Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/w0qb3408

CLINICAL AND FUNCTIONAL OUTCOMES BEFORE AND AFTER SURGERY IN PATIENTS WITH CARPAL TUNNEL SYNDROME

Vineesh V [1]*, H. S Madan[2], Sachin[3] Arun I[4], Pradhumam Pareek[5]

[1*,3,5]Postgraduate Resident, Department of Orthopaedics, Shaheed Hasan Khan Mewati Govt. Medical College Nalhar, Nuh, Haryana, India
[2]Associate Professor, Department of Orthopaedics, Shaheed Hasan Khan Mewati Govt. Medical College Nalhar, Nuh, Haryana, India
[4']Postgraduate Resident, Department of Orthopedics, Government Stanley Medical College'

***Corresponding Author:** Dr. Vineesh V,
*Postgraduate Resident, Department Of Orthopaedics, Shaheed Hasan Khan Mewati Govt. Medical College Nalhar, Nuh, Haryana, India Email Id – 1757vineesh@Gmail.Com

Abstract:

Background: The carpal tunnel is a narrow fibro-osseous passageway in the wrist that houses the median nerve and nine flexor tendons, facilitating hand and finger movement. This tunnel is structurally rigid, bordered on three sides by carpal bones and enclosed on the palmar side by the transverse carpal ligament (TCL), also known as the flexor retinaculum. **Objective:** Assess the clinical, functional outcomes of open carpal tunnel release surgery in CTS patients. **Methods:** This prospective study was conducted over 12 months in the Department of Orthopaedics, SHKM Government Medical College, Nalhar, Nuh, Harayana involving 23 patients with Carpal Tunnel Syndrome who were treated in the same department. Improvement was assessed based on grip strength, Quick Disabilities of the Arm, Shoulder, and Hand (Q-DASH) Score. **Result:** The study included 23 patients diagnosed with CTS, with a mean age of 53 years, and a mild male preponderance (56.5%). Most patients belonged to the 51–60 age group (43.5%), which aligns with previous research showing that middle-aged individuals are the most affected by CTS. Occupational exposure, repetitive hand use, and age-related degeneration were identified as contributing factors to CTS, while the condition showed no significant laterality preference (52.2% left hand vs. 47.8% right hand). Clinical assessment revealed that numbness, tingling, pain, and weakness in the median nerve distribution were the most commonly reported symptoms. The Phalen's test, Tinel's sign, and Durkan's test were frequently positive, supporting the diagnosis of CTS. Preoperative grip strength was 26.91 ± 8.49 kg, which initially declined postoperatively due to surgical trauma (21.48 ± 7.153 kg at three weeks) but showed significant improvement by six months (30.13 ± 9.421 kg). Functional recovery was assessed using the QuickDASH questionnaire, a validated tool for evaluating upper limb disability. The preoperative QuickDASH score (66.26 ± 8.42) decreased significantly to 18.91 ± 4.58 at six months, reflecting marked functional improvement post- surgery. The statistically significant improvement reinforced the effectiveness of OCTR in reducing disability and restoring hand function.

Conclusion: This study demonstrated significant postoperative improvements in grip strength, and QuickDASH scores, confirming the clinical benefits of surgical decompression.

Keywords: Clinical, Functional, Outcomes, Carpal Tunnel Syndrome

INTRODUCTION: Carpal Tunnel Syndrome (CTS), first described by Paget in 1854, is the most common upper extremity compression neuropathy, affecting a significant portion of the global population. [1] It occurs due to median nerve compression within the carpal tunnel, a narrow passageway in the wrist that houses the median nerve and flexor tendons. [2] Among patients referred for electrophysiological studies, CTS accounts for 7% of all peripheral nerve disorders and 83.6% of entrapment neuropathies, indicating its high prevalence among nerve- related conditions.[3]

CTS primarily presents as tingling and numbness in the median nerve distribution, affecting the thumb, index, long, and the radial side of the ring fingers. Patients often report a deep, aching, or throbbing pain, which may radiate up to the forearm. As the condition progresses, muscle weakness and thenar muscle atrophy become apparent, particularly in chronic or severe cases[4]. Several clinical tests are used for CTS diagnosis. Phalen's test, which involves wrist flexion for 30 to 60 seconds, is considered positive if tingling occurs, with a sensitivity of 75% and specificity of 80% [5]. Tinel's sign, where the examiner taps over the median nerve, is positive when tingling is elicited, though its sensitivity varies between 50% and 75%[6]. Durkan's Test, also known as the Median Nerve Compression Test, involves direct pressure over the carpal tunnel for 30 seconds, with a sensitivity of approximately 80% [5]. Other diagnostic maneuvers include the Hand Elevation Test, where raising hands for one to two minutes reproduces symptoms (sensitivity~75%)[7]], and the Flick Sign, where symptom relief upon shaking the hands strongly suggests CTS[8].

Nerve conduction studies (NCS) play a crucial role in diagnosing CTS by assessing median nerve function, evaluating the speed and efficiency of electrical impulses[9]. Sensory nerve conduction studies are particularly sensitive in detecting early nerve compression, while motor nerve conduction studies confirm motor fiber involvement in severe cases[10]. Preoperative NCS is often used to predict surgical outcomes, while postoperative NCS helps evaluate nerve recovery and determine long-term prognosis[11].

Electrophysiological studies are essential in CTS evaluation. A distal motor latency (DML) greater than 4.5 milliseconds and sensory latency greater than 3.5 milliseconds are considered abnormal [12]. NCS demonstrates a sensitivity of 90%, making it a reliable diagnostic tool in differentiating CTS from other peripheral nerve disorders [13].

For mild to moderate CTS, non-surgical interventions aim to reduce symptoms and prevent progression. Wrist splinting, particularly at night, helps alleviate symptoms by reducing median nerve compression[14]. Activity modification, such as avoiding tasks that overextend the wrist, is advised to prevent worsening symptoms. Ergonomic adjustments, like proper keyboard positioning, can also reduce strain[15].

When conservative treatments fail, Carpal Tunnel Release (CTR) surgery is considered. Two primary surgical approaches are available. Open Carpal Tunnel Release (OCTR) involves making a 2-inch incision near the wrist, allowing for the direct visualization and division of the transverse carpal ligament, thereby relieving pressure on the median nerve[16]. Percutaneous needling is a minimally invasive technique used as an alternative treatment for Carpal Tunnel Syndrome (CTS). This method involves inserting a fine needle into the transverse carpal ligament (TCL) to create micro-injuries that promote tissue remodeling and reduce compression on the median nerve. And Endoscopic Carpal Tunnel Release (ECTR) is a minimally invasive technique utilizing a small incision and an endoscope, leading to a faster recovery time compared to OCTR[17].

The Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) questionnaire is an 11-item validated tool used to assess functional impairment and symptoms in CTS patients. Higher scores indicate greater disability. A postoperative QuickDASH score ≤ 34 and a change of ≥ 20 points has been found to be highly predictive of patient satisfaction.

Material and Methods: This prospective observational study was conducted among Patients diagnosed with carpal tunnel syndrome in the Department of Orthopaedics, SHKM GMC Nalhar, Nuh, Haryana over a period of 12 months. The study was commenced after obtaining Institutional Ethics Committee (IEC) approval

Sample Size & Sampling
- A minimum of 20 patients were enrolled based on hospital records.
- If fewer than 20 patients were available, data collection continued until the target was met.
- All consenting CTS patients meeting inclusion criteria were included in the study.

Inclusion Criteria:
- Age > 30 years
- Clinical and electrophysiological diagnosis of CTS scheduled for surgery
- Medically fit for surgery
- Willing to give informed written consent

Exclusion Criteria:
- Patients with rheumatoid arthritis, polyneuropathy
- Pregnancy, thyroid disorders, and other systemic conditions
- Patients unwilling for surgery

Methodology
1. Demographic details were collected using a pre-designed proforma.
2. Clinical and electrophysiological assessments of CTS patients were conducted.
3. Preoperative evaluation included:
   - Medical history
   - Clinical examination (Tinel's sign, Phalen's test, Durkan's test, hand diagrams
   - Duration of symptoms
   - Nerve conduction studies (NCS)
   - Grip strength measurement using a Hand Dynamometer
   - QuickDASH questionnaire

4. Surgical Procedure:
   - All patients underwent open carpal tunnel release (OCTR) surgery under brachial block or general anesthesia.
5. Postoperative Care:
   - Limb elevation using an arm sling
   - Early active finger movements initiated from day one
   - Suture removal performed after two weeks
   - Hand physiotherapy for grip strengthening
   - Patients were advised to avoid repetitive hand use for one month

6. Follow-up Evaluations at 3 Weeks, 3 Months, and 6 Months included:
   - QuickDASH questionnaire
   - Grip strength measurement
   - Nerve conduction study
   - Any complications will be noted
   - Outcome was assessed as follows

Data Collection & Outcome Measures
- Grip Strength: Measured using a Hand Dynamometer.
- QuickDASH Questionnaire: Assessed patient-reported functional outcomes.

B) Statistical Analysis
- Data were entered into Microsoft Excel and analyzed using IBM SPSS 20.0 statistical software.
- Results were expressed as percentages and proportions, with appropriate statistical tests applied.

EXIBIT 1

Exhibit 1.1: Skin Incision

Exhibit 1.2: Flexor retinaculum release

Exhibit 1.3: Median nerve decompression

Exhibit 1.4: Skin closure

Results:

Table 1: Distribution of Patients by Age-group

Age group	**No. of cases**	**Percentage**
30 to 40 years	2	8.7%
41 to 50 years	7	30.4%
51 to 60 years	10	43.5%
61 to 70 years	4	17.4%
Total	23	100%
Mean Age: 53 years ± 1.91 SD		

The distribution of patients by age group reveals that the highest proportion of cases (43.5%) falls within the 51 to 60-year age range, as depicted in **table 1**. This suggests that middle-aged individuals are the most affected. The mean age of the patients is 53 years with a standard deviation of 1.91, indicating a relatively narrow spread around the mean.

The mean age of the study population is **53 years (±1.91 SD)**, indicating a central tendency toward the late 40s to early 50s.

Table 2: Gender distribution of patients

Gender	**No. of patients**	**Percentage**
Female	10	43.5%
Male	13	56.5%
Total	23	100%

Among the 23 patients studied, males constitute a slightly higher proportion (56.5%) compared to females (43.5%), as shown in **table 2**. This suggests a mild male preponderance in the condition under investigation.

Table 3: Distribution of side affected of patients

Side affected	**Frequency**	**Percentage**
Left	12	52.2%
Right	11	47.8%
Total	23	100%

Our study reveals a near-equal distribution of the affected side, with 52.2% of patients having involvement on the left side and 47.8% on the right, as shown in **table 3**. This suggests that there is no strong laterality preference for the condition.

Table 4: Time duration between onset of symptoms and operation

	Duration b/w onset of symptoms and operation			
	< 3 months	3-6 months	6-9 months	>9 months
No. of Patients	6	5	10	2

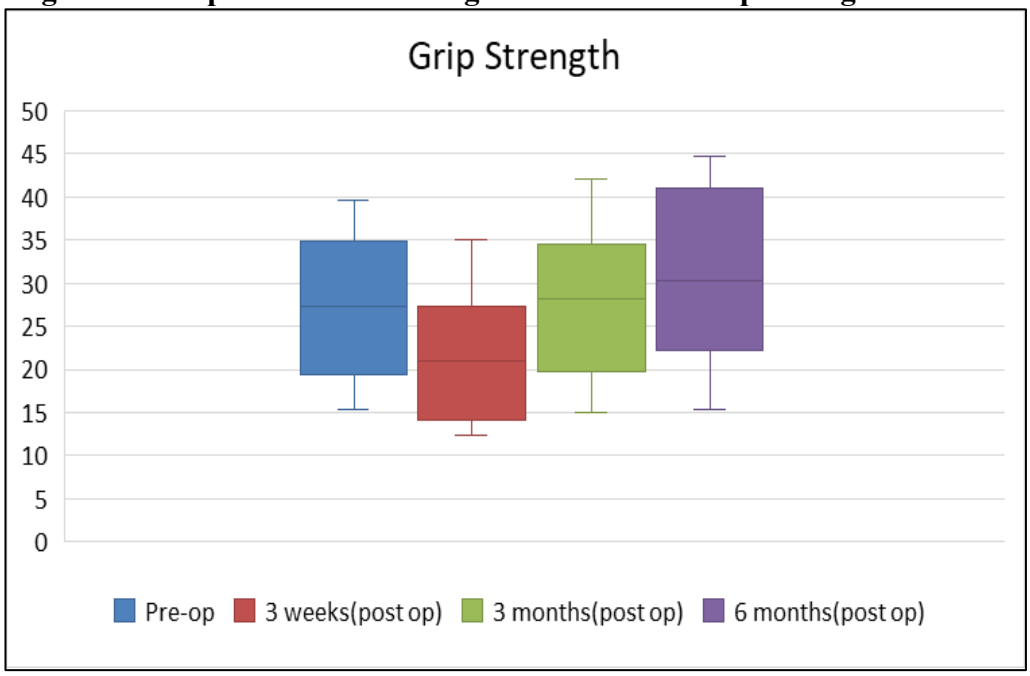
This study reveals that the majority of patients (43.5%) underwent surgery between **6-9 months**, while only **8.7%** had surgery after **9 months**. Early surgical intervention within **<3 months** was observed in **26.1%** of patients, and **21.7%** underwent surgery between **3-6 months**, as shown in **table 4**.

The majority of patients (43.5%) had **delayed intervention (6-9 months)** and **low percentage of patients opting for early surgery (<3 months, 26.1%).**

Table 5: Mean Grip strength of patient's pre-op and follow ups

Grip Stength	**Mean ± SD**	**Min**	**Max**
Pre op	26.91 ± 8.49	15	40
3 weeks (post op)	21.48 ± 7.153	12	35
3 months (post op)	26.65 ± 8.397	15	42
6 months (post op)	30.13 ± 9.421	15	45

Figure 1: Box plots demonstrating distribution of Grip Strength over time

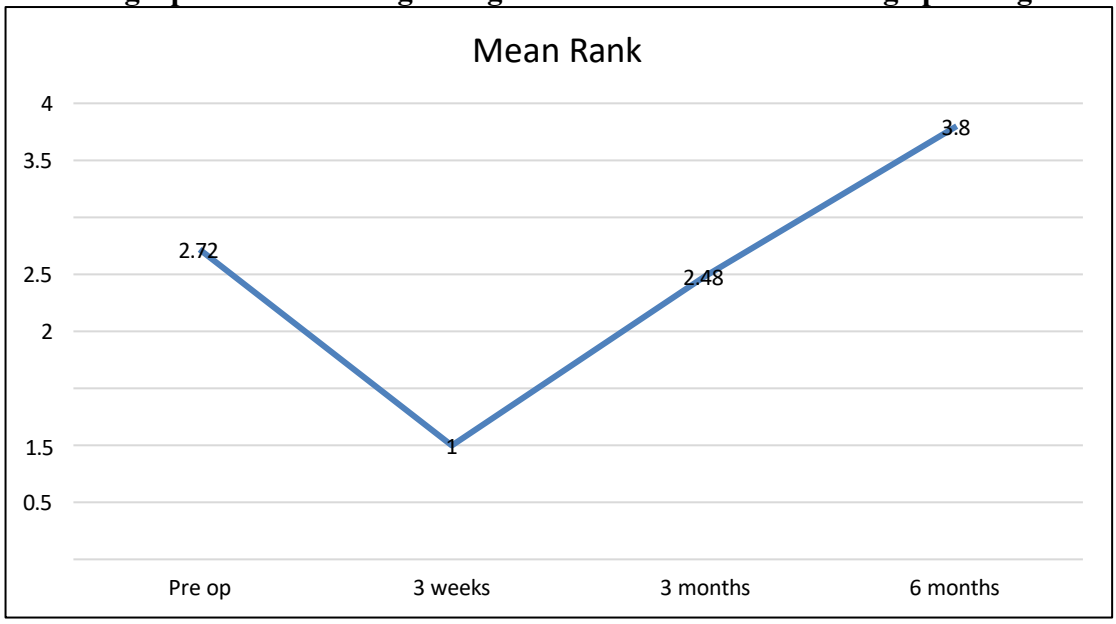


The mean grip strength shows a declining trend immediately postoperatively, with a reduction from a preoperative mean of 26.91 ± 8.49 kg to 21.48 ± 7.153 kg at 3 weeks. However, subsequent follow-ups show progressive recovery, reaching a mean of 30.13 ± 9.421 kg at 6 months, as depicted in **table 5**. The box plots (**Figure 5**) visualize this trend effectively, demonstrating a gradual return to normal strength postoperatively.

Table 6: Mean rank friedman test of grip strength on pre-op and follow ups

Grip Strength	**Mean Rank**	**χ^2, p value**
Pre op	2.72	
3 weeks (post op)	1	
3 months (post op)	2.48	χ^2= 56.4,
6 months (post op)	3.8	p value < 0.001

Figure 2: Line graph demonstrating change in mean friedman rank of grip strength over time

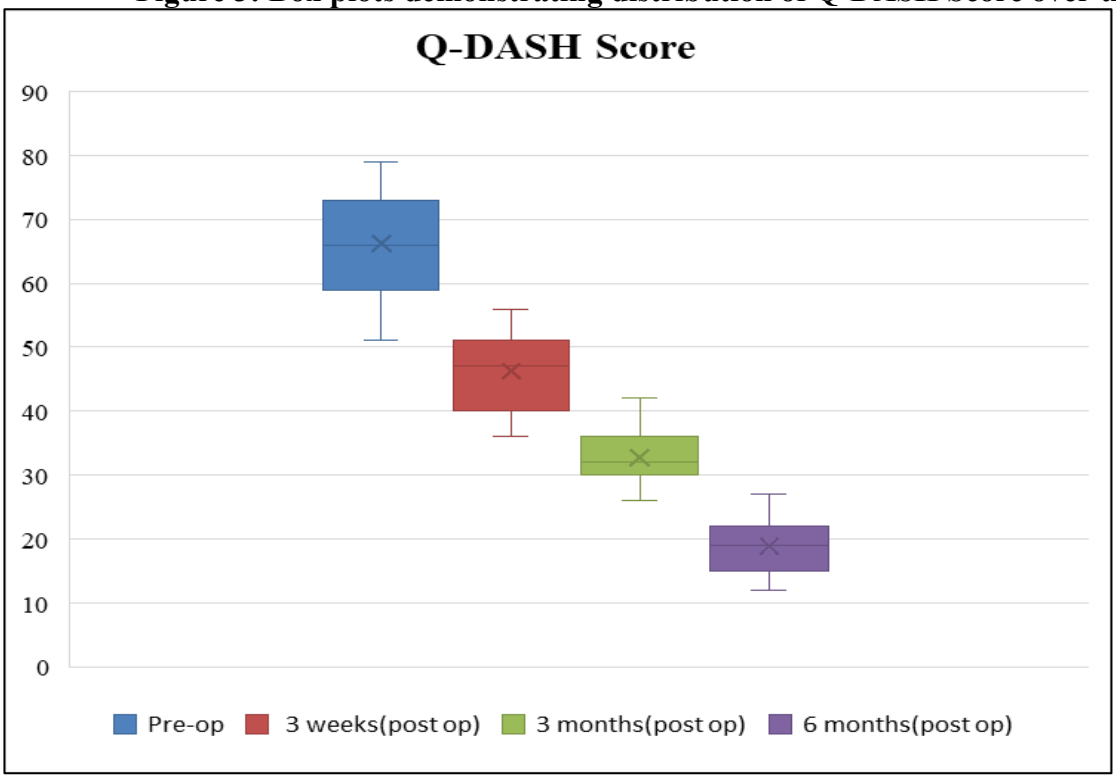


The Friedman test results (χ^2**=56.4, p<0.001**) indicate a statistically significant difference in grip strength across time points. The lowest rank is observed at 3 weeks postoperatively, reflecting the immediate post-surgical weakness, whereas the highest rank at 6 months suggests substantial recovery, as depicted in **table 6**. The line graph (**Figure 2**) captures this progression.

Table 7: Mean Q-DASH Score of patient's pre-op and follow ups

Q-DASH Score	**Mean ± SD**	**Min**	**Max**
Pre op	66.26 ± 8.42	51	79
3 weeks (post op)	46.30 ± 5.91	36	56
3 months (post op)	32.78 ± 4.67	26	42
6 months (post op)	18.91 ± 4.58	12	27

Figure 3: Box plots demonstrating distribution of Q-DASH Score over time



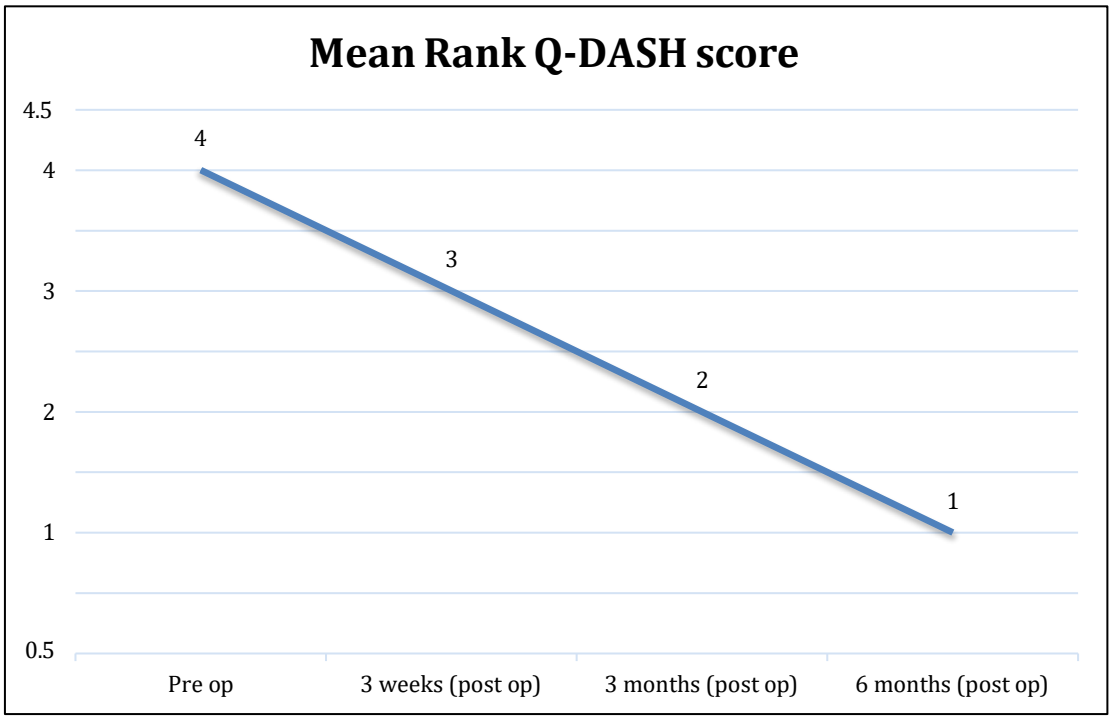
The Q-DASH score, which measures disability, shows a significant improvement postoperatively. The preoperative mean score of 66.26 ± 8.42 declines to 18.91 ± 4.58 at 6 months, indicating a substantial reduction in disability, as shown in **table 7**. The box plots (**Figure 3**) illustrate this trend, showing a progressive improvement in functional ability over time.

Table 8: Mean rank friedman test of Q-DASH Score on pre-op and follow ups

Q-DASH SCORE	**Mean Rank**	**χ^2, p value**
Pre op	4.00	
3 weeks (post op)	3.00	χ^2= 69,

3 months (post op)	2.00	p value < 0.001
6 months (post op)	1.00	

Figure 4: Line graph demonstrating change in mean friedman rank of Q-DASH Score over time



The Friedman test results ($\chi 2=69$, $p<0.001$) confirm a statistically significant improvement in the Q-DASH scores. The highest rank is seen preoperatively, representing the greatest disability, whereas the lowest rank at 6 months postoperatively confirms significant functional recovery, as shown in **table 8**. The line graph (**Figure 4**) effectively demonstrates this trend.

Discussion:

Carpal Tunnel Syndrome (CTS) is a common nerve disorder that affects hand function and daily activities. Open Carpal Tunnel Release (OCTR) is a well-established surgical treatment for moderate to severe cases, aimed at relieving symptoms and improving hand strength. This study evaluates how patients recover after surgery by measuring changes in grip strength, nerve function, and overall hand use.[3]

In this section, we compare our findings with previous research to understand patterns in symptom relief, strength recovery, and nerve function improvement.[18] We also examine how factors like age, occupation, and pre-surgery nerve damage affect recovery.[11] While most patients show significant improvement, some continue to experience minor symptoms, highlighting differences in individual recovery rates[9].

The discussion also looks at complications such as delayed healing, nerve irritation, and scar tenderness, which have been previously reported in CTS surgeries[17]. Understanding these issues can help improve patient care and surgical outcomes.

By reviewing both the benefits and challenges of OCTR, this section provides a clearer picture of its effectiveness in treating CTS. The goal is to explore what contributes to a successful recovery and how treatment approaches can be improved for better patient outcomes[18].

Demographic Details

In this study, a total of 23 patients diagnosed with Carpal Tunnel Syndrome (CTS) were included, with a mean age of 53 ± 1.91 SD years. The majority of cases were observed in the 51–60 years age group (43.5%), followed by the 41–50 years age group (30.4%) and 61–70 years age group (17.4%). These findings are consistent with previous studies that indicate CTS predominantly affects middle-aged and elderly individuals (Shankar et al., 2020) [19]. This trend is attributed to age-related degenerative changes in the carpal tunnel structure, cumulative mechanical strain, and declining nerve regenerative capacity

Gender distribution in this study showed a mild male predominance, with 56.5% of patients being male and 43.5% female. This contradicts previous studies that CTS is more prevalent in females (Bland, 2019) [20], our study showed a slight male predominance (56.5%), likely due to occupational risk factors, such as heavy manual labor and repetitive hand movements, as previously documented by De Roo et al. (2021) [21].

Laterality analysis in this study revealed that 52.2% of cases affected the left hand, while 47.8% affected the right hand, suggesting a near-equal distribution. This finding is consistent with research by Pace et al. (2023)[22]. However, certain studies suggest that dominant-hand involvement is more common, likely due to greater mechanical stress and repetitive strain (Orhurhu et al., 2020) [23].

The etiology of CTS is known to be multifactorial, and in this study, occupational exposure, repetitive hand use, and age-related degenerative changes were identified as major contributing factors. Similar to the present study, research by Hutting & van Uchelen (2018) [24] also emphasizes the role of forceful gripping and vibratory tool use in CTS pathogenesis., particularly among industrial workers and those engaged in manual labour [20]. Although the role of keyboard use and office work in CTS remains controversial, recent studies by Ayache et al. (2020)[25]suggest that prolonged static wrist positioning may exacerbate symptoms

Systemic conditions, including diabetes mellitus, rheumatoid arthritis, and hypothyroidism, have been linked to CTS due to their role in increasing median nerve vulnerability (Soltani et al., 2017) [26] . However, these conditions were excluded from our study to ensure a homogeneous patient population. Genetic predisposition has also been suggested as a contributing factor, with certain populations exhibiting higher CTS prevalence due to hereditary carpal tunnel anatomy variations (Duetzmann et al., 2018) [27].

Clinical Features

The most commonly reported symptoms in this study were numbness, tingling, pain, and weakness in the median nerve distribution, which are characteristic of CTS. The clinical examination revealed positive Phalen's test, Tinel's sign, and Durkan's test, all of which are widely used for CTS diagnosis. These findings are consistent with prior findings by De Roo et al. (2021) [21]. Phalen's test, Tinel's sign, and Durkan's test were positive in most patients, supporting their diagnostic reliability as reported by Pace et al. (2023) [22]. Nighttime exacerbation of symptoms, a hallmark of CTS, was commonly observed, aligning with findings by Ayache et al. (2020) [25], which attribute this to increased intracarpal pressure during sleep.

Muscle weakness, particularly involving the thenar muscles, was observed in some chronic cases, indicating advanced nerve compression and motor fiber involvement. Similar findings were documented by Soltani et al. (2017) [26], who observed that prolonged untreated CTS leads to irreversible motor fiber damage.

Grip Strength

Grip strength was assessed preoperatively and postoperatively using a hand dynamometer, revealing a characteristic pattern of initial postoperative decline followed by progressive recovery. Preoperative grip strength in this study was 26.91 ± 8.49 kg, which declined to 21.48 ± 7.153 kg at three weeks postoperatively due to surgical trauma and temporary nerve dysfunction. However, there was a gradual increase to 26.65 ± 8.397 kg at three months and further improvement to 30.13 ± 9.421 kg at six months, indicating functional recovery and nerve regeneration.

Recent literature supports this trend, indicating that initial muscle weakness post-surgery is often temporary and gradually resolves as nerve regeneration and muscle reactivation occur (Duetzmann et al., 2018) [27]. The statistically significant improvement (χ^2=56.4, p<0.001) in grip strength confirms the positive impact of OCTR in restoring functional hand capacity. Additionally, rehabilitation strategies such as hand therapy and progressive resistance exercises have been shown to expedite grip strength recovery (Ayache et al., 2020) [25].

QuickDASH Score

Functional recovery after open carpal tunnel release (OCTR) surgery was evaluated using the Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) questionnaire, a validated tool for assessing upper limb disability and functional impairment. The findings revealed a steady decline in QuickDASH scores postoperatively, indicating a progressive improvement in hand function. The preoperative QuickDASH score of 66.26 ± 8.42 significantly decreased to 46.30 ±5.91 at three weeks, 32.78 ± 4.67 at three months, and 18.91 ± 4.58 at six months. This statistically significant reduction suggests that surgical decompression effectively alleviates disability and enhances functional outcomes over time.

The statistically significant reduction in QuickDASH scores (p<0.001) is consistent with prior studies. De Roo et al. (2021) [21] and Pace et al. (2023) [22] reported that functional disability declines sharply within the first six months following OCTR. The primary reasons for this improvement include relief of nerve compression, reduction in pain and numbness, and progressive muscle reactivation. Patients in this study reported noticeable improvements in daily activities, including grasping objects, performing fine motor tasks, and reduced night-time discomfort.

Although most patients achieved significant recovery, mild residual symptoms persisted in some cases, as reflected by the QuickDASH score of 18.91 ± 4.58 at six months. This aligns with Orhurhu et al. (2020) [23] found that longer symptom duration before surgery correlates with slower functional improvement. Additionally, adherence to postoperative rehabilitation, particularly nerve gliding exercises and ergonomic adjustments, has been shown to significantly enhance recovery outcomes (Soltani et al., 2017)[26]. Overall, the steady decline in QuickDASH scores confirms that OCTR is highly effective in reducing disability and restoring hand function in CTS patients.

Conclusion: Carpal Tunnel Syndrome is a major cause of upper limb disability, affecting millions of individuals worldwide. Open carpal tunnel release (OCTR) surgery remains the gold-standard treatment for moderate to severe CTS, effectively alleviating median nerve compression and restoring hand function. This study demonstrated significant postoperative improvements in grip strength, and QuickDASH scores, confirming the clinical benefits of surgical decompression.

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