each visit. Pain scores were verbalized by the patient on a 0-10 scale, with 0 representing no pain, and 10 representing the worst pain possible. The orthopedic surgeons or their physician's assistant(s) administered the HGS and TPD tests at each follow-up visit and documented the results in the patient chart.

The research assistant had access to the patient charts throughout the duration of this study and was therefore able to determine the dates and times of all subsequent patient follow-ups. The data entered into the patient charts by the

orthopedic staff could be gathered at any time throughout the duration of this study to be input into the data sheet.

Data Analysis

Microsoft Excel (Microsoft Corp, Redman, WA) was used to track all patient data for the duration of this study. Patient identifiers included a previously designated clinic number, last name, and first name. No other patient identifying data was included into the Excel file. All identifiable data was removed prior to analysis. Upcoming patient follow-ups, subjective patient data, objective patient data, pain score, procedure, and orthopedic surgeon were also included for each patient.

Descriptive statistics for all subjects were calculated with means and standard deviations reported for continuous variables and frequencies and percentages reported for categorical variables. Prior to performing any comparisons, a formal test of normality was initially utilized for each dependent variable. The Shapiro-Wilk test for normality was employed revealing the variables were normally distributed which allowed independent t-tests to be utilized for between group (LOCTR versus ECTR) comparisons and paired t-tests for within group (pre-surgery versus post-surgery) comparisons. Due to the prospective design of the study and the variation in patient appointment times, all pre-surgical measurements were compared to the most recent follow-up (MRFU). Patients had to attend at least one post-operative visit between the 2-6-week time periods in order to be included in this study. Statistical significance was set at $\alpha \leq 0.05$. All statistical calculations were performed using STATA/SE (version 15.1 for Windows, StataCorp, LP, College Station, TX).

Results

Patient demographic variables are reported in Table 1. This study had 35 patients with complete data (age 60±16.9 years, height 169±10.3cm, weight 95±24kg), with 21 receiving ECTR and 17 receiving LOCTR (Table 1). Females dominated the patient population, with 24 (63%) females and 14 (37%) males.

Within Group Subjective Patient Reported Outcome Results

Within group comparisons were made for both surgical interventions. These comparisons assessed the preoperative variable with the MRFU variable for all ECTR (Table 2) patients, and all LOCTR patients.

Patients in the ECTR group reported improved pain scores (p=0.001). The patients in this group also had significant differences in all PSFS scores, with PSFS1, PSFS2, and PSFST (PSFS total) having a significance of p<0.001, and PSFS3 a significance of P=0.002. QuickDASH scores also showed a significant difference (p<0.001) in the ECTR group. (Table 2)

Patients in the LOCTR had a significant difference in pain scores (p=0.009) as well as QuickDASH scores (p=0.017). The patients in this group did not, however, show a significant difference in any PSFS score variables. (Table 2) The lack of significant improvements may be dependent on the amount of function on the PSFS by this patient population at pre-operative data collection.

Within Group Objective Patient Reported Outcomes

Neither group showed any significant difference for TPD or HGS when comparing preoperative to MRFU. (Table 2)

Between Group Subjective Patient Reported Outcome Results

There was a significant difference (p=0.030) noted in QuickDASH when comparing results between the two carpal tunnel operations. (Table 3) Although preoperative QuickDASH scores for the ECTR patients were significantly higher compared to the LOCTR patients, MRFU comparison of ECTR and LOCTR QuickDASH scores showed no significant differences. Similar results are noted with all PSFS variables between the two surgical methods. (Table 3)

Between Group Objective Patient Reported Outcomes

Preoperative TPD showed a significant difference when compared to MRFU of the entire patient population (p=0.040). When comparing HGS, no significant difference was noted when assessing preoperative to MRFU between ECTR and LOCTR. (Table 3)

Discussion

80% of the current cases of CTS are in the female population, with 20% of incidences in males, as determined in a general population prevalence study by Mondelli, Giannini, and Giacchi.[5] The current study had a prevalence of 24 females (63%) and 14 males (37%). In both instances, females represent a significant portion of the CTS population, which is consistent with the literature that currently exists.

Interestingly, preoperative QuickDASH scores for the ECTR patients were significantly higher compared to the LOCTR patients, however; the MRFU comparison of ECTR and LOCTR QuickDASH scores showed no significant differences. The average QuickDASH score for the ECTR group went from 48.80 to 20.45, whereas the LOCTR

group went from an average of 32.17 to 13.80. This shows that the ECTR patients had higher initial QuickDASH scores (more disability) than the LOCTR patients. The reason for these higher initial scores is unknown. This study did not assess how long symptoms persisted before the patients sought treatment, however; this may be a beneficial variable to test and classify in future studies. Both surgical techniques did result in significant improvements in QuickDASH scores from the preoperative time period to the MRFU (P=0.000).

All three PSFS scores in both groups showed a significant improvement from preoperative scores to MRFU scores. PSFS totals scores were also significant when comparing all patients preoperatively and at MRFU, however; between the ECTR and LOCTR there were no significant differences. These findings suggest that patients are perceiving their functional ability to be improved after receiving CTS. McMillan and Binhammer[60] found that patients had a significant improvement in PSFS scores from preoperative scores and six months post-operation. The authors note that the PSFS was not responsive in this patient population at earlier time periods.[60] The current study assessed PSFS at 2, 4, and 6 weeks post-operation and found positive results, therefore there is some inconsistency with the PSFS timeframe post-operation. Furthermore, the QuickDASH results mirrored the PSFS findings in the current study suggesting that the patients were indeed at lower levels of function and higher levels of disability. However, both study populations increased their perceived function indicating that the surgical interventions were successful at reducing the functional concerns.

The current study demonstrated that there were significant differences within all subjective data measures from the preoperative time period to most recent follow-up (MRFU), however, there were no significant differences between the two surgical techniques. These findings suggest that in both surgical techniques, patients feel that they are getting better when asked to rate their symptoms in a subjective manner. This finding is inconsistent with a post-operative comparison between ECTR and open carpal tunnel release (OCTR) by Orak et. al. Post-operative pain following the two procedures was assessed at 1, 2, 4, and 24 hours post operation. The authors noted that there was significantly less pain reported in the ECTR group compared to the OCTR group.[42] The current study utilized a post-operation time frame of 2-6 weeks in order to allow for the inflammatory process to react, anesthesia to clear the body, and pain medication to be halted. The current study showed no significant difference between preoperative pain and pain at MRFU when comparing the ECTR population to the LOCTR population. This lack of significance between the two groups is likely due to the similar level of invasiveness of each CTR method. In the study by Orak et. al., the comparison was between a minimally invasive technique (ECTR) and a standard technique (OCTR). The open method of CTR involves an incision of 3-4 centimeters, spanning the ventral wrist and hand. In contrast, the ECTR method used in this study involves one incision of about 1-1.5 centimeters along the transverse plane. The LOCTR method used in the current study involves an incision of approximately 1 centimeter in length over the distal aspect of the TCL. Due to the similarity in incision length and location of the ECTR and LOCTR methods utilized in the current study, it can be

understood why there was no significant difference in pain scores between the two groups.

In the current study, patients were put into surgical groups based on which orthopedic surgeon they were currently seeing for treatment, which is not the same technique used in the literature. In a study by Rab et al., the clinicians wanted to assess open and two-port ECTR on patients who had elected to receive bilateral CTR. In this population, every patient received both methods of surgical decompression; OCTR on one wrist, ECTR on the other.[59] Both studies reached positive patient outcomes, therefore CTR is shown as a valid treatment strategy for patients with CTS. Based on these results, it can be concluded that open, limited-open, and endoscopic techniques improve patient perceived pain, function, and disability outcomes.

Regarding objective data, there was a significant improvement in TPD in both groups when comparing preoperative sensory function with MRFU sensory function. However, no significant difference was noted when comparing TPD between ECTR and LOCTR groups. The average ECTR TPD reading in the present study, however, went from 6.36mm to 5.0mm. This improvement in sensation by only 1.36mm brings these patients into the normal range of sensation, which supports the theory that ECTR may lead to decreased numbness and tingling, along with increases in sensory function This normative value is also found in TPD reliability measurements that were assessed by Delion and Mackinnon. The findings of their study note that a TPD of 5mm is the normative value, with an upper limit of 15mm.[40] The current study showed a

significant improvement in TPD between preoperative and MRFU, however there was no significant difference when comparing the TPD between the two surgical groups.

HGS was noted by Simpson to be a useful objective evaluation tool for carpal tunnel patients.[31] In the current study, however, HGS showed no significant increase across all patients, nor was there a significant difference between ECTR and LOCTR groups. These results agree with Rab et. al, who found no significant difference in grip strength at three weeks, six weeks and three months.[59]Ludlow et al. noted a decrease in grip strength if tested too soon after CTR, however the authors state that testing two-weeks post-operation or later is a reasonable timeframe[32]

It is of importance to note that fewer patients completed the HGS variable in the LOCTR group (8 total patients) than in the ECTR group (21 total patients). This difference in patient completion is one possible explanation for the overall lower MRFU grip strength of the patients in the LOCTR group, due to the stronger influence of lower scores on a smaller population. Therefore, this finding should be interpreted with caution. Although previous studies have shown an increase in HGS after CTR[31], it cannot be verified if the HGS of the current study patient population was positively or negatively affected following surgery.

Taken together, these findings can be interpreted as having significant improvements in CTS as a result of ECTR or LOCTR surgical methods. The differences in the ECTR show exceeding results in some variables (PSFS scores), however there were more patients in this surgical group. The LOCTR group had less of an adherence rate to follow-up data measurements, and this may have led to the decreased results.

Therefore, patients who elect to have surgery are likely to benefit from either route of surgical decompression.

The current study shows the effectiveness of ECTR and LOCTR operations, with both lending to positive results when testing patient outcome measures. The patients in both groups showed significant improvements in every tested measure except for grip strength. Of the patients who responded (13 total responses) to the staff questions on satisfaction and whether they would have the procedure again, 100% of patients answered yes.

This study shows the need for more objective measures to be performed on CTR patients electing to receive any surgical intervention, both pre- and post-operatively. There are significant improvements shown in the literature in many different outcomes, showing the effectiveness of these procedures.

Limitations

Limitations of the current study include limited study population, adherence to measurements, and the subjective premise of the surveys used. The study population size could be increased by extending the data collection timeframe. A larger study population could possibly affect the significance of the data points that were measured, especially the objective measures which showed little to no change. An increase in data collection by six months to one year would likely allow for a substantial increase in the study population and could allow for better interstudy comparisons. Adherence to the study measurements could be increased by developing better reminder strategies for all involved staff in order to distinguish study population

patients from standard clinic patients. Future studies may choose to include flags or notification on the patient chart, signs in the patient rooms, or various other notification strategies.

Subjective patient data measures are a common limitation when using patient-reported outcomes. In the current study, the research assistant and/ or the orthopedic technician gave verbal instructions for the patient when he or she was completing the surveys in order to increase patient understanding. Brief instructions for completion were also included at the top of each survey to ensure the patients were complying with the survey measures. Finally, the physicians in this study exclusively performed a single procedure. It is possible that different results could be generated if a randomized design allowing both surgeons to perform both techniques were employed.

Further research on the current topic should include a larger study population and longer duration in order to increase the number of patient outcomes gathered on each surgical method. A notification system to differentiate the study population from normal clinic population may also be useful. Lastly, subjective patient-reported outcomes should include verbal and written instructions and the progress of survey completion should be monitored by the research team.

Conclusions

The current study showed that across all patients, there was a significant difference between pre-operation and MRFU for pain, all PSFS scores, and QuickDASH. When comparing each study population separately from pre-operative to MRFU,

however, the ECTR patients showed a significant difference in pain, all PSFS scores, and QuickDASH. In comparison, the LOCTR patients showed a significant difference in pain and QuickDASH. The lack of significant difference in HGS scores for the LOCTR patients is likely due to decreased adherence to all study variables, with only eight patients from this population completing HGS measures.

The current study found that there was a significant difference in TPD across all patients, yet no significant difference in HGS across the entire population. Between the study groups, however, there was no significant difference seen in either measurement. The average ECTR TPD reading in the present study, however, went from 6.36mm to 5.0mm. This improvement in sensation by only 1.36mm brings these patients into a normal range of sensation. This study shows the usefulness of pain scores, as well as PSFS and QuickDASH surveys for assessing patient improvement after ECTR or LOCTR.

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APPENDICES

APPENDIX A: IMAGES

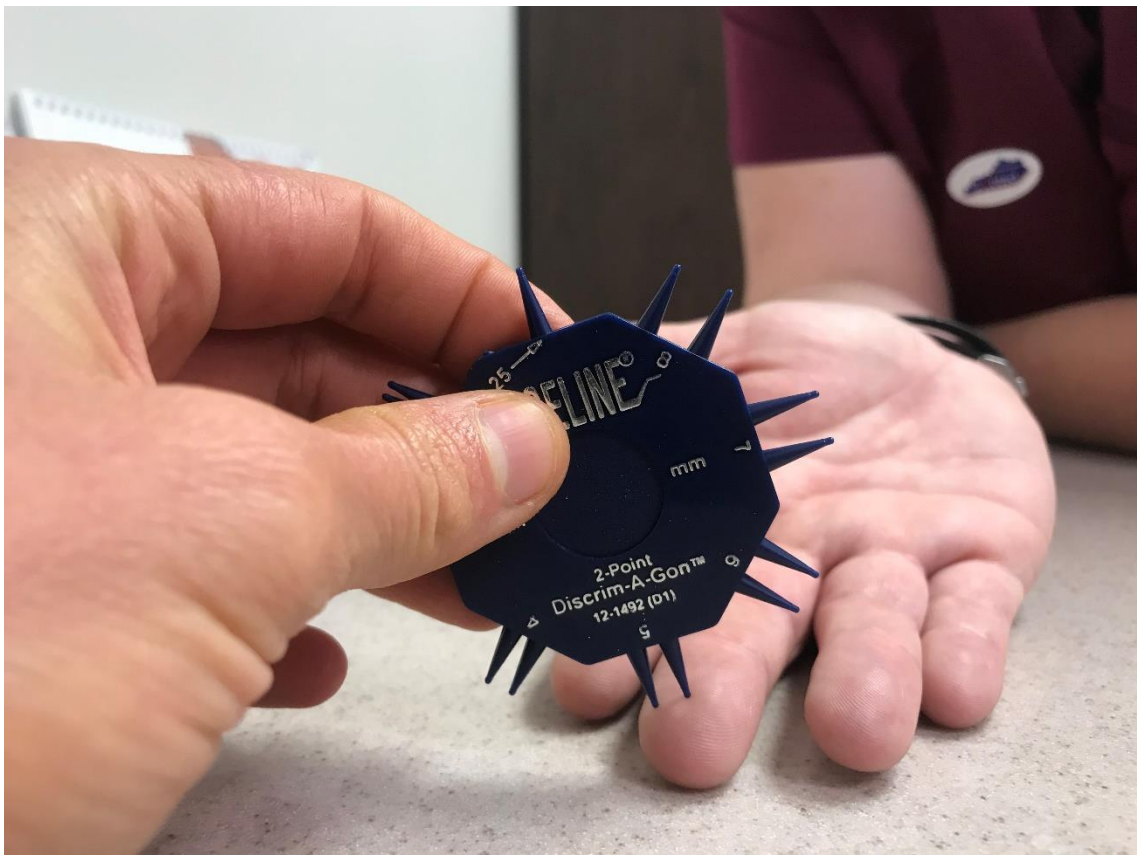

Figure 1: Two Point Discrimination Evaluation

Figure 2: Hand Grip Strength Evaluation

APPENDIX B: TABLES

Table 1: Patient Demographics

	Age (years)	Female	Male	Height (centimeters)	Weight (kilograms)
All Patients	60 ± 15.6	24 (63%)	14 (37%)	169 ± 10.3	95 ± 24.0
ECTR	59 ± 17.0	15 (71%)	6 (29%)	169 ± 11.1	100 ± 27.1
LOCTR	62 ± 14.2	9 (53%)	8 (47%)	169 ± 10.0	88 ± 18.3

ECTR=endoscopic carpal tunnel release; LOCTR=limited open carpal tunnel

Table 2: Pre-Operation to MRFU Within Group Comparisons (values reported as mean ± standard deviation)

	Pre-Surgery (n=35)	MRFU (n=35)	P-Value	Pre-Surgery ECTR (n=20)	MRFU ECTR (n=20)	P-value	Pre-Surgery LOCTR (n=15)	MRFU LOCTR (n=15)	P-Value
Pain	3.26±3.2	0.54±1.50	<0.001	2.95±3.05	0.25±0.64	0.001	3.67±3.35	0.93±2.15	0.009
PSFS 1 Score	4.71±2.84	8.24±2.58	<0.001	3.90±2.88	8.60±2.04	<0.001	5.86±2.44	7.71±3.22	0.165
PSFS 2 Score	4.84±2.45	7.83±2.53	<0.001	4.15±2.41	7.85±2.48	<0.001	6.00±2.13	7.79±2.73	0.172
PSFS 3 Score	4.67±2.56	7.41±3.18	0.003	3.75±2.44	7.75±3.26	0.002	6.00±2.19	6.90±3.14	0.480
PSFS Total	12.60±7.16	21.93±7.63	<0.001	11.05±6.47	23.30±6.98	<0.001	14.67±7.73	20.10±8.31	0.070
QuickDASH	41.75±22.06	17.63±20.44	<0.001	48.80±19.07	20.45±24.68	<0.001	32.17±22.87	13.80±12.57	0.017
TPD	6.36±3.18	5.19±1.75	0.039	6.32±2.96	5.00±0.00	0.061	6.41±3.54	5.44±2.66	0.3.08
HGS	52.68±34.00	53.68±25.80	0.850	44.00±25.84	51.06±27.83	0.148	71.13±43.22	59.25±21.47	0.370

MRFU = most recent follow-up, ECTR = endoscopic carpal tunnel release, LOCTR = limited-open carpal tunnel release, PSFS = patient-specific functional scale, QuickDASH= Quick Disabilities of the Arm Shoulder and Hand Score, TPD= Two-point discrimination, HGS= hand grip strength

Table 2:. Pre-Operation and MRFU Comparisons Between Surgical Techniques (values reported as mean ± standard deviation)

	Pre-Surgery ECTR (n=20)	Pre-Surgery LOCTR (n=15)	P-value	MRFU ECTR (n=20)	MRFU LOCTR (n=15)	P-Value
Pain	2.95±3.10	3.67±3.40	0.514	0.43±1.00	0.93±2.15	0.220
PSFS 1 Score	3.90±2.88	5.86±2.44	0.047	8.60±2.04	7.71±3.22	0.236
PSFS 2 Score	4.15±2.41	6.00±2.13	0.036	7.85±2.48	7.79±2.73	0.684
PSFS 3 Score	3.75±2.44	6.00±2.19	0.021	7.61±3.31	6.90±3.14	0.612
PSFS Total	11.05±6.47	14.67±7.73	0.142	23.30±6.98	20.10±8.31	0.225
QuickDASH	48.80±19.07	32.17±22.87	0.030	22.07±24.03	13.80±12.57	0.160
TPD	6.32±2.96	6.41±3.54	0.932	5.00±0.00	5.44±2.66	0.467
HGS	44.00±25.84	71.13±43.22	0.061	48.38±27.17	59.25±21.47	0.340

MRFU= most recent follow-up, ECTR = endoscopic carpal tunnel release, LOCTR = limited-open carpal tunnel release, PSFS = patient-specific functional scale, QuickDASH= Quick Disabilities of the Arm Shoulder and Hand Score, TPD= Two-point discrimination, HGS= hand grip strength