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Grip Strength Measurement for Outcome Assessment in Common Hand Surgeries

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Grip strength has been used to evaluate the upper extremity functional status and clinical outcomes following upper extremity trauma or surgery. Understanding general recovery patterns of grip strengthening can be helpful in assessing the patients' recovery status and in assisting in preoperative consultations regarding expectations for recovery. We summarize related studies on grip strength measurement and recovery patterns in common hand conditions, including carpal tunnel syndrome, cubital tunnel syndrome, triangular fibrocartilage complex injury, and distal radius fractures.

Keywords: *Grip strength, Distal radius fracture, Triangular fibrocartilage complex, Carpal tunnel syndrome, Cubital tunnel syndrome*

Since measuring grip strength is cost-effective and closely related to activities of daily living,[1] researchers have utilized grip strength as a parameter to evaluate the upper extremity functional status and clinical outcomes following treatment for upper extremity disease or trauma.[2,3] In addition, grip strength is becoming more important because it is one of the major components for diagnosis of sarcopenia and is associated with several chronic diseases including osteoporosis and cognitive disorders.[1] Upper extremity grip strength recovery is closely related to baseline nerve and muscle status, invasiveness, the extent of surgical treatment, and rehabilitation protocols. Understanding general grip strength recovery patterns can be helpful in assessing the recovery status as they are related to conditions or treatments. This understanding also helps in preoperative consultations about recovery expectations.

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Therefore, in this review, we summarize related studies on grip strength measurement and recovery patterns in common hand conditions, including carpal tunnel syndrome (CTS), cubital tunnel syndrome (CuTS), triangular fibrocartilage complex (TFCC) injury, and distal radius fractures (DRFs).

MEASUREMENT OF GRIP STRENGTH USING A DYNAMOMETER IN COMMON HAND CONDITIONS

Four characteristics of an ideal dynamometer required for grip strength measurements are[4] (1) reproducible and accurate measurements regardless of grip strength, (2) functionally independent from hand size, (3) comfortable for the subjects to use, and (4) small size and readily portable. Based on these requirements, there are three types of dynamometers, which are frequently used in clinical practice:[1] hydraulic type (Jamar and its variants), pneumatic type (Martin Vigorimeter), and mechanical type (Smedley) (Fig. 1). The Jamar and its variants are currently most widely used and have acceptable reliability and validity.[1] It consists of two handles and one handle is curbed to fit the hand. It has five handle positions for different hand sizes, and among them the second handle is the standard posi-

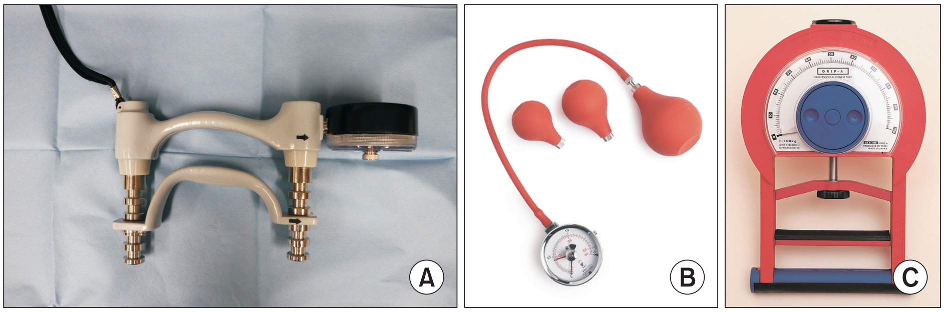

Fig. 1. Various types of dynamometers for measurement of grip strength (Reproduced from Lee and Gong[1]). (A) Hydraulic type dynamometer (Jamar). (B) Pneumatic type dynamometer (Martin Vigorimeter). (C) Mechanical type dynamometer (GRIP-A, Takei).

tion.[1] However, because the machine is heavy and weighs 1.5 kg, as well as requiring at least 3 to 4 pounds to move the scale, measurement can be inaccurate in patients with arthritis or weak muscles.[5,6] In such cases, the pneumatic type can be an alternative.[5,6] Patients can squeeze it with less force than other types of dynamometers, thus minimizing pain. For different hand sizes, it provides three sizes of balloons.[1] The mechanical type (Smedley) is commonly used is Asia.[6] It measures grip strength based on the amount of tension generated in a steel spring.[1] It consists of two handles, and the distance between the handles can be adjusted depending on the size of the hand.[1] However, the Smedley has a potential for systematic bias with an underestimation of grip strength as compared to the Jamar.[7] When comparing grip strength measurements between the Smedley and Jamar, we should keep this bias in mind.

Grip strength varies depending on the testing position because related muscles have different optimal lengths and use different axes to generate the most powerful grip force.[1] Multiple studies have reported differences in grip strength according to the body and arm positions, although there were conflicting reports on the effect of the position.[1] Therefore, in comparing grip strengths, it is recommended using the same testing and body positions. Two frequently used protocols for measuring grip strength are the American Society of Hand Therapists (ASHT) protocol[8] and the Southampton protocol.[9] ASHT protocol suggested following subject positions: (1) sitting position, (2) the shoulder adducted, (3) the elbow flexed at 90°, and (4) the forearm and wrist in a neutral position, and (5) the wrist between 0° and 30° extension and 0° and 15° of ulnar deviation.[9] Southampton protocol suggested subject positions as follows: (1) seated position (same chair for every measurement), (2) forearms rested on the arms of the chair, and (3) the wrist just over the end of the arm of the chair in a neutral position with the thumb facing upwards.[9]

GRIP STRENGTH IN CARPAL TUNNEL SYNDROME

CTS is the most common upper compressive neuropathy in the upper extremity and is caused by compression of the median nerve at the wrist.[10] Although extrinsic muscles, which play a major role in generating grip strength, are innervated by the proximal median nerve in the forearm, weakening of the intrinsic thenar muscles affected by CTS can result in decreased grip strength.[11] In addition, sensory changes can also affect those precision grip motions that affect grip strength.[11]

Several studies reported that grip strength decreased in patients with CTS in various age- and sex-matched control groups.[11,12] In addition, Kozin et al.[13] reported that the average decrease in grip strength following median nerve block at the wrist level was 32%. They suggested that if the intrinsic muscles did not function, the grasping mechanism would be delegated to the extrinsic muscles, resulting in an asynchronous nonintegrated grasp. However, the degree of the grip strength decrease seems not to be related to the severity of CTS. Atalay et al.[14] compared 99 patients according to their electrophysiological status and reported that there was no difference between the severity of disease and grip strength although grip strength tended to decrease slightly with disease progression. They argued that the synergistic muscles compensated for thenar muscle weakening.[14]

Grip strength has been used as one of the indicators of functional recovery following carpal tunnel release (CTR). However, assessing grip strength recovery can be difficult because grip strength usually decreases temporarily following division of transverse carpal ligament (TCL), which plays a role in the digital flexor pulley system.[15,16] There are abundant reports on grip strength recovery patterns following CTR, and most researchers have suggested that patients usually achieved total grip strength recovery 3 to 6 months postoperatively (Table 1).[2,17-27] Some researchers reported rapid grip strength recovery in 4 to 6

Table 1. Grip Strength Recovery after CTR

Study	Study design	Participant (n)	Age (yr)	Dynamometer	Recovery of HGS (%)
Mackenzie et al. (2000)[17]	RCT	Open CTR (14)	NA	Jamar	1 wk: 53.8, 2 wk: 74.4, 4 wk: 76.9*
		Endoscopic CTR (22)			1 wk: 67.4, 2 wk: 97.7, 4 wk: 102.3*
Trumble et al. (2002)[18]	RCT	Open CTR (95)	56	Jamar	2 wk: 67.7, 52 wk: 103.2*
		Endoscopic CTR (97)	56		2 wk: 45.5, 52 wk: 103.0*
MacDermid et al. (2003)[2]	RCT	Open CTR (32)	53	Digit-grip device	1 wk: 50, 6 wk: 86.4, 12 wk: 122.7*
		Endoscopic CTR (91)	45		1 wk: 60, 6 wk: 104, 12 wk: 108*
Dias et al. (2004)[19]	RCT	CTR with TCL dividing (26)	56 (23–84)	Jamar	2 wk: 71.3, 6 wk: 103.9, 12 wk: 115.2, 25 wk: 119.1†
		CTR with TLC lengthening (26)			2 wk: 69.0, 6 wk: 95.2, 12 wk: 110.7, 25 wk: 115.0†
Atroshi et al. (2006)[26]	RCT	Open CTR (65)	44 (25–59)	Baseline hydraulic	3 wk: 55.8, 6 wk: 78.8, 12 wk: 95.8*
		Endoscopic CTR (63)	44 (26–59)		3 wk: 63.5, 6 wk: 82.2, 12 wk: 96.6*
Tan et al. (2012)[20]	Case-series	Open CTR (74)	57 (35–86)	Jamar	6 wk: 82.1, 12 wk: 102.4, 24 wk: 116.1*
Zyluk et al. (2013)[22]	Prospective case-control study	Open CTR without NCS (48)	55 (38–80)	Jamar	Preop: 88, 4 wk: 56, 24 wk: 113†
		Open CTR with NCS (45)	61 (41–84)		Preop: 90, 4 wk: 68, 24 wk: 100†
Zyluk et al. (2013)[21]	Retrospective case-control study	Open CTR with DM (41)	63	Jamar	Preop: 83, 24 wk: 92†
		Open CTR without DM (345)	56		Preop: 86, 24 wk: 106†
Castillo et al. (2014)[23]	RCT	Open CTR (16)	62.9 ± 17.2	NA	2 wk: 58, 6 wk: 103.6, 24 wk: 117*
		Two-incision CTR (14)	62.0 ± 14.1		2 wk: 35, 6 wk: 58.8, 24 wk: 97.9*
Puchalski et al. (2017)[24]	Case-control study	CTR after clinical diagnosis (551)	59	Jamar	Preop: 85, 4 wk: 65, 24 wk: 103*
		CTR after electrodiagnosis (392)	57		Preop: 86, 4 wk: 69, 24 wk: 105*
Gutierrez-Monclus et al. (2017)[27]	RCT	CTR with TCL release (58)	54.3 ± 9.6	Jamar	Preop: 69.1, 24 wk: 77.7*
		CTR with TCL reconstruction (59)	53.7 ± 9.3		Preop: 66.7, 24 wk: 101.3*
Bai et al. (2018)[25]	Retrospective case-control study	Open CTR (43)	52.5 ± 8.9	NA	52 wk: 149†
		Mini-incision CTR (42)	53.2 ± 9.4		52 wk: 148.8†

Values are presented as mean (range) or mean ± standard deviation unless otherwise indicated.
CTR: carpal tunnel release, HGS: hand grip strength, RCT: randomized controlled trial, NA: not available, TCL: transverse carpal ligament, NCS: nerve conduction study, DM: diabetes mellitus.
*% of uninjured side. †% of preoperative level.

weeks postoperatively.[2,17,19,23)]

It is known that three factors affect grip strength recovery following CTR. These are decompressed median nerve recovery,[21,28)] pillar pain,[2,17,18,26)] and TCL function.[16,27)] A few studies have reported that grip strength recovery tends to be lower in patients with diabetes as compared to patients without diabetes. This could be caused by inadequate nerve recovery in diabetic patients.[21,28)] Regarding pillar pain, studies comparing open and endoscopic CTR demonstrated the endoscopic group had a reduction in grip strength and a faster recovery in the early postoperative period although there was no significant difference in grip strength after a long-term follow-up period.[2,17,18,26)] Regarding the TCL, Netscher et al.[16)] compared CTR with and without TCL reconstruction and found that both groups had recovered preoperative grip strength by 12 weeks, but the reconstruction group had recovered grip strength more rapidly. Gutierrez-Monclus et al.[27)] also demonstrated that a TCL reconstruction group showed significantly higher grip strength in a randomized clinical trial. However, Dias et al.[19)] showed that grip strength did not differ between the TCL lengthening and dividing groups at any time postoperatively. A recent systematic review suggests that CTR with TLC reconstruction group did not show a significant advantage in grip strength although there was a significant difference of grip strength in favor of the TCL reconstruction group at 3 months or less postoperatively.[29)]

In summary, grip strength can deteriorate in patients with CTS, which can be used as an indicator of recovery following surgical treatment. Grip strength can usually recover to at least a preoperative level 3 to 6 months following surgery. Recovery may be affected by median nerve regeneration, pillar pain, or TCL function. Grip strength recovery can vary at short-term follow-up depending on the surgical method. However, there is no significant difference in long-term follow-up.

GRIP STRENGTH IN CUBITAL TUNNEL SYNDROME

CuTS is the second most common peripheral nerve compression in the upper extremity.[30)] The ulnar nerve is responsible for the intrinsic muscles involved in fine movements in the hand and extrinsic flexors of the 4th and 5th digits.[30)] Advanced ulnar neuropathy causes loss of thumb adduction power (Froment sign), claw hand, loss of transverse carpal arch, and abduction of the small finger (Wartenberg sign).[30)]

Regarding baseline grip strength weakness, Hazelton

Table 2. Studies Showing Significant Grip Strength Recovery after Surgical Treatment for Cubital Tunnel Syndrome

Study	Study design	Participant (n)	Age (yr)	Follow-up period (mo)	Surgical method	Dynamometer	Recovery of HGS (% of uninjured side or kg or pounds)	
							Preoperative	Postoperative
Kokkalis et al. (2010)[31)]	Case series	17 (8 male)	51 (30–67)	Evaluated at 1 yr	Open decompression (revision)	Jamar	41% ± 30%	59% ± 40%
Ido et al. (2016)[32)]	Case series	52 (44 male)	67.3 (51–83)	More than 2 yr	Anterior transposition	Jamar	18.9 kg (16.6–21.2)	25.2 kg (133%, 22.6–27.9)
Gaspar et al. (2016)[33)]	Case series	8 (5 male)	47.5 (39–57)	30 (16–41)	Open decompression (revision)	Jamar	Grip strength improved by 25 pounds (38% of recovery)	
Zhang et al. (2017)[34)]	Case series	51 (33 male)	45 (32–64)	63 ± 7.3	Anterior transposition	NA	14.2 ± 7.7 kg	35.2 kg (248% ± 12.7%)
Zengin et al. (2017)[35)]	Case series	29 (16 male)	44.4 (22–66)	16	Endoscopic decompression	Jamar	67.90%	85.50%
Lee et al. (2018)[36)]	Case series	36 (30 male)	42.2 (19–73)	52.6 (25–120)	Anterior transposition	Jamar	48.7% ± 10.7%	86.6% ± 19.2%

Values are presented as mean (range) or mean ± standard deviation unless otherwise indicated.
HGS: hand grip strength, NA: not available.

et al.[37] described the percentage of total force allocated to each finger and reported that the index finger contributes 25.4% of grip strength, the long finger contributes 33.9%, the ring finger contributes 20.9%, and the little finger contributes 15.2%, which suggest that the contribution of the ring and little fingers to grip strength is not negligible. Wachter et al.[38] reported that when an ulnar nerve block was performed on the Guyon canal in 25 healthy volunteers, grip strength decreased by 26.9%.

Various studies have reported that grip strength improved significantly after surgical treatment for CuTS (Table 2).[31-36] Giladi et al.[39] reported that grip strength and sensation continued to improve for 1 year following surgery. According to their report, the average grip strength was 25 kg before surgery and improved to 26.7 kg (106.8%) at 6 weeks following surgery, 28.5 kg (114%) at 3 months, 29.8 kg (119.2%) at 6 months, and 32.5 kg (130%) at 1 year, demonstrating continuous recovery.[39] However, in elderly patients over 59 years of age, full recovery was not seen until 6 months after surgery.[39] Ido et al.[32] reported on the clinical outcomes of 52 patients with CuTS who had been treated with an anterior subcutaneous ulnar nerve transposition. Three months following surgery, their grip strength had significantly improved, but afterwards there was no further improvement.[32] Their numbness or Semmens Weinstein test scores had significantly improved by 1 month following surgery, which was faster than their grip strength recovery.[32] According to their explanation, degenerated axons with weakened muscles took longer for meaningful strength recovery, since it took time for ulnar nerve decompression to affect the muscles, although sensation showed faster recovery upon immediate restoration of an intraneural blood supply.[32] Matsuzaki et al.[40] reported that electrophysiologic recovery and functional outcomes continued to improve for more than 2 years, but they had not evaluated grip strength. Although diabetes is known to affect the recovery of CTS, there are not many related studies about whether diabetes adversely affects CuTS recovery. Recently, Zimmerman et al.[41] reported that women with diabetes benefited from simple decompression of the ulnar nerve to the same extent as women without diabetes. However, this was not true for men, although they had not been evaluated for grip strength.

In summary, with CuTS surgical treatment, grip strength recovery following nerve decompression is slower than improvement of sensation, showing meaningful recovery after 3 months and continued recovery after 1 year. In patients with more severe neuropathy and advanced age, grip strength recovery tends to be more limited and reaches a plateau in a shorter period of time.

GRIP STRENGTH IN TRIANGULAR FIBROCARTILAGE COMPLEX TRAUMATIC INJURY

The TFCC is known to play an important role in wrist stabilization, rotation, translation, and loading transmission functions.[42,43] It is vulnerable to damage and degenerative changes because it is a load-bearing and rotational stabilizing structure.[44] When the TFCC is damaged, the patient typically complains of ulnar side pain, weakness, or instability upon power gripping.[45]

Patients with TFCC tears had a 52.9% to 92.7% grip strength difference when compared with their contralateral side.[46-61] Following surgery, grip strength improved from 61% to 103.6%.[46-61] Most studies have reported statistically significant grip strength recovery (Table 3).[48-50,52-57,61]

In TFCC injuries, Ruch and Papadonikolakis[62] reported a significant correlation between grip strength and pain ($r = -0.656$, $p = 0.002$). In patients without pain, grip strength on the contralateral side was 88%, whereas it was 61% in patients with pain.[62] Kwon et al.[61] found no significant differences in grip strength recovery following TFCC repair based on the status of ulnar variance. In regards to surgery timing, Park et al.[57] found no differences, even if the operation had been performed 12 months after the initial injury. Most researchers could not obtain a recovery of 90% grip strength or greater on the contralateral side even more than 1 year postoperatively[46,47,49-52,55,56,58-62] except in a few reported cases.[48,53,54,57]

In conclusion, grip strength can be significantly recovered following repair of a TFCC tear, although it may be difficult to achieve a preinjury status. Grip strength recovery can be related to the degree of postoperative pain. Ulnar positive variance or timing of surgery may not affect grip strength recovery following TFCC repair.

GRIP STRENGTH IN DISTAL RADIUS FRACTURES

Multiple studies suggested a possible association between the risk of DRFs and low grip strength, which may be associated with weak bone strength and increased risk of falling.[63-68] Wagner et al.[63] revealed that in 821 men, low grip strength was associated with a more rapid decrease in total volumetric bone mineral density at the distal radius. Cho et al.[64] found that DRF patients had a significantly lower grip strength than a control group. They suggested that a subtle decrease in grip strength may be associated with an increased risk of falling. Low grip strength may be related to poor cortical trabecular microarchitecture of the

Table 3. Studies Showing Significant Grip Strength Recovery after TFCC Repair

Study	Study design	Participant (n)	Age (yr)	Follow-up period (mo)	Surgical method	Dynamometer	Recovery of HGS (% of uninjured side or kg)	
							Preoperative	Postoperative
Estrella et al. (2007)[52]	Case series	35 (22 male)	33 (13–51)	39 (4–82)	AS	Jamar	58% ± 32%	82% ± 28%
Shinohara et al. (2013)[53]	Case series	11 (7 male)	27 (16–35)	30 (20–51)	AS	NA	84% ± 22%	98% ± 16%
Moritomo (2015)[54]	Case series	21 (13 male)	31 (14–52)	26 (6–65)	Open	NA	65% ± 20%	92% ± 10%
Atzei et al. (2015)[48]	Case series	48 (28 male)	34 (17–54)	33 (6–52)	AS	Jamar	92.7% ± 19%	103.6% ± 16%
Bayoumy et al. (2015)[50]	Case series	37 (29 male)	23.3 (18–34)	Evaluated at 2 yr	AS	NA	82.5% (60–100)	89% (75%–100%)
Park et al. (2018)[55]	Case series	16 (12 male)	29.8	31.1 (24–42)	AS	NA	57.30%	79.60%
Park et al. (2018)[56]	Case series	10 (6 male)	33.4 (19–50)	23.5 (12–42)	AS	NA	67.50%	79.30%
Park et al. (2020)[57]	Comparative study	80 (56 male)	27.8 (20–43)	Evaluated at 2 yr	AS	Baseline	77.1%	95.6%
Auzias et al. (2020)[49]	Case series	24 (11 male)	41 (20–77)	44 (23–81)	AS	Jamar	35 ± 13.6 kg	43 ± 13.7 kg
Kwon et al. (2020)[61]	Comparative study	UPV group (28)	33 (18–56)	21(12–45)	AS	NA	55% ± 33%	86% ± 21%
		Non-UPV group (22)	25 (18–54)	18 (12–37)			65% ± 26%	80% ± 14%

Values are presented as mean (range) or mean ± standard deviation unless otherwise indicated.
TFCC: triangular fibrocartilage complex, HGS: hand grip strength, AS: arthroscopy, NA: not available, UPV: ulnar positive variance.

Table 4. Studies Showing Grip Strength Recovery at More Than 1 Year after Volar Plating for Distal Radius Fractures

Study	Study design	Participant (n)	Age (yr)	Follow-up period (mo)	Dynamometer	Recovery of HGS (% of uninjured side)
Campbell (2000)[69]	Case series	ORIF (25)	Men: 40 (18–59) Women: 48 (19–71)	16 (12–26)	NA	76% (33%–100%) at final follow-up
Schneeberger et al. (2001)[70]	Case series	ORIF (19)	43 (23–60)	23 (12–25)	Jamar	87% (70%–105%) at final follow-up
Jupiter et al. (2002)[71]	Case series	ORIF (20)	68 (60–81)	38 (24–90)	NA	80% (50%–100%) at final follow-up
Orbay et al. (2002)[72]	Case series	ORIF (29)	54 (25–86)	12.5 (53–98 wk)	Jamar	79% (60%–110%) at final follow-up
Ring et al. (2004)[73]	Case series	ORIF (25)	46 (26–72)	26 (14–48)	NA	78% (45%–100%) at final follow-up
Beharrie et al. (2004)[74]	Case series	ORIF (18)	71 (60–86)	26 (12–40)	Sammons Preston	86% (64%–133%) at final follow-up
Orbay et al. (2004)[75]	Case series	ORIF (23)	78.6 (75–94)	63 wk (53–98 wk)	Jamar	77% (67%–105%)

Values are presented as mean (range) unless otherwise indicated.
HGS: hand grip strength, ORIF: open reduction and internal fixation with volar plating, NA: not available.

Table 5. Studies Comparing Grip Strength Recovery between Volar Plating and Other Methods for Distal Radius Fractures

Study	Study design	Participant (n)	Age (yr)	Follow-up period	Dynamometer	Recovery of HGS (% of uninjured side)
Egol et al. (2008)[76]	RCT	EF (50)	49.9 (18–78)	At least 1 yr	NA	3 mo: 29%, 6 mo: 52%, 12 mo: 100%
		ORIF (57)	52.2 (19–87)			3 mo: 36%, 6 mo: 41%, 12 mo: 85%
Rozental et al. (2009)[77]	RCT	CRPP (22)	51 (19–77)	1 yr	NA	6 wk: 25.6%, 12 wk: 69.8%, 1 yr: 90.2%
		ORIF (21)	52 (24–79)			6 wk: 49.3%, 12 wk: 64.5%, 1 yr: 87.9%
Marcheix et al. (2010)[78]	RCT	CRPP (53)	73 ± 11	26 wk	NA	12 wk: 45%, 26 wk: 58%
		ORIF (50)	75 ± 11			12 wk: 54%, 26 wk: 70%
Hollevoet et al. (2011)[79]	RCT	CRPP (20)	66	At least 1 yr	Jamar	3 mo: 56%, 1 yr: 94%
		ORIF (20)	67			3 mo: 60%, 1 yr: 82%
Lee et al. (2012)[80]	Case-control study	CRPP (31)	50–70	15.2 ± 10.8 mo	NA	Final follow-up: 84%
		ORIF (31)	50–70	19.2 ± 7.1 mo		Final follow-up: 91%
Wilcke et al. (2011)[81]	RCT	ORIF (33)	55 (20–69)	1 yr	Grippit	3 mo: 72%, 6 mo: 89%, 12 mo: 94%
		EF (30)	56 (21–69)			3 mo: 46%, 6 mo: 72%, 12 mo: 85%
Karantana et al. (2013)[82]	RCT	CRPP (64)	51 ± 16	1 yr	Jamar	6 wk: 10%, 12 wk: 45%, 1 yr: 84%
		ORIF (66)	48 ± 15			6 wk: 40%, 12 wk: 65%, 1 yr: 95%
Goehre et al. (2014)[3]	RCT	CRPP (19)	73.8 ± 8.9	1 yr	Jamar	3 mo: 51%, 6 mo: 75%, 12 mo: 88%
		ORIF (21)	71.3 ± 5.7			3 mo: 63%, 6 mo: 75%, 12 mo: 88%
Bialas et al. (2016)[83]	Case-control study	CRPP (29)	57 (28–87)	At least 1 yr	MG 4800	Final follow-up: 80%
		ORIF (31)				Final follow-up: 85.3%
Hammer et al. (2019)[84]	RCT	EF (82)	54 (18–70)	2 yr	Jamar	6 wk: 6.8%, 3 mo: 41.7%, 6 mo: 66.7%, 1 yr: 84.6%, 2 yr: 92.9%
		ORIF (84)	56 (18–70)			6 wk: 38.2%, 3 mo: 64.9%, 6 mo: 84.3%, 1 yr: 95.0%, 2 yr: 99.1%

Values are presented as mean (range) or mean ± standard deviation unless otherwise indicated.
HGS: hand grip strength, RCT: randomized controlled trial, EF: external fixation, ORIF: open reduction and internal fixation with volar plating, NA: not available, CRPP: closed reduction and percutaneous pinning.

distal radius and the risk of DRFs.[66-68]

Grip strength measurement has been widely used as an index of recovery following DRF repair.[3,69-80,82,83,85] This correlates with the Disabilities of the Arm, Shoulder and Hand Score and the Patient-Rated Wrist Evaluation Score.[86] A majority of studies found that about 50% of grip strength was recovered within 3 to 6 months following surgery, and more than 75% was recovered after 1 year (Tables 4 and 5).[3,69-85] Brogren et al.[87] suggested that grip strength could continue to improve, even 1 year after surgery. They reported that the mean grip strength of the injured side at 1 year postoperatively was 88% of the contralateral side, which was significantly lower (mean differences: 3.2 kg, $p < 0.001$).[87] However, there was no significant difference in grip strength between the injured side and the healthy side, even 2 to 4 years postoperatively.[87]

During the early postoperative period, the grip strength of the volar plating group seemed to recover faster as compared to the external fixator group. This difference disappeared after 6 months to 1 year postoperatively (Table 5). However, there were contradictory results in studies comparing closed reduction and percutaneous pinning (CRRP) to open reduction using volar plating (Table 5). Hollevoet et al.[79] and Goehre et al.[3] reported that there were no significant differences in grip strength recovery between the two groups. However, Marcheix et al.[78] and Karantana et al.[82] reported that a volar plating group showed superior grip strength recovery. On the other hand, Rozental et al.[77] reported that a CRRP group showed faster grip strength recovery than did a volar plating group. But these differences diminished after 12 weeks.

Regarding treating DRFs with volar plating, Lozano-Calderon et al.[88] compared early-to-late (2 to 6 weeks) rehabilitation groups. They reported that there were no significant differences in grip strength at 3 and 6 months following surgery. However, Quadlbauer et al.[89] showed that an early rehabilitation group had a significantly stronger grip strength up to 6 months postoperatively, but there were no significant differences at 1 year following volar plating. Dennison et al.[90] also reported similar results. Gutierrez-Espinoza et al.[91] recently conducted a meta-analysis comparing functional recovery following early and late rehabilitation in DRFs treated with volar plates. They suggested that grip strength was superior in the early rehabilitation group at a 6-week and 3-month follow-up, but these differences were diminished at 1-year follow-up.

In summary, studies suggest that weak grip strength is related to an increased risk of DRFs. Patients with DRFs could regain more than 50% of their grip strength after 3 months and more than 75% after 1 year following surgery. Grip strength seems to recover faster in the volar plating group during the early postoperative period as compared to the external fixator group. However, these differences even out in a long-term follow-up. A short-term follow-up may show that grip strength can be recovered more quickly in the early rehabilitation group, but there is no significant difference in a long-term follow-up.

CONCLUSION

Since measuring grip strength is cost-effective and closely related to activities of daily living,[1] many investigators have reported grip strength outcomes in research on hand surgery. Grip strength recovery in the upper extremity can be closely related to the baseline nerve and muscle status, invasiveness, the extent of the surgical treatment, as well as rehabilitation protocols. We have summarized the clinical implications of grip strength in common hand conditions, including CTS, CuTS, TFCC injury, and DRFs. The peripheral nerve compression syndromes (CTS and CuTS) can involve baseline weakness in the innervated muscles that generate grip strength. Change in the grip strength seems to be more dramatic in CTS than in CuTS because grip strength decreases after TCL division but recovers faster because of its short reinnervation length. Patients with CuTS do not show postoperative temporary grip strength decreases, and recovery can take a longer time. In TFCC repair, most researchers have reported significant improvement in grip strength, but it seems that grip strength does not reach a preinjury level. In DRFs, low grip strength is associated with low bone mass and a higher risk of falling. With surgical treatment, patients can regain more than 50% of their grip strength after 3 months and more than 75% of their grip strength after 1 year. Considering that grip strength assessment can be influenced by multiple factors, including types of dynamometers, body and arm positions, anthropometric parameters,[1] and psychologic factors,[92] which have been overlooked in most studies, future studies should consider the various factors influencing grip strength recovery. An understanding of the general recovery patterns of grip strength according to different situations can be helpful for patients in evaluating their expectations of recovery before undergoing surgery.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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