Original article

Dorsal locking plates versus staples in four-corner fusion: A comparative clinical and radiological study

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1. Introduction

Four-corner fusion was first described by Watson and Ballet [1] for the treatment of ostearthritis of the wrist secondary to scaphoid lunate advanced collapse: SLAC wrist. It consists in scaphoiectomy with mediocarpal fusion, conserving only radioulnar joint motion and leaving the wrist free of osteoarthitis. Indications were soon extended to scaphoid non-union advanced collapse (SNAC wrist), scaphoid chondrocalcinosis advanced collapse (SCAC wrist) and mediocarpal instability. The technique has undergone little modification since its first description, debate focusing on the means of fixation. Multiple pinning was initially used, then replaced by stapling in the 1990s. Various improvements in staple design were followed in the 2000s by the introduction of circular dorsal plates, more recently using a locking design.

These developments were aimed at stable fixation by minimally sized material, to enable rapid recovery of motion, improving final range of motion without jeopardizing fusion. The present study reports our experience with the titanium Aptus Four-Corner Fusion® dorsal locking plate (4CF®, Medartis; Fig. 1), comparing results with traditional four-corner fusion by bipodal or quadripodal staples, to test the hypothesis that the former provides better stability, shorter immobilization and a quicker return to daily activities.

2. Materials and methods

Ninety-one 4-corner fusions using either staples or the 4CF® dorsal locking plate were performed in our department between January 1994 and March 2012. Seven patients (5 managed by

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staples and 2 by plates) underwent further surgery liable to influence results, and were excluded from analysis. Retrospective analysis finally concerned 61 patients (66 fusions), divided into 2 groups according to fixation technique. All 30 patients (31 fusions) in the plate group and 65% of the 53 fusions (35 fusions; 31 patients) in the staple group could be assessed. Fusion technique was comparable for the two groups, except with regard to fixation. It consisted in a posterior approach through the 3rd and 4th extensor compartments. After dorsal capsulotomy, the scaphoid was resected, the cartilage between the four bones was removed, and dorsal intercalated segment instability (DISI) was reduced by temporary capitolunar and hamatomotriquetral K-wires. A cancellous graft between the four bones was harvested from the radial metaphysis or from the morcelized scaphoid if the aspect permitted. Final fixation used staples or, at the surgeon’s discretion, the 4CF® plate (introduced only in November 2010). Plate fixation used at least 1 non-locking screw (central holes) and 1 locking screw (peripheral holes) per bone.

In the plate group, mean age at surgery was 50.9 years, with 23 male and 7 female patients; in 21 cases, the dominant wrist was involved. Etiology comprised 14 SLACs (6 Watson grade 3 [1] and 8 grade 2), 13 SNACs (7 Watson grade 3 [2] and 6 grade 2), and 4 other etiologies. Twenty patients were working preoperatively, including 14 in heavy manual work. Mean follow-up was 13.1 months (range, 6–25 months). Mean immobilization time was 4.8 weeks (range, 2–10 weeks).

In the staple group, mean age at surgery was 53 years, with 25 male and 6 female patients; in 25 cases, the dominant wrist was involved. Etiology comprised 17 SNACs (8 grade 3 and 9 grade 2), 14 SLACs (8 grade 3 and 6 grade 2) and 4 other. Twenty-two patients were working preoperatively, including 17 in heavy manual work. Mean follow-up was 80.4 months (range, 16–154 months). Mean immobilization time was 8.9 weeks (range, 4–17 weeks).

The two groups were comparable epidemiologically except for follow-up time. Immobilization time also differed, surgeons adopting the respective literature recommendations.

The 61 included patients (66 fusions) gave consent to clinical and radiological assessment by an independent investigator. Clinical assessment comprised joint range of motion, force on Jamar dynamometer compared to the contralateral side when healthy, self-assessed pain (none, slight, moderate, severe) and satisfaction (satisfied, not satisfied). PRWE and QuickDASH pain and disability questionnaires and assessment of conditions of return to work, time off work (initial sick leave plus any further leave for surgical revision) and number of postoperative physical therapy sessions. Radiologic assessment comprised AP and lateral wrist views to assess fusion, capitolunar angle and material-related issues. In case of doubt regarding fusion, CT was performed.

The Student t-test for non-matched variables was used to compare means between groups. The significance threshold was set at 5% (P = 0.05).

3. Results

At follow-up, 1 case in the plate group had been converted to total fusion at 16 months after the initial operation, due to ulnar translation of the carpal in a context of Marfan’s syndrome; the original indication was probably mistaken in this case of hyperlaxity with preoperative infra-ulnar projection, which, according to Ashmead et al. [3], is a contraindication for 4-corner fusion. Two patients in the staple group also underwent secondary total fusion: 1 at 7 months for disabling pain, and 1 at 2 years for onset of painful radiolunar osteoarthritis. All 3 patients were counted as failure and excluded from the clinical results.

Complications included 2 non-unions in the staple group (fusion rate, 94.3%), requiring revision by iliac graft (Fig. 2). There were no non-unions in the plate group, but 1 case of delayed capitolunar joint line consolidation was observed at 9 months, requiring revision surgery at 12 months; intraoperative exploration found complete fusion of all joint lines. The reason for this late consolidation is uncertain, but the patient, a farmer, would appear to have ceased all working activity between the 9th and 12th postoperative months, stopping the severe stress to which he had previously been subjecting his wrist. In 2 cases, CT was performed to check fusion, the radiographic images being inconclusive. The fusion rate in the plate group was thus 100%.

There were 2 cases of material-related symptomatic dorsal impingement in the plate group. The first required complete removal of material. In the second, onset followed radiolunar osteoarthritis with progressive destruction of the lunatum and loss of lunar height (Fig. 3); as the patient was relatively...

Fig. 1. 4-corner fusion using the Medartis Aptus Four-Corner Fusion® (4CF®) plate. Each bone is fixed by a locking screw (peripheral holes) and a non-locking screw (central holes).

Fig. 2. Complete non-union with fractured bipodal staples, requiring revision by iliac graft.

asymptomatic, total fusion had not been performed at the time of writing. In another case, a screw penetrating the pisotriquetral joint was removed. There was no breakage of material in the plate group.

In the staple group, 11 cases of dorsal impingement due to projecting staples and 2 of staple migration required removal of material (Fig. 4). In 7 cases, the assembly had been reinforced with K-wires, which required removal after fusion was achieved. There were 3 cases of staple fracture, including 1 early breakage with non-union. There were also 3 cases of weakly symptomatic early radiolunar osteoarthritis.

Radiologic assessment likewise found better mean capitolunar angle correction, at 2.2° (from 18.5° preoperatively) in the plate groups, versus 8.3° (from 13°) in the staple group (P < 0.05).

Postoperative range of motion and force did not significantly differ between groups (Table 1). Flexion-extension arc was 67.3° in the plate group and 60.6° in the staple group. Force on Jamar dynamometry was 29.6 kgF (70.7% of contralateral) in the plate group and 28 kgF (64.15% of contralateral) in the staple group.

Pain assessments in the plate group were 13 none, 10 slight, 7 moderate and 0 severe (n = 30), and in the staple group 11 none, 17 slight, 5 moderate and 0 severe (n = 33). 91.4% of patients expressed satisfaction in the staple group and 93.5% in the plate group.

Mean PRWE score was 34.8/150 in the plate group, versus 40.9 in the staple group (P = 0.371), and mean QuickDASH score respectively 19.83/100 versus 30 (P = 0.035).

Mean time off work was 4.5 months in the plate group, versus 7.9 months in the staple group (P = 0.030); return to work was possible for 90% of patients in the plate group and 77.2% in the staple group: 4 patients in the plate group needed job adaptation, and 3 in the staple group (Table 2).

Table 1
Comparison of clinical results between 4CF® and staple groups.

<table>
<thead>
<tr>
<th>Results</th>
<th>4CF® (n = 30)</th>
<th>Staples (n = 33)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Follow-up (months)</td>
<td>13.1</td>
<td>80.4</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>F-E arc (°)</td>
<td>67.3</td>
<td>60.6</td>
<td>0.132</td>
</tr>
<tr>
<td>R-U arc (°)</td>
<td>30.5</td>
<td>30.7</td>
<td>0.594</td>
</tr>
<tr>
<td>Force (kgF)</td>
<td>29.6</td>
<td>28</td>
<td>0.546</td>
</tr>
<tr>
<td>Force (% contralateral)</td>
<td>70.7</td>
<td>64.15</td>
<td>0.293</td>
</tr>
<tr>
<td>Time off work (months)</td>
<td>4.5</td>
<td>7.9</td>
<td>0.030</td>
</tr>
<tr>
<td>PRWE (/150)</td>
<td>37.8</td>
<td>40.88</td>
<td>0.371</td>
</tr>
<tr>
<td>QuickDASH (/100)</td>
<td>19.83</td>
<td>30</td>
<td>0.035</td>
</tr>
<tr>
<td>Fusion rate (%)</td>
<td>100</td>
<td>94.3</td>
<td>-</td>
</tr>
</tbody>
</table>

F-E arc: flexion-extension arc; R-U arc: radiolunar inclination arc. Bold data are statistically significant difference (p < 0.05).

Table 2
Comparison of conditions of return to work in 4CF® and staple groups.

<table>
<thead>
<tr>
<th>Occupational data</th>
<th>Active population 4CF® (n = 20)</th>
<th>Active population Staples (n = 22)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of return to work (%)</td>
<td>18/20 (90%)</td>
<td>17/22 (77.2%)</td>
<td>0.449</td>
</tr>
<tr>
<td>Time off work (months)</td>
<td>4.5</td>
<td>7.9</td>
<td>0.030</td>
</tr>
<tr>
<td>Job adaptationb</td>
<td>4/18 (22.2%)</td>
<td>3/17 (17.6%)</td>
<td>-</td>
</tr>
</tbody>
</table>

Bold data are statistically significant difference (p < 0.05).

a Duration of payment of national health insurance benefit, including subsequent time off work for surgical revision or ablation of material.

b Rate for all patients having returned to work: temporary or definitive adaptation of job.


Fig. 3. Onset of symptomatic dorsal radiocarpal impingement secondary to radiolunar osteoarthritis and loss of lunar height. A. Immediate postoperative view. B and C. X-ray and CT scan at 15 months post-surgery.
The mean number of postoperative physical therapy sessions was smaller in the plate group: (33.2 per fusion, versus 42.6; \( P=0.164 \)).

4. Discussion

A succession of fusion fixation procedures have been implemented since the first description by Watson and Ballet [1]. K-wires give an acceptable rate of non-union, ranging from 3% to 16% [1–6]; there are, however, considerable rates of migration, tendon irritation and entry-point infection, and ablation is more or less systematic, discomforting the patient. Other means of fixation were introduced, such as staples or compression screws. Non-union rates, however, remained comparable (1.6% to 9.7%; 5.7% in the present staple group) and immobilization time unchanged (6–10 weeks) [7–10]. Material-related dorsal impingement is frequent with staples, often requiring ablation, as in the present staple group (11 cases of impingement). Several teams therefore turned to non-locking dorsal plates (NLDP), in the hope of achieving greater stability, allowing earlier mobilization and improved final range of motion. Unfortunately, results were varied, with non-union rates as high as 62.5% and no improvement in range of motion [11–17]. Merrell et al. [14] pleaded that these poor results were partly due to surgeons using the plate to compensate for technical imprecision and failing to respect the basic principles of fusion such as high-quality reaming into healthy cancellous bone, radial grafting, elimination of reaming debris, correct plate positioning avoiding dorsal impingement, and fixation of each bone by two screws; they also recommended 4 to 6 weeks’ strict immobilization.

Given the lack of benefit demonstrated with NLDPs, dorsal locking plates (DLP) were introduced. Kraisarin et al. [18] in particular demonstrated their biomechanical superiority (Xpode® plate, Biotech) in comparison to NLDPs or K-wires in a cadaver study of 4-corner fusion. The present series reports another DLP, the Aptus Four-Corner Fusion® (Medartis), with 3 central holes to allow central compression by non-locking screws before fixing each bone by a supplementary locking screw. The miniaturized design also enables sufficiently deep insertion to avoid dorsal impingement, of which there were only 2 cases in the present series. The absence of non-union in the present plate group and absence of material fracture despite short immobilization (mean, 4.8 weeks) confirmed the good stability achieved. These results encourage us to further shorten immobilization, although reports for other DLPs counsel caution: Rhee and Shin [19] reported a 4% rate of non-union with 6 weeks’ strict immobilization, while Luengmair and Houvet [20]. Tchurukdichian [21] and Roux [22] reported 8% to 9% non-union with 1 to 2 weeks’ strict immobilization followed by a removable orthosis and initiation of self-rehabilitation for 4 weeks.

The shorter immobilization in the plate group did not, however, significantly improve range of motion as compared with the staple group. Nor do DLPs seem to provide better results in terms of force or postoperative pain. In interpreting the functional scores, it must be borne in mind that the QuickDASH is a bi-manual scale, and the significant difference in favor of the 4CF® plate may have been due to the smaller number of bilateral cases: the locking plate finally may not provide better functional results than staples. Taken together, the clinical findings tend to agree with the literature data on traditional fixation and locking plates (Table 3).

The data on return to work, on the other hand, show a real difference between DLPs and traditional fixation such as staples. Mean time off work in the plate group was 3.4 months less than in the staple group, although the groups were comparable for age, proportion of patients in work and types of work. The rate of return to work was also higher in the plate group (90% versus 77.2%). This faster return to work may be due to faster functional recovery, thanks to better stability, allowing earlier mobilization, and also to a lower rate of surgical revision: early ablation of material was frequent in the staple group, because of dorsal impingement, leading to more time off work. The smaller mean number of postoperative rehabilitation sessions in the plate group also suggests faster functional recovery.

Finally, the better capitoluminar angle correction in the plate group may testify to the easier technical performance of fusion by DLP than staples.

The considerable difference in follow-up (13.1 versus 80.4 months) does, however, constitute a bias to be borne in mind in interpreting the present results. It also accounts for the difference in follow-up rate, which represents a definite further assessment bias. Clinically, the follow-up of just over 1 year in the plate group was enough to include the functional plateau suggested by Chung et al. [16] and Bain and Watts [8]; moreover, the difference in follow-up had no impact on fusion rates or time off work, although longer follow-up in the plate group might have detected some deterioration in results and a greater number of revision surgeries. The two periods (before and after November 2010) also coincided with distinct economic situations, which may

Table 3

<table>
<thead>
<tr>
<th>Series</th>
<th>Follow-up (years)</th>
<th>Sample (n)</th>
<th>Type of assembly</th>
<th>F-E arc (°)</th>
<th>Force (% contralateral)</th>
<th>Quick DASH (100)</th>
<th>Immobilization time (+ orthosis) (weeks)</th>
<th>Non-union (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watson and Ballet [1]</td>
<td>3.6</td>
<td>252</td>
<td>K-wire</td>
<td>–</td>
<td>80</td>
<td>–</td>
<td>6.7</td>
<td>8 (3%)</td>
</tr>
<tr>
<td>Bain and Watts [8]</td>
<td>10</td>
<td>31</td>
<td>Staples</td>
<td>57</td>
<td>78</td>
<td>–</td>
<td>8</td>
<td>3 (10%)</td>
</tr>
<tr>
<td>Vance et al. [11]</td>
<td>4.9</td>
<td>31</td>
<td>K-wire, staples, screw</td>
<td>65</td>
<td>79</td>
<td>8</td>
<td>–</td>
<td>1 (3%)</td>
</tr>
<tr>
<td>Rhee and Shin [19]</td>
<td>1.33</td>
<td>23</td>
<td>Xpode®</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>6</td>
<td>1 (4%)</td>
</tr>
<tr>
<td>Luengmair and Houvet [20]</td>
<td>5.25</td>
<td>24</td>
<td>Xpode®</td>
<td>64</td>
<td>70</td>
<td>19.11</td>
<td>2 (+4)</td>
<td>2 (8%)</td>
</tr>
<tr>
<td>Tchurukdichian [21]</td>
<td>1.4</td>
<td>24</td>
<td>Xpode®</td>
<td>61</td>
<td>69</td>
<td>–</td>
<td>2 (+4)</td>
<td>2 (8%)</td>
</tr>
<tr>
<td>Roux [22]</td>
<td>0.75</td>
<td>11</td>
<td>Xpode®</td>
<td>63</td>
<td>65</td>
<td>–</td>
<td>1 (+4)</td>
<td>1 (9%)</td>
</tr>
<tr>
<td>Oznyerekou et al. [10]</td>
<td>2.33</td>
<td>33</td>
<td>Compression screw</td>
<td>71</td>
<td>80</td>
<td>13</td>
<td>7</td>
<td>2 (6%)</td>
</tr>
<tr>
<td>Present 4CF® group</td>
<td>1.09</td>
<td>30</td>
<td>Fusion®</td>
<td>67.3</td>
<td>70.7</td>
<td>19.83</td>
<td>4.8</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Present staples group</td>
<td>6.7</td>
<td>33</td>
<td>Staples</td>
<td>60.6</td>
<td>64.15</td>
<td>30</td>
<td>8.9</td>
<td>2 (5.7%)</td>
</tr>
</tbody>
</table>

F-E arc: flexion-extension arc.

* In brackets, duration of removable orthosis, removed only for active self-mobilization sessions.
have influenced the prescription of sick leave, although this would probably be a minor factor not in itself explaining the size of the difference. A prospective randomized comparative study could avoid all these sources of possible bias.

Proximal row carpectomy (PRC) is an alternative that is socio-economically preferable to 4-corner fusion according to Vanhove et al. [23]; time off work was 9.8 weeks in the PRC group versus 36 weeks in the fusion group. PRC resection, however, is feasible only in grade 1 or 2 osteoarthritis, and the series had a marked female predominance and the manual nature of work was not specified. Moreover, fusion fixation used K-wires, with the consequent elevated rate of complications, lengthy immobilization and more or less systematic ablation of material. Finally, Ali et al. [24], reporting 81 PRCs at 20 years’ follow-up, did not recommend the technique for young patients or manual workers (74% dissatisfaction, 15% conversion to total fusion).

To sum up, DLP as a fixation method in 4-corner fusion does not seem to improve outcome in terms of range of motion, force, pain or function as compared to traditional techniques. It does, however, provide enough stability for shorter immobilization and faster clinical and functional recovery, as seen in the smaller number of postoperative rehabilitation sessions and shorter mean time off work as compared to traditional fixation techniques such as staples. For this reason, our team now uses only the 4C® plate. Although initial costs are higher, considerable savings can be made on postoperative costs, such as sickness benefit, shifting the debate to the field of public health. A comparative economic study thus seems essential to determine the usefulness of DLPs.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References