Predictors of Pain Intensity and Functional Limitation After Conservative Treatment in Idiopathic Ulnar Impaction Syndrome: High Work-Related Exposure or Degenerative Complex TFCC Tear Inevitably Results in Surgical Treatment of Idiopathic Ulnar Impaction Syndrome

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Research article

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Abstract

**Background:** This study aimed to identify predictors of pain intensity and functional limitation after conservative treatment in idiopathic ulnar impaction syndrome (UIS).

**Methods:** One hundred seventy-seven patients with UIS who inevitably underwent ulnar shortening procedures because of considerable pain or functional limitation despite at least 6 months of conservative treatment were included. To identify the predictors of pain intensity and functional limitation after appropriate conservative treatment in UIS, pain intensity was estimated using the visual analog scale (VAS) score, while functional limitations of the wrists were evaluated by the Disabilities of the Arm, Shoulder, and Hand score (DASH; subjective functional limitation), wrist range of motion, and grip strength (objective functional limitation) just before surgery. We considered sex, age, dominance of the affected wrist, work-related exposure, length of ulnar variance, types of distal radioulnar joint (DRUJ) on the coronal, degree of ulnocarpal degeneration, presence of degenerative complex triangular fibrocartilaginous complex (TFCC) tear, and presence of bony lesions (cyst or sclerosis or erosion of lunate or triquetrum or ulnar head) as possible predictors of pain intensity and functional limitations of the wrists. The relationship between pain intensity and functional limitation and the possible predictors were statistically analyzed using a linear regression test.

**Results:** Only work-related exposure was positively correlated with pain intensity and subjective functional limitation. The degenerative complex TFCC tear was a common predictor of an objective functional limitation.

**Conclusions:** Patients with unavoidable excessive wrist use and degenerative complex TFCC tears tended to have more significant pain intensity and functional limitations despite at least 6 months of conservative treatment. Early surgical treatment should be considered for these patients.

Background

Idiopathic ulnar impaction syndrome (UIS) is a chronic degeneration of the ulnocarpal joint resulting from an excessive load of the ulnar head against the triangular fibrocartilage complex (TFCC) and the ulnar carpal bones [1, 2]. Degeneration of the ulnocarpal structures including the TFCC, lunate, triquetrum, ulnar head, and lunotriquetral ligament leads to ulnar wrist pain, limited range of motion, and diminished grip strength [1, 2]. Degeneration is commonly considered the result of positive ulnar variance [1, 2]. Hence, surgeons believe that a longer ulnar variance induces more significant symptoms and tend to choose surgical treatment for wrists with a longer ulnar variance and conservative treatment for wrists with neutral or negative ulnar variance. However, the symptoms of UIS can be more significant in the ulnar neutral or negative wrist and may not be present in wrists with a longer ulnar variance [1, 3–5].

Since established surgical indications for UIS are lacking and little attention has been given to it, it is impossible to recognize patients at the first visit who would inevitably need surgical treatment for UIS. Surgical treatment for chronic musculoskeletal disorders has been considered for patients with significant pain intensity and functional limitations despite appropriate conservative treatment for at least 6 months [6–8]. Recognition of the predictors of pain intensity and functional limitation after conservative treatment is helpful for establishing a reasonable treatment plan for UIS and avoiding unnecessary wastes of cost and time during conservative treatment. This study aimed to identify predictors of pain intensity and functional limitation that
would not be improved by conservative treatment for UIS. We hypothesized that patients with high work-related exposure and advanced degeneration in the ulnocarpal joint would show significant pain intensity and functional limitation despite conservative treatment for UIS.

Methods

Patients

This study was approved by the local institutional review board and all enrolled patients provided informed consent (2018AS0047). The study protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki. We enrolled 415 wrists that were diagnosed with idiopathic UIS between September 2014 and August 2018. Wrists in this study were managed conservatively at first. All patients followed the same protocol of conservative treatment, including medication, physiotherapy, and life or work style modifications. Surgery was performed with an ulnar shortening procedure included simultaneous arthroscopy in wrists, not showing improvement despite at least 6 months of conservative treatment. Of the 415 wrists, the surgery cases of 177 that met our inclusion and exclusion criteria were selected and retrospectively reviewed (Fig. 1).

Inclusion and exclusion criteria for patient selection

The wrists underwent an ulnar shortening procedure with simultaneous arthroscopy and had the full medical records were included. Patients with prior trauma or congenital anomalies or diseases in either upper extremity, including bilateral UIS, were excluded (Fig. 1). The diagnostic criteria for UIS included symptoms of ulnar wrist pain that are aggravated by wrist pronation and ulnar deviation, pain on an ulnar stress test, tenderness at the ulnocarpal joint, and degenerative changes to the lunate or triquetrum or ulnar head cartilage on magnetic resonance images (MRI) [9, 10]. All cases of ulnocarpal degeneration were re-evaluated and confirmed in simultaneous wrist arthroscopy during the ulnar shortening procedure.

Study design

To identify the predictors of pain intensity and functional limitation after appropriate conservative treatment of UIS, we performed a linear regression test of age, sex, dominance of the affected wrist, distal radioulnar joint (DRUJ) type on simple frontal radiography, work-related exposure, ulnar variance, grade of ulnocarpal degeneration, presence of degenerative complex TFCC tear, and presence of bony lesions (cyst or sclerosis or erosion of lunate or triquetrum or ulnar head).

Measurement of pain intensity and functional limitation

To assess the pain intensity and functional limitations of the UIS, the visual analog scale (VAS) score (pain intensity), Disabilities of the Arm, Shoulder and Hand (DASH) Score (subjective functional limitation), wrist range of motion, and grip strength (objective functional limitation) just before surgery were scored. The VAS and DASH scores were completed by the patients who received no interventions. The active wrist range of motion was measured with a goniometer, while grip strength was measured using a Jamar dynamometer (Lafayette, IN, USA). Grip strength values are expressed as a percentage of the strength against the unaffected side.

Evaluation of possible predictors
To evaluate the possible predictors of pain intensity and functional limitations. Age, sex, and dominance of the affected wrist were recorded from the participants' medical charts at their first visit. The work-related exposures were estimated by the patient's self-reported form for that within 1 month. Patients reported average daily time for each of the six physical exposures using the modified Nordstrom questionnaire: 1) wrist bending, 2) forearm rotation, 3) pinch grip, 4) finger/thumb pushing/pressing, 5) forceful grip, and 6) lifting > 1 kg [11–13]. The work-related exposures were recorded as the sum of the average daily times of each of the six physical exposures ranging from 0 (doing nothing) to 144 hours (working all day without sleep).

Ulnar variances were measured using the method of perpendiculars; that is, after identifying the longitudinal axis of the radius, a line is drawn through the distal ulnar aspect of the radius that is perpendicular to its longitudinal axis [14]. The distance between this line and the distal cortical rim of the ulna was measured to determine the ulnar variance [14]. The DRUJ type was determined using Tolat's DRUJ classification system (type 1: vertical; type 2: oblique; type 3: reverse oblique) [15]. All radiographic factors were measured using a picture archiving and communication system (PiView STAR, INFINITT Healthcare, Seoul, Korea), which obtains reliable orthopedic measurements[16, 17]. The ulnocarpal degeneration (Palmar classification stage), the presence of degenerative complex TFCC tears and bony lesions were assessed with simple radiography and MRI of the wrists and arthroscopy during the ulnar shortening procedure. The degenerative complex TFCC tear was defined as a tear with complex tear configurations and degenerative tear margins; this differs from TFCC wear or perforation in common TFCC degeneration (Fig. 2,3). To avoid intra- and interobserver errors, radiological and intraoperative assessments for ulnar variance, DRUJ type, ulnocarpal degeneration, presence of degenerative complex TFCC tear, and bony lesions were repeated twice at 2-week intervals by two orthopedists.

**Statistical Analysis**

To identify the predictors of pain intensity (VAS score) and functional limitation of the wrists (DASH score, active range of wrist motion, and grip strength), we performed a linear regression test of age, sex, dominance of the affected wrist, DRUJ type, work-related exposure, ulnocarpal degeneration grade, presence of degenerative complex TFCC tear, ulnar variance, and presence of bony lesions (cyst or sclerosis or erosion of lunate or triquetrum or ulnar head). The effects of DRUJ type and ulnocarpal degeneration grade on pain intensity and functional limitation were analyzed to consider Tolat's type 3 DRUJ and Palmar class 2 B degeneration as reference Dummy variables. Regression coefficients (unstandardized, standardized) with 95% confidence intervals and p value were determined for all possible predictors. In all analyses, values of p < 0.05 were considered significant.

**Results**

The patients were aged 17–72 years (mean, 41.9 ± 11.1 years). Of the wrists, 105 were from men and 72 were from women (Table 1). Ninety-one (51.4 %) of the UIS cases occurred in the dominant arm, and the average ulnar variance was 3.2 ± 1.7 mm. Most wrists (53.1%, 94 wrists) had the reverse oblique type of DRUJ (Tolat's type 3) on the coronal plane. The mean amount of work-related exposure (the modified Nordstrom questionnaire score) was 27.6 ± 12.1 hours per day. Wrist MRI and arthroscopy showed Palmar class 2B ulnocarpal degeneration in 38 (21.5%), 2C in 87 (49.2%), 2D in 45 (25.4%), and 2E in 7 (4.0%) of UIS cases. Forty-two (23.7%) of UIS cases had degenerative complex TFCC tears in their arthroscopies. Simple
radiography and MRI showed 68 (38.4%) cystic lesions, 82 (46.3%) scleroses, and 66 (37.3%) erosions in the lunate or triquetrum or ulnar head. The mean VAS score was 4.9 ± 2.1, while the mean DASH score was 46.2 ± 22.6. The mean range of wrist motion was 281.1 ± 27.0°, while the mean grip strength was 57.9 ± 22.5 kg (Table 1).

Only the work-related exposure (the modified Nordstrom questionnaire score) had strong positive correlations with pain intensity (VAS score [p < 0.001, regression coefficient = 0.394, 95% CI = 0.040–0.094]) and subjective functional limitation (DASH score [p < 0.001, regression coefficient = 0.464, 95% CI = 0.594–1.141]) (Table 2,3). The presence of a degenerative complex TFCC tear was a common predictor for both active range of wrist motion (p = 0.013, regression coefficient = 0.268, 95%CI = 3.579–30.312) and grip strength (p < 0.001, regression coefficient = 0.420, 95% CI = 11.023–33.319) (objective functional limitation) (Table 4,5). The ulnar variance affected only the active range of wrist motion (p = 0.049, regression coefficient = -0.143, 95% CI = -4.638 to -0.010) and palmar stage 2D (p = 0.037, regression coefficient = 0.938, 95% CI = 2.875–93.752) and 5 (p < 0.022, regression coefficient = 0.426, 95% CI = 7.197–90.885) were also predictors of diminished grip strength (Table 4,5).

**Discussion**

Since apparent structural abnormalities, such as a malunited distal radius fracture, radial head resection, and Madelung deformity, are seen in secondary UIS, choosing surgical treatment is not difficult [1]. However, it is almost impossible to recognize patients whose conditions would be improved by conservative treatment or will inevitably require surgical treatment for idiopathic UIS. The consensus to decide on surgical treatment for idiopathic UIS is when the pain or disability is not improved even after appropriate conservative treatment[6–8]. In this study, the authors also managed all UIS cases conservatively for at least 6 months. After that, surgical treatments were chosen for patients without pain or disability improvement. If UIS may not respond to conservative treatment, it will be wastes of time and cost. Identifying factors associated with pain intensity or functional limitation after conservative treatment can help predict inevitable surgeries and decide immediately on surgical or non-surgical treatment of UIS at the first visit. This is the first study to predict the conservative treatment failure and inevitable surgery in UIS with clinical and radiologic findings.

Based on our findings, daily work-related exposure was the only significant predictor of pain intensity (VAS score) and subjective functional limitation (DASH score) after the conservative treatment of UIS (Table 2,3). This means that high work exposure results in the failure of conservative treatment in UIS, and surgical treatment would be inevitable in these patients. On the contrary, a longer ulnar variance did not affect the results of the conservative treatment. Since it has been known thatUISs are frequently associated with longer ulnar variance [1, 18], the longer ulnar variance has been considered to induce more significant symptoms in UIS. However, the longer ulnar variance did not always cause more significant pain and subjective functional limitation in this study, even though the longer ulnar variance has a greater chance of impinging with ulnar carpus. This seems to be because the impinging occurs only during wrist movement, and an immobile wrist can not induce the impinging [18]. Positive ulnar variance with lower work-related exposure can be asymptomatic, whereas neutral or even negative ulnar variance with higher work-related exposure can be symptomatic[1]. Repetitive wrist movement and load is the key to inducing symptoms of UIS.
The degenerative complex TFCC tear was a common predictor of objective functional limitation (both limited active wrist motion and diminished grip strength) in the present study (Table 4,5). The UIS with degenerative complex TFCC tears tended not to improve with conservative treatment. Degeneration commonly progresses slowly over a long time. Therefore, the ulnocarpal degeneration includes central wear or perforation of the TFCC with a smooth margin and focal chondromalacia of bony cartilage in UIS (Fig. 2) [2]. However, the degenerative complex TFCC tear in this study had a complex tear configuration accompanied by a severely degenerated tear margin and fragmented detachment of the bony cartilage that differed from usual TFCC and cartilage lesions in UIS (Fig. 3). Moreover, none of the patients included had a history of trauma on their wrist, and a degenerative complex tear could be found at any stage of ulnocarpal degeneration in this study. Hence, it was thought that the degenerative complex TFCC tear was caused by neither a usual degeneration process nor trauma of the ulnocarpal joint. Similar to a degenerative complex meniscus tear of the athlete's knee [19, 20], the degenerative complex TFCC tear seems to have occurred because of excessive load concentration in the ulnocarpal joint during a short time. This was also associated with excessive wrist use over a short time. The excessive load transfer across the ulnocarpal joint was increased during repetitive wrist ulnar deviation, forearm pronation, and a powered hand grip [21, 22]. In this situation, the TFCC is torn rather than worn or perforated. In the present study, 42 degenerative complex TFCC tears were found on arthroscopy of 177 wrists, and they consisted of three types of tear components (horizontal, radial, and flap tear) (Fig. 4). Complex TFCC tears can cause mechanical irritation and consequential pain in the ulnocarpal joint during wrist motion or grip[19, 20, 23, 24]. However, mechanical irritation is not induced if patients do not move their wrists. This is the main reason for the objective functional limitation [19, 20, 23, 24]. In a previous study, a longer ulnar variance did not affect the clinical outcome of TFCC repair, and degenerative TFCC tear is associated with unfavorable clinical outcomes of TFCC repair [25, 26]. This also supports our findings that it is not a longer ulnar variance but a degenerative complex TFCC tear associated with UIS symptoms. The mechanical irritation of the degenerative complex TFCC tear will not improve with conservative treatment, and it results in inevitable surgery such as arthroscopic debridement or repair [27, 28].

The longer ulnar variance was only associated with limited wrist motion. The ulnar variance is increased during wrist ulnar deviation and forearm rotation[15, 21, 22]. This induces impingement of the ulnocarpal joint, which is the reason for this limitation. The Palmar class 2D and 2E degeneration also reduced the grip strength in this study. In the Palmar classification system, the presence of the lunotriquetral ligament tear differs from 2B or 2C class degeneration [2]. The lunotriquetral ligament tear can elicit dynamic instability of the lunotriquetral joint [29]. The lunotriquetral instability can cause pain during hand grip, reducing its strength [29].

This study has one limitation. First, the questionnaire for assessing the amount of work-related exposures in this study was modified from the Nordstrom questionnaire and not specific for patients with UIS. The original Nordstrom questionnaire is the patient's self-reported sum of the daily occurrences of seven physical exposures for carpal tunnel syndrome [11–13]. Since six of the seven items were related to UIS and we excluded irrelevant item (time of use of handheld vibrating power tool) from the Nordstrom questionnaire to make it more suitable for UIS in this study [11–13], it was considered enough to quantify the work-related exposure in this study.

Conclusions
Conservative treatment would be unsuccessful in patients with high wrist usage and degenerative complex TFCC tears. Before conservative treatment, it would be better to recommend surgical treatment to patients who cannot decrease their wrist use or have a degenerative complex TFCC tear within the wrist.

**Abbreviations**

TFCC: Triangular fibrocartilagenous complex tear; UIS: Ulnar impaction syndrome; USO: Ulnar shortening osteotomy; DRUJ: Distal radioulnar joint; VAS: Visual analog scale; DASH: Disabilities of the Arm, Shoulder, and Hand; Magnetic resonance image: MRI; CI: 95 %confidence interval; ROM: Range of motion

**Declarations**

**Ethics approval and consent to participate**

This study was approved by the local institutional review board (2018AS0047) and informed consent was obtained from all enrolled patients. The study protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki.

**Consent for publication**

Consents for publication were obtained from all corresponding authors.

**Availability of data and materials**

The datasets generated and/or analyzed during the current study are available in the Mendeley Data, [http://dx.doi.org/10.17632/s3pdtrt8nt.1](http://dx.doi.org/10.17632/s3pdtrt8nt.1).

**Competing interests**

The authors declare that they have no conflict of interest.

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**Authors' contributions**

Dong Hun Suh and Jong Woo Kang contributed to the study design, data collection, data analysis, and writing of the manuscript. Jong Woong Park and In Cheol Choi supervised the investigation and reviewed the initial manuscript for intellectual content. Jong Woo Kang was controlled overall investigation as the principal investigator of the project. The authors approved all the contents and agreed with the submission.

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Tables
Table 1  
Descriptions of Variables for Regression Analysis.

| Variables                                      | Value                           |
|------------------------------------------------|---------------------------------|
| Age (years)                                    | 41.9 ± 11.1                     |
| Sex (Male : Female)                            | 105 (59.3) : 72 (40.7)          |
| Dominance of affected side (Yes : No)          | 91 (51.4) : 86 (48.6)           |
| Ulnar variance (mm)                            | 3.2 ± 1.7                       |
| DRUJ type (I : II : III)                       | 57 (32.2) : 26 (14.7) : 94 (53.1)|
| Modified Nordstrom questionnaire score         | 27.6 ± 12.1                     |
| Degeneration in Palmar classification (2B : 2C : 2D : 2E) | 38 (21.5) : 87 (49.2) : 45 (25.4) : 7 (4.0) |
| Degenerative complex TFCC tear (Yes : No)      | 42 (23.7) : 135 (76.3)          |
| Bony lesion (Yes: No)                          | Cyst 68 (38.4) : 109 (61.6)     |
|                                              | Sclerosis 82 (46.3) : 95 (53.7) |
|                                              | Erosion 66 (37.3) : 111 (62.7)  |
| VAS score                                      | 4.9 ± 2.1                       |
| DASH score                                     | 46.2 ± 22.6                     |
| ROM ( °)                                       | 281.1 ± 27.0                    |
| Grip strength (%)                              | 57.9 ± 22.5                     |

DRUJ = Distal radioulnar joint; TFCC = triangular fibrocartilaginous complex tear; VAS = Visual analog scale; DASH = Disabilities of the Arm, Shoulder, and Hand; ROM = Range of wrist motion; *Continuous variables expressed as mean ± Standard deviation.
Table 2  
Regression Analysis for Predictors of Pain Intensity.

| Variable                        | Univariable linear regression analysis | Multivariable linear regression analysis |
|---------------------------------|----------------------------------------|------------------------------------------|
|                                 | **B** | **CI**               | **p value** | **B** | **St(B)** | **CI**               | **p value** |
| Age                             | -0.003 | (-0.031, 0.024)     | 0.811 | *        |            |                        |             |
| Sex                             | 0.259  | (-0.362, 0.880)     | 0.411 | *        |            |                        |             |
| Dominance of affected side      | -0.162 | (-0.773, 0.450)     | 0.603 | *        |            |                        |             |
| Work-related exposure           | 0.092  | (0.007, 0.113)      | 0.000 | 0.067 | 0.394 | (0.040–0.094) | <0.001†     |
| Ulnocarpal degeneration         | Palmar class 2B** |            |            |            |            |                        |             |
|                                   | Palmar class 2C      | 0.550 | (-0.225, 1.324) | 0.163 | 0.256 | 0.062 | (-0.413–0.924) | 0.451     |
|                                   | Palmar class 2D      | 1.311 | (0.433, 2.188)  | 0.004 | 2.944 | 0.625 | (-0.814–6.702) | 0.124     |
|                                   | Palmar class 2E      | 1.282 | (-0.356, 2.920) | 0.124 | 2.979 | 0.283 | (-0.488–6.445) | 0.092     |
| Degenerative complex TFCC tear  | -1.947 | (-2.604, -1.290)   | 0.001 | -0.747 | -0.155 | (-1.704–0.210) | 0.125     |
| Ulnar variance                  | 0.025  | (-0.161, -0.210)   | 0.794 | *        |            |                        |             |
| DRUJ type                       | 1      | 0.113 | (-0.570, 0.796) | 0.745 | *        |            |                        |             |
|                                   | 2      | -0.342 | (-1.244, 0.560) | 0.455 | *        |            |                        |             |
|                                   | 3**    |            |            |            |            |                        |             |
| Bony lesion                     | Cyst   | -0.283 | (-0.910, 0.344) | 0.375 | *        |            |                        |             |
|                                   | Sclerosis | -0.810 | (-1.411, -0.208) | 0.009 | 0.321 | 0.078 | (-0.325–0.966) | 0.328     |
|                                   | Erosion | -1.516 | (-2.106, -0.925) | 0.001 | -0.179 | -0.042 | (-0.963–0.605) | 0.653     |

B = Unstandardized coefficients; St(B) = Standardized coefficient; CI = 95%Confidence interval; DRUJ = Distal radioulnar joint; TFCC = triangular fibrocartilaginous complex tear; VAS = Visual analog scale; DASH = Disabilities of the Arm, Shoulder, and Hand; ROM = Range of wrist motion; *Analysis was not performed because of no significance in univariable analysis.; †indicates a statistical difference; **indicates a reference dummy variable.
## Table 3
Regression Analysis for Predictors of Subjective Functional Limitation (DASH score).

| Variable                          | Univariable linear regression analysis | Multivariable linear regression analysis |
|----------------------------------|----------------------------------------|------------------------------------------|
|                                  | B   | CI            | p value                                | B   | St(B) | CI            | p value                                |
| Age                              | 0.196 | (-0.107, 0.499) | 0.204 *                                | 0.204 | *     |
| Sex                              | 3.675 | (-3.152, 10.501) | 0.290 *                                | 0.290 | *     |
| Dominance of affected side       | -1.751 | (-8.477, 4.975) | 0.608 *                                | 0.608 | *     |
| Work-related exposure            | 1.097 | (0.871, 1.323) | < 0.001 †                              | 0.868 | 0.464 | (0.594, 1.141) | < 0.001 †                              |
| Ulnocarpal degeneration          | Palmar class 2B** | Palmar class 2C | 2.660 | (-5.970, 11.290) | 0.544 | -1.892 | -0.042 | (-9.037, 5.253) | 0.602 |
|                                 | Palmar class 2D | Palmar class 2D | 9.952 | (0.174, 19.730) | 0.046 † | 13.287 | 0.257 | (-26.875, 53.450) | 0.515 |
|                                 | Palmar class 2E | Palmar class 2E | 9.062 | (-9.192, 27.317) | 0.329 | 10.370 | 0.090 | (-26.616, 47.355) | 0.581 |
| Degenerative complex TFCC tear   | -25.326 | (-32.273, -18.379) | < 0.001 †                              | -8.939 | -0.169 | (-18.793, 0.914) | 0.075 |
| Ulnar variance                   | 0.613 | (-1.422, 2.648) | 0.553 *                                | 0.553 | *     |
| DRUJ type                        | 1    | -0.468 | (-7.972, 7.035) | 0.902 *                                | 0.902 | *     |
|                                  | 2    | -6.009 | (-15.913, 3.895) | 0.233 *                                | 0.233 | *     |
|                                  | 3**  |        |                |                                        |        |        |                |                                        |
| Bony lesion                      | Cyst | -1.507 | (-8.420, 5.406) | 0.668 *                                | 0.668 | *     |
|                                 | Sclerosis | Sclerosis | -10.469 | (-17.032, -3.905) | 0.002 † | 2.829 | 0.063 | (-4.026, 9.685) | 0.416 |
|                                 | Erosion | Erosion | -19.181 | (-25.522, -12.840) | < 0.001 † | -4.698 | -0.101 | (-12.935, 3.538) | 0.262 |
| Variable                  | Univariable linear regression analysis | Multivariable linear regression analysis |
|---------------------------|----------------------------------------|------------------------------------------|
|                           | B  | Cl | p value | B  | St(B) | Cl | p value |

B = Unstandardized coefficients; St(B) = Standardized coefficient; CI = 95% Confidence interval; DRUJ = Distal radioulnar joint; TFCC = triangular fibrocartilagenous complex tear; VAS = Visual analog scale; DASH = Disabilities of the Arm, Shoulder, and Hand; ROM = Range of wrist motion; *Analysis was not performed because of no significance in univariable analysis.; † indicates a statistical difference; ** indicates a reference dummy variable.
| Variable                        | Univariable linear regression analysis | Multivariable linear regression analysis |
|--------------------------------|---------------------------------------|-----------------------------------------|
|                                | B         | CI                        | p value  | B        | St (B)   | CI                        | p value  |
| Age                            | -0.233    | (-0.595, 0.129)           | 0.206 *  |          |          |                          |          |
| Sex                            | 1.346     | (-6.823, 9.515)           | 0.745 *  |          |          |                          |          |
| Dominance of affected side     | 1.023     | (-7.007, 9.053)           | 0.802 *  |          |          |                          |          |
| Work-related exposure          | -0.618    | (-0.938, -0.299)          | < 0.001  | -0.254   | -0.114   | (-0.640, 0.133)          | 0.197    |
| Ulnocarpal degeneration        | Palmar class 2B** |                      |          |          |          |                          |          |
|                                | Palmar class 2C | (-14.637, 6.202)         | 0.425 *  |          |          |                          |          |
|                                | Palmar class 2D | (-15.742, 7.870)         | 0.511 *  |          |          |                          |          |
|                                | Palmar class 2E | (-29.202, 14.879)        | 0.522 *  |          |          |                          |          |
| Degenerative complex TFCC tear| 20.253    | (11.315, 29.192)          | < 0.001  | 16.946   | 0.268    | (3.579, 30.312)          | 0.013†   |
| Ulnar variance                 | -2.476    | (-4.879, -0.074)          | 0.043    | -2.324   | -0.143   | (-4.638, -0.010)         | < 0.050† |
| DRUJ type                      | 1         | 0.548                     | (-8.380, 9.477) | 0.904 *  |          |                          |          |
|                                | 2         | 9.118                     | (-2.667, 20.903) | 0.129 *  |          |                          |          |
|                                | 3**       |                          |          |          |          |                          |          |
| Bony lesion                    | Cyst      | -2.313                    | (-10.558, 5.932) | 0.581 *  |          |                          |          |
|                                | Sclerosis | 5.872                     | (-2.130, 13.872) | 0.149 *  |          |                          |          |
|                                | Erosion   | 12.756                    | (4.676, 20.836) | 0.002    | -0.728   | -0.013 (-11.659, 10.202) | 0.896    |
| Variable | Univariable linear regression analysis | Multivariable linear regression analysis |
|----------|----------------------------------------|-----------------------------------------|
|          | B | CI | p value | B | St (B) | CI | p value |

B = Unstandardized coefficients; St(B) = Standardized coefficient; CI = 95% Confidence interval; DRUJ = Distal radioulnar joint; TFCC = triangular fibrocartilagenous complex tear; VAS = Visual analog scale; DASH = Disabilities of the Arm, Shoulder, and Hand; ROM = Range of wrist motion; *Analysis was not performed because of no significance in univariable analysis.; †indicates a statistical difference; **indicates a reference dummy variable.
Table 5
Regression Analysis for Predictors of Objective Functional Limitation (Grip Strength).

| Variable                          | Univariable linear regression analysis | Multivariable linear regression analysis |
|-----------------------------------|----------------------------------------|-----------------------------------------|
|                                   | B          | 95%CI            | p value | B      | St B | 95%CI            | p value |
| Age                               | -0.274     | (-0.575, 0.026)  | 0.073    | *      |       |                   |         |
| Sex                               | 2.159      | (-4.648, 8.965)  | 0.532    | *      |       |                   |         |
| Dominance of affected side        | 1.023      | (-4.881, 8.503)  | 0.594    |       |       |                   |         |
| Work-related exposure             | -0.541     | (-0.806, -0.276) | 0.000    | -0.155 | -0.083 | (-0.464, 0.155)  | 0.326 |
| Ulnocarpal degeneration           | Palmar class 2B** |       |         |       |       |                   |         |
|                                   | Palmar class 2C | -7.177 | (-15.770, 1.415) | 0.101 | -3.248 | -0.072 | (-11.331, 4.835) | 0.429 |
|                                   | Palmar class 2D | -10.159 | (-19.894, -0.424) | 0.041 | 48.313 | 0.938 | (2.875, 93.752) | 0.037† |
|                                   | Palmar class 2E | -1.709 | (-19.883, 16.466) | 0.853 | 49.041 | 0.426 | (7.197, 90.885) | 0.022† |
| Degenerative complex TFCC tear    | 21.355     | (14.161, 28.549) | 0.000    | 22.171 | 0.420 | (11.023, 33.319) | 0.001† |
| Ulnar variance                    | 0.396      | (-1.630, 2.422)  | 0.700    | *      |       |                   |         |
| DRUJ type                         | 1          | 0.410 | (-8.380, 9.477)  | 0.914    | *      |       |                   |         |
|                                   | 2          | 6.107 | (-2.667, 20.903) | 0.223    | *      |       |                   |         |
|                                   | 3**        |       |                   |         |       |                   |         |
| Bony lesion                       | Cyst       | 3.676 | (-3.183, 10.536)  | 0.292    | *      |       |                   |         |
|                                   | Sclerosis  | 9.738 | (3.184, 16.292)   | 0.004    | 1.550 | 0.034 | (-6.206, 9.306) | 0.694 |
|                                   | Erosion    | 11.362 | (4.651, 18.073)   | 0.001    | -4.030 | -0.087 | (-13.349, 5.288) | 0.394 |
| Variable | Univariable linear regression analysis | Multivariable linear regression analysis |
|----------|--------------------------------------|----------------------------------------|
|          | B  | 95% CI | p value | B  | St(B) | 95% CI | p value |

B = Unstandardized coefficients; St(B) = Standardized coefficient; CI = 95% Confidence interval; DRUJ = Distal radioulnar joint; TFCC = triangular fibrocartilagenous complex tear; VAS = Visual analog scale; DASH = Disabilities of the Arm, Shoulder, and Hand; ROM = Range of wrist motion; *Analysis was not performed because of no significance in univariable analysis.; †indicates a statistical difference; **indicates a reference dummy variable.