Intermediate and long-term radiographic and functional outcomes of ulnar shortening osteotomy in patients with ulnar impaction syndrome and reverse oblique sigmoid notch

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Research article

Keywords: ulnar impaction, oblique, reverse, sigmoid notch, ulnar shortening

Posted Date: April 30th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-23876/v1

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Version of Record: A version of this preprint was published on February 3rd, 2021. See the published version at https://doi.org/10.1186/s12891-021-04029-7.
Abstract

Background: Ulnar shortening osteotomy (USO) is an effective treatment for the ulnar impaction syndrome. But there has been a concern of osteoarthritis developing in the distal radioulnar joint (DRUJ) if we perform the USO in patients with reverse oblique sigmoid notch. This study was to evaluate the radiographic and functional outcomes following USO in patients with reverse oblique sigmoid notch.

Methods: Between 2002 and 2013, we retrospectively reviewed our patients with reverse oblique sigmoid notch underwent USO in treating the ulnar impaction syndrome. We evaluated the radiographic changes in the DRUJ and their functional outcomes.

Results: We enrolled 22 patients (22 wrists) with an average age at operation of 49.6 years and mean follow-up of 93.2 months. We found that there were changes in the inclination angle of sigmoid notch, from an average of reverse oblique 14.9° preoperatively to a more parallel of 5.1° at the final follow-ups. The functional results at the final follow-ups were good with the mean VAS for pain of 0.3 at rest and 1.4 during activity, QuickDASH of 16.5, and modified Mayo Wrist Score of 91.4. There were 7 wrists (31.8%) noted to have osteoarthritic change, but they did not exhibit significantly worse function, except supination motion, pain during activity, and grip strength.

Conclusions For the patients with reverse oblique sigmoid inclination following USO, the inclination angle would have a tendency to become more parallel and some would develop the osteoarthritic change in the DRUJ, but the functional outcomes could still be good in the intermediate and long-term. The reverse oblique sigmoid inclination seems not to be an absolute contraindication for USO.

Background

Ulnar shortening osteotomy (USO) is a commonly performed procedure which can treat many ulnar-sided wrist problems, including ulnar impaction syndrome, triangular fibrocartilage complex (TFCC) problems, instability of the distal radioulnar joint (DRUJ), and lunotriquetral ligament tear [1–5]. The USO was found to not only unload the ulnar-sided wrist from the carpus, but also tighten the ulnocarpal and DRUJ. Also, it was noted that a greater shortening length leads to increased pressure within the DRUJ [1, 6, 7].

The relationship between the inclination of the sigmoid notch and the ulnar shaft was classified to be Tolat type 1, parallel; type 2, oblique; type 3, reverse oblique [8]. There is a concern if the USO was carried out on the wrist with a type 3 reverse oblique pattern sigmoid notch, it could increase more contact pressure at the proximal aspect of the inverted sigmoid notch. Thus, accelerated degenerative changes at the contacted articulation were suspected to be occurring [9, 10].

The percentage of type 3 reverse oblique sigmoid notch was about 4–19% [8, 11, 12]. Hollevoet et al analyzed 248 wrists (248 patients) and found 81% of the reverse oblique sigmoid notches appeared in the positive ulnar variance and 19% in the neutral ulnar variance. Also, there were 37% wrists presenting positive ulnar variance and 37% presenting neutral variance [11]. The ulnar impaction syndrome is
usually associated with positive ulnar variance, and the USO is an effective treatment [5, 13, 14]. As above mentioned, it would be not difficult to meet a patient with ulnar impaction syndrome combined with a reverse oblique sigmoid notch. However, from reviewing the literature, the reports of solving the osteoarthritic problem in DRUJ following a USO procedure to treat ulnar impaction syndrome were not many.

Therefore, our hypothesis is that performing USO in patients with reverse oblique sigmoid notch would be not so harmful to the DRUJ. The purpose of this study was to evaluate the radiographic changes and functional outcomes after USO in patients with ulnar impaction and reverse oblique sigmoid inclination.

**Methods**

This study was based on a retrospective design and approved by the ethics committee of our institution. We reviewed our patients who had reverse oblique inclination of the sigmoid notch (Tolat type 3) and underwent USO in treating ulnar impaction syndrome between 2002 and 2013. We included patients with well-documented clinical records and radiographic evaluations, and with a follow-up of minimum three years. Patients with a neurologic deficit involving the same upper extremity, immunological disease, or renal failure under dialysis were excluded.

All the surgeries were performed by 3 senior hand surgeons, and all of them were classified as level III (experienced specialist) according to Tang’s grading [15]. The surgical approach was made between the flexor carpi ulnaris and the extensor carpi ulnaris muscle, beginning at the distal third of the forearm and extending proximally. The shortening osteotomy was performed at the distal third of the ulnar shaft and the limited-contact dynamic compression plate (LC-DCP) was used for fixation.

**Radiographic evaluations**

Radiographs of the wrist were taken in the postoperative follow-ups. The posteroanterior radiographs of the wrist were taken with shoulder in 90° abduction, elbow in 90° flexion, and the wrist in the neutral rotation position. The inclination angle of the sigmoid notch was measured between the long axis of the ulna (>10cm of ulnar shaft presented on the radiograph) and the bony sigmoid notch line on the posteroanterior radiographs [9]. The measurements were carried out by two independent observers who were blinded to the results. Intra-observer reliability was evaluated by asking the observer to repeat the assessment after a period of 1 month to minimize the recall. The measurements were taken three times. A total of six items of data were available after the two observers taking measurements three times. We took the median of two numbers to achieve a mean as our final data.

**Functional evaluations**

The shortened disabilities of the arm, shoulder and hand questionnaire (QuickDASH) and modified Mayo Wrist Score were used for the final evaluations [16, 17]. The Visual Analog Pain Scale (VAS) for pain (where 0: no pain; 10: worst pain) at rest and during activity were also evaluated. Grip strength was
evaluated using a Jamar dynamometer (Sammons Preston, Bolingbrook, IL, USA) set to the second position. The level of activity to which each patient returned was also recorded.

**Statistic evaluations**

Data are presented as a mean for the continuous response variables. We analyzed the data using the Student's t test for each continuous variable. SPSS Statistics for Windows, version 17.0 (SPSS Inc., Chicago, USA) software was used to test the differences between results. The p value was set at 0.05 prior to the data analysis.

**Results**

There were 22 patients (22 wrists) with an average age at operation of 49.6 years (range, 25-63 years) enrolled. The mean follow-up period was 93.2 months (range, 36-179 months). The mean preoperative ulnar plus was 4.1 mm (range, 3-6 mm) and the mean shortening length was 3.8 mm (range, 3-6 mm). We found there were changes in the sigmoid inclination angle, from an average of reverse oblique 14.9° (11°-23°) preoperatively to a more parallel 5.1° (0°-11°) at the final follow-ups (Fig. 1). The functional results are shown in Table 1. The mean wrist range of motion, VAS for pain during activity, and grip power was significantly better in the final follow-ups than those in the preoperative evaluations. The mean QuickDASH and the modified Mayo Wrist Score were good in the final follow-ups, but we did not have the preoperative data for comparison. All patients were able to return to their previous full level of work and activities with no or mild pain, and no wrist braces were needed.

There were 7 wrists (31.8%) noted to have osteoarthritic changes. Compared with the patients without obvious osteoarthritic change in DRUJ, these 7 patients exhibited no poorer functional outcomes, except supination angle, pain during activity, and grip strength (Table 2).

**Discussion**

In this study, we found that the reverse oblique inclination of the sigmoid notch after USO would have changes in the inclination angles. In the intermediate and long-term follow-ups, osteoarthritic change at the DRUJ could happen, but it seems not to impair the functional results.

Sagerman et al. noted that there is a wide variation between the sigmoid notch inclination and ulnar seat angles. So the articular incongruity could occur following USO in all the three Tolat types of sigmoid inclination [9, 10]. Because of the articular incongruity, there will be a reduction of joint contact area, and then it will lead to an increase of the joint reaction force for the per unit of the contact area. This would be a possible factor producing subsequent occurrence of remodeling or osteoarthritis at the DRUJ. From the reviews, the incidence of DRUJ remodeling or degenerative change after USO were from 16.7% to 43.3% [3, 5, 18-20]. But these were only the radiographic changes without functional impairment (Table 3).
As for the asymptomatic bony spur or remodeling change noted after USO in Table 3, their followed-duration after surgery were reported to be 18-60 months. Tatebe et al reported that most of these bony spurs developed within 18 months postoperatively [5]. Our mean follow-up duration of the 7 patients with developed osteoarthritis was 83.7 months. It is longer than those studies and these patients can still have good functional results at the final follow-ups. Their wrist function was not worse than those without osteoarthritis, except in the wrist supination angle, VAS for pain during activity, and grip strength. So, according to the reviews and our results, the DRUJ bony changes after USO might be not so harmful to the wrist function in the short and intermediate-term.

ROSS et al. reported there would be no reverse oblique inclination if the cartilage thickness is included in the evaluation [12]. There will be a thinner cartilage toward the proximal of the sigmoid notch, which forms the cartilage inclination to be no more reverse oblique while the bony inclination is reverse oblique. Deshmukh et al reported USO will cause the DRUJ articular incongruity and reduction in area of contact of the DRUJ [10]. The proximal part of sigmoid notch would be the contact area after the USO in the reverse oblique inclination. Both the increased pressure and thinner sigmoid cartilage at the proximal contact area would be able to make the DRUJ to develop osteoarthritic changes. In our result, there were 31.8% patients developing osteoarthritic change. In addition, we saw the sigmoid inclination angle would change. Without MRI for identification, we are unable to confirm these bony inclination changes resulting from the proximal layer cartilage wear or from the response of an increased force transmitting through the cartilage. But from our results, these bony changes did not tend to cause symptoms.

The main limitations of this study are the retrospective nature and small case number. No available complete preoperative functional evaluations and not all the patients could have both pre- and postoperative MRI-scans, or even CT-scans, for evaluating the cartilage thickness and bony inclination change, which would be more informative for DRUJ changes [12, 21, 22]. The interobserver variability would also be the bias. In addition, as in the long-term, the influence of degeneration on the wrist should be a concern.

Conclusions

USO is an effective treatment for ulnar impaction syndrome. For patients with reverse oblique sigmoid inclination following USO, the inclination angle would have a tendency to become more parallel and some would possible to develop the osteoarthritic change in the DRUJ, but the functional outcomes could still be good in the intermediate and long-term. According to the finding of this study, the reverse oblique sigmoid inclination seems not to be an absolute contraindication for USO.

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Tables

Table 1 The functional evaluations at pre-operation and final follow-up

| Evaluations                  | Pre-operation Mean ± SD (Range) | Final follow-up Mean ± SD (Range) | P-value |
|-----------------------------|---------------------------------|-----------------------------------|---------|
| Flexion (°)                 | 67.5 ± 6.5 (55-80)             | 74.6 ± 8.6 (50-90)               | <0.001  |
| Extension (°)               | 69.3 ± 5.0 (60-80)             | 76.8 ± 6.5 (65-90)               | <0.001  |
| Pronation (°)               | 73.0 ± 6.3 (60-80)             | 78.4 ± 3.2 (70-80)               | <0.001  |
| Supination (°)              | 75.5 ± 4.1 (70-80)             | 82.5 ± 5.5 (70-90)               | <0.001  |
| VAS at rest                 | 0.8 ± 0.7 (0-2)                | 0.2 ± 0.4 (0-1)                  | <0.001  |
| VAS during Activity         | 6.0 ± 0.9 (5-8)                | 1.3 ± 0.9 (0-3)                  | <0.001  |
| QuickDASH                   | NA                             | 15.1 ± 8.8 (2.3-34.1)            | -       |
| Modified Mayo Wrist Score   | NA                             | 91.6 ± 6.4 (70-100)              | -       |
| Grip strength (Kg)          | 17.9 ± 6.7 (10-33)             | 28.2 ± 7.7 (19-50)               | <0.001  |
Abbreviations: VAS, Visual Analog Pain Scale; SD, standard deviation; NA, not available. *P*-value: for partied Student’s t test

**Table 2** The functional evaluations at final follow-up, comparing the patients with and without osteoarthritic change

| Evaluations                          | Patients (n=7) with DRUJ osteoarthritic change | Patients (n=15) without DRUJ osteoarthritic change | *P* value |
|--------------------------------------|-----------------------------------------------|--------------------------------------------------|-----------|
| Age at operation (years)             | 54.1 ± 8.2 (37-61)                            | 47.5 ± 13.2 (25-63)                               | 0.235     |
| Follow-up period (Months)            | 83.7 ± 32.7 (36-134)                          | 97.7 ± 40.8 (62-179)                              | 0.438     |
| Shortening length (mm)               | 4.0 ± 0.8 (3-5)                               | 3.7 ± 0.8 (3-6)                                  | 0.469     |
| Inclination angle change (°)         | 8.9 ± 1.5 (6-10)                              | 10.1 ± 2.6 (6-15)                                | 0.245     |
| Flexion (°)                          | 68.6 ± 11.1 (50-80)                           | 77.3 ± 5.6 (70-90)                               | 0.086     |
| Extension (°)                        | 75.0 ± 6.5 (70-85)                            | 77.7 ± 6.5 (65-90)                               | 0.380     |
| Pronation (°)                        | 76.4 ± 4.8 (70-80)                            | 79.3 ± 1.8 (75-80)                               | 0.163     |
| Supination (°)                       | 78.6 ± 5.6 (70-85)                            | 84.3 ± 4.6 (80-90)                               | 0.018*    |
| VAS in rest                          | 0.3 ± 0.5 (0-1)                               | 0.1 ± 0.4 (0-1)                                  | 0.412     |
| VAS during Activity                  | 1.9 ± 0.9 (1-3)                               | 1.0 ± 0.8 (0-2)                                  | 0.030*    |
| QuickDASH                            | 18.0 ± 12.1 (4.5-34.1)                        | 13.8 ± 6.8 (2.3-27.3)                            | 0.312     |
| Modified Mayo Wrist Score            | 90.0 ± 9.6 (70-95)                            | 92.3 ± 4.6 (80-100)                              | 0.442     |
| Grip strength (Kg)                   | 23.9 ± 2.6 (19-27)                            | 30.2 ± 8.5 (20-50)                               | 0.017*    |

Abbreviations: DRUJ, distal radioulnar joint; VAS, Visual Analog Pain Scale; SD, standard deviation; NA, not available
Table 3 Reviews of radiographic bony change in distal radioulnar joint and functional impairment after ulnar shortening osteotomies

| Study | Mean Age (years) | Mean shortening distance (mm) | Remodeling / degenerative changes in DRUJ (%) | Mean follow-up duration (months) | Functional impairment (evaluation tools) |
|-------|------------------|-------------------------------|---------------------------------------------|---------------------------------|------------------------------------------|
| Köppel (2018) | NA | NA | 38.3% | 18 | NO (Chun and Palmer grading score) |
| Minami (2019) | 32 (range, 17-57) | 3 | 28% | 35 | NO (pain, ROM) |
| Iwasaki (2020) | 37.5 (range, 14-67) | 2.3 | 24% | 26.3 | NO (modified Mayo wrist score) |
| Baek (203) | 45.8 (SD 11.5) | 5.3 | 16.7% | 60 | NO (Gartland and Werley wrist score) |
| Tatebe (205) | 37 (range, 16-64) | 2.4 | 43.3% | 18 | NO (Hand20 questionnaire) |

Abbreviations: NA, not available; ROM, range of motion; SD, standard deviation

Figures
Figure 1

27-year-old man. A Radiographs before ulnar shortening osteotomy showing the reverse oblique sigmoid notch; B Radiographs of 36-month follow-up after surgery. The bony inclination of the sigmoid notch had become more parallel.