Clavicle Nonunion: Matchstick Bone-grafting and Osteosynthesis

Yong Bok Park*, Jae Chul Yoo¹*, Geun Min Park¹, Dong Ho Kum¹, Mohammed Tauheed¹, Jeung Yeol Jeong¹

Department of Orthopaedic Surgery, Soonchunhyang University Bucheon Hospital, Soonchunhyang University College of Medicine, Bucheon, ¹Department of Orthopaedic Surgery, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea

Background: This study was conducted to evaluate the surgical outcomes of plate fixation using autologous iliac bone graft shaped in the form of a matchstick in clavicle nonunion resulting from prior surgical or non-surgical management.

Methods: From May 2005 to February 2013, 17 patients underwent surgery for clavicle nonunion. The mean age at the time of surgery was 48.8 years. The iliac bone was harvested and shaped into slivers approximately 3 cm long, which resembled matchsticks. After opening of the medullary canal, the plate and screws were applied and cancellous bone was placed at the nonunion site. Matchstick bone grafts which were longitudinally placed and encircled on the nonunion site were tied with periosteum using 3–4 stitches. Union was determined via postoperative plane X-ray. Clinical status was evaluated using the visual analogue scale score for pain, and Constant and American Shoulder Elbow Surgeon score.

Results: All patients had a stable radiological union at the follow-up. The mean duration from index operation to nonunion operation was 13.2 months (7–32 months). The mean follow-up period was 20.1 months (8–56 months), and the mean duration until union was 11.2 weeks (8–16 weeks). All clinical scores were improved at the final follow-up (p<0.001). The mean segmental defect was 3.3 ± 2.6 mm (1–18 mm); and the difference in clavicular length between operative and non-operative site was 5.9 ± 6.9 mm.

Conclusions: Matchstick shaped autologous iliac bone grafting technique in clavicle nonunion is acceptable with a high union rate.

Key Words: Nonunion; Bone graft; Clavicle; Matchstick

Introduction

Clavicle fractures are common injuries accounting for 5% to 10% of all fractures. ¹ A large meta-analysis study reported the incidence of clavicle nonunion as 5.9% for undisplaced, to 15.1% for displaced fractures.² However, the incidence of nonunion is variable according to different studies.

In non-surgically managed clavicle fractures, displacement and comminution of fractures, female gender, advancing age,³ and >2 cm shortening⁴ have been reported as the cause of clavicle nonunion. Even though the fractures were treated surgically, improper choice of implant or failure of fixation can result in nonunion.⁵,⁶

Various implants including intramedullary fixation with the Steinmann pin,⁷ Hagie pin,⁸ Rush pins,⁹ Kirschner wires,¹⁰ external fixators,¹¹ plate and screws,¹² and screws alone¹³ are used in the treatment of clavicle nonunion. Some authors have advocated vascularized bone graft reconstruction¹⁴ or osteosynthesis with pectoralis major muscle augmentation in recurrent nonunion.¹⁵ However, the definitive management is still controversial.

Numerous studies have reported open reduction and internal fixation with autologous bone grafting as an acceptable technique to regain the necessary clavicle length in the treatment of clavicle nonunion in cases with atrophied fracture ends and or shortening of the fracture site.¹⁶-¹⁸ However, we sometimes feel that the conventional method should not be used in cases with failed atrophic nonunion surgery using conventional cancellous
chip bone graft technique.

The purpose of this study was to evaluate the surgical outcomes of plate fixation using autologous iliac bone graft shaped in the form of a matchstick in clavicle nonunion previously treated with non-surgical or surgical management including failed nonunion surgery.

The hypothesis was that the healing rate would be as good as that of previous reports.

**Methods**

**Patient Demographics**

This study was a retrospective review of 17 operations for atrophic clavicle nonunion between May 2005 and February 2013 by 1 surgeon at a single institution. Indications were patients with no evidence of radiological union, persistence of pain, cosmetic deformity, dysfunction or gross movement at the fracture site even after 16 weeks, but usually more than 2 years of conservative treatment or in cases of primary fixation failure. Exclusion criteria included patients with an active infection at the nonunion site at the time of surgery, nonunion following a pathological fracture or through previously irradiated bone, previous history of clavicle fracture, or callus formation of the nonunion site (hypertrophic). Institutional Review Board approval was obtained before data collection.

Of the 17 patients, 13 were male and 4 were female with a mean age of 48.8 years at the time of surgery. The right clavicle was involved in 6 cases and the left clavicle in 11 cases. Nine patients sustained fracture following a fall; 4 from a road traffic accident; 2 from sports injury; and 2 from falling off a bicycle. The clavicle fractures were classified according to the Edinburg classification.1

In total 17 cases of nonunion, 10 cases received primarily non-surgical treatment. In 10 cases of nonunion with non-surgical treatment, 7 cases were type IIB1 (displaced mid-3/5th shaft fracture with or without a single fragment), 2 cases were type IIB2 (displaced mid-3/5th shaft fracture with multi-fragment or segmental), and 1 case was IIB1 (displaced extra articular lateral end fracture). In 17 cases of nonunion, 7 cases resulted in nonunion after surgical treatment. Among these, 5 cases were nonunion with hardware failure including plate breakage, and 2 with an intact plate. Of the 5 cases of hardware failure, 3 had cerclage wires that were inserted as a primary procedure for a comminuted fracture at a different institution and 2 were fixed with a plate and lag screws for fragment fixation; 1 of these patients presented to us with 3 failed operations performed else-

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**Table 1. Detailed Demographic Data of the Patients Who Had Open Reduction and Internal Fixation with Autologous Iliac Bone Graft Shaped in the Form of a Matchstick in Clavicle Nonunion**

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Sex</th>
<th>Age (yr)</th>
<th>Site</th>
<th>Duration from injury to surgery (wk)</th>
<th>Cause of injury</th>
<th>Prior management</th>
<th>Classification*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>65</td>
<td>Lt</td>
<td>16</td>
<td>Soccer</td>
<td>Conservative</td>
<td>IIB1</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>53</td>
<td>Lt</td>
<td>28</td>
<td>Slip and fall</td>
<td>Conservative</td>
<td>IIB2</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>58</td>
<td>Lt</td>
<td>17</td>
<td>Traffic accident</td>
<td>Conservative</td>
<td>IIB2</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>38</td>
<td>Lt</td>
<td>48</td>
<td>Fall down</td>
<td>Operative</td>
<td>II1,3</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>57</td>
<td>Lt</td>
<td>20</td>
<td>Traffic accident</td>
<td>Conservative</td>
<td>IIB1</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>34</td>
<td>Lt</td>
<td>29</td>
<td>Fall down</td>
<td>Operative</td>
<td>II1,3</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>36</td>
<td>Rt</td>
<td>62</td>
<td>Traffic accident</td>
<td>Operative</td>
<td>II1,8</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>62</td>
<td>Rt</td>
<td>20</td>
<td>Fall down</td>
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<td>IIB1</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>60</td>
<td>Lt</td>
<td>36</td>
<td>Fall down</td>
<td>Conservative</td>
<td>IIB1</td>
</tr>
<tr>
<td>10</td>
<td>F</td>
<td>62</td>
<td>Rt</td>
<td>41</td>
<td>Bicycle</td>
<td>Conservative</td>
<td>IIB1</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>57</td>
<td>Rt</td>
<td>80</td>
<td>Slip and fall</td>
<td>Conservative</td>
<td>IIB1</td>
</tr>
<tr>
<td>12</td>
<td>M</td>
<td>42</td>
<td>Lt</td>
<td>20</td>
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<td>Operative</td>
<td>II1,8</td>
</tr>
<tr>
<td>13</td>
<td>M</td>
<td>47</td>
<td>Rt</td>
<td>56</td>
<td>Bicycle</td>
<td>Operative</td>
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<tr>
<td>14</td>
<td>M</td>
<td>32</td>
<td>Lt</td>
<td>27</td>
<td>Snow board</td>
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<tr>
<td>15</td>
<td>F</td>
<td>51</td>
<td>Rt</td>
<td>43</td>
<td>Fall down</td>
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<tr>
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<td>M</td>
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<td>Lt</td>
<td>52</td>
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</tr>
<tr>
<td>17</td>
<td>M</td>
<td>52</td>
<td>Lt</td>
<td>54</td>
<td>Fall down</td>
<td>Conservative</td>
<td>IIB1</td>
</tr>
</tbody>
</table>

M: male, F: female, Lt: left, Rt: Right.

*According to Edinburg classification of clavicle fracture. †Detailed classification of the fracture was impossible because of prior surgery performed at other institutions. ‡Nonunion with hardware failure. §Nonunion with hardware in situ.
where for treatment of the nonunion. The mean duration from the onset of fracture to surgery for nonunion was 38.2 weeks (range, 16–80 weeks). All patients were symptomatic with pain, restricted mobility, weakness, or cosmetic deformity. Plain X-ray showed 17 cases as atrophic nonunion. The mean follow-up duration was 20.1 months (range, 8–56 months). The patients’ demography is described in Table 1.

**Surgical Procedure**

All operations were performed under general anesthesia in the beach-chair position. The corticocancellous bone graft was typically harvested from the ipsilateral iliac crest and shaped into slivers approximately 3 cm long that resembled matchsticks (Fig. 1). A skin incision was made over the superior surface along the longitudinal axis of the clavicle. Careful sub-periosteal dissection was performed and the nonunion site was approached, the fibrous tissue was excised along with the sclerotic bone ends and the medullary canals of both fragments were opened using a 3.5 mm drill bit (Fig. 2). The debrided fracture ends were reduced, and the plate was applied with screws of at least 3 cortices. A 3.5 mm reconstruction plate (reconstruction plate; AO Synthes, Paoli, PA, USA) was used in 8 cases, a 3.5 mm anatomical

plate (locking compression plate [LCP]; AO Synthes) in 8 cases (including 1 case of type IIIB1), and a 3.5 mm anatomical plate (LCP; Acumed, Hillsboro, OR, USA) in 1 case. After application of the plate and screws, cancellous bone was placed at the nonunion site. Using Ethibond no. 5, 3, or 4 stiches purchasing periosteum were passed around the fracture ends with the plate, and then the individual sticks of bone graft were longitudinally placed encircling nonunion site.

Fig. 2. The medullary canals of both fragments were opened with a 3.5 mm drill bit.

Fig. 3. Using Ethibond no. 5, 3, or 4 stiches purchasing periosteum were passed around the fracture ends with the plate, and then the individual sticks of bone graft were longitudinally placed encircling nonunion site.

Fig. 4. The sutures are tied with periosteum, firmly opposing the bone graft to the nonunion site.
individual sticks of bone graft were placed encircling the non-union site (Fig. 3). The sutures were tied with periosteum, firmly opposing the bone graft to the nonunion site (Fig. 4). Remaining cancellous bone was also placed at the nonunion site and the soft tissue and skin were closed in layers. An arm sling was used for immobilization for 2 to 4 weeks.

**Clinical and Radiological Evaluation**

Patients were evaluated in the outpatient clinic at regular intervals using the visual analogue scale score for pain (pVAS), American Shoulder and Elbow Surgeon (ASES) score,\(^{20}\) and Constant-Murley shoulder scoring system.\(^{21}\) Union was defined as disappearance of the fracture line, continuity of the bony cortices and remodeling on 2 plain X-ray views (Anteroposterior and 15 degree cephalic tilt view). Fracture gap between both fracture ends was measured, and clavicular length was compared with the non-operative site.

**Statistical Analysis**

Preoperative and postoperative clinical scores (pVAS, ASES, Constant scores) were compared by t-test or Wilcoxon signed rank test. Statistical analyses were performed by IBM SPSS statistics ver. 20.0 (IBM Co., Armonk, NY, USA) and a confidence interval of 95% was used throughout.

**Results**

The mean follow-up period was 20.1 months (range, 8–56 months). The mean pVAS was significantly decreased from 4.1 ± 2.2 points (range, 1–8 points) to 1.3 ± 1.7 points (range, 0–5 points) at the final follow-up (\(p<0.001\)). The mean Constant score and ASES score were significantly increased from 55.5 ± 16.2 points (range, 23–82 points) to 88.7 ± 8.1 points (range, 71–100 points) and from 51.7 ± 16.0 (range, 10–70 points) to 87.4±10.6 points (range, 62–100 points) (\(p<0.001\)). All patients had a stable radiological union at the end of the follow-up period (Fig. 5). The mean duration until union was 11.2 weeks (range, 8–16 weeks). The mean segmental defect was 3.3 ± 2.6 mm (range, 1–18 mm). The mean difference in clavicular length between operative and non-operative site was 0.9 ± 4.9 mm, and the mean difference in clavicular length between operative and non-operative site was 5.9 ± 6.9 mm (operative site, 155.5 ± 15.9 mm; non-operative site, 161.5 ± 16.7 mm). There were no complications pertaining to the hardware, or infection.

**Discussion**

Our study showed a 100% union rate in 17 cases of non-union treated with open reduction and internal fixation with a plate using autologous iliac bone graft. The key modification of the autograft was the shape of the iliac crest graft, which was

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Fig. 5. (A) Radiologic images of the patient who had 3 previously failed operations at other institutions (1st operation-for fracture, 2nd and 3rd operation-for nonunion with hardware failure). Preoperative X-ray image before 1st operation for fracture. (B) Postoperative X-ray of 1st operation for fracture. (C) Preoperative X-ray of 4th operation for nonunion. Nonunion with hardware failure was noted. (D) Immediate postoperative X-ray using matchstick technique for nonunion. Auto-iliac bone graft shaped matchsticks were noted (white arrow). (E) Hardware was removed at postoperative 24 months. Complete union was noted.
shaped in the form of a matchstick.

Clavicle fractures have a high healing rate with nonsurgical treatment and result in good functional outcomes. However, more recent evidence recommends surgical treatment for larger subsets of clavicle fractures than previously known, due to a higher risk of nonunion, symptomatic malunion, and suboptimal functional outcomes. Hill et al. reported that the majority of displaced mid-shaft clavicle fractures that were treated conservatively were associated with higher rates of nonunion and patient dissatisfaction with the final result.

Despite several concerns regarding autologous bone graft, including donor site morbidity and blood loss, open reduction and internal fixation with plate and autologous bone graft is an accepted technique for atrophic nonunion of the clavicle, because of its osteoconductive, osteoinductive, and osteogenic effect.

Some authors have suggested that autologous bone graft might be unnecessary in every case of clavicle nonunion. En-drizzi et al. reported a high union rate (44 of 47 patients, 93%) in their series treated with local bone graft or demineralized matrix alone. Ramoutar et al. reported a 100% union rate (11 patients) in their series treated by fragment decortication and compression without bone graft. However, the definitive interpretation of these reports is not that bone graft is unnecessary in all cases of clavicle nonunion. Conventional internal fixation without bone graft or with demineralized matrix alone might be insufficient for bone healing in patients with repeated failed operations for nonunion. Autologous bone graft is accepted as the gold standard for nonunion surgery and a high healing rate of bone graft surgery was often reported. Addition of the bone graft to conventional internal fixation, as compared to conventional technique without bone graft could increase the union rate, particularly in difficult cases.

This technique has an advantage for bone healing, as compared with conventional cancellous bone graft, because of the comparatively large amount of bone graft and the strut bone effect.

According to systematic review of clavicle fractures, the most common type of nonunion was the type IIb1 fracture that was initially treated with conservative management. We likewise found that the majority of fractures among the nonunion cases were type IIb1. The classification was not possible on X-ray for the nonunion cases that were treated with an earlier operation. We observed 1 case of lateral 1/5th fracture nonunion of the clavicle. Displaced lateral end fractures of the clavicle are difficult to treat due to their small size and high rate of delayed union i.e., up to 45%, and nonunion up to 30%. We achieved complete union using 3.5 mm LCP with a matchstick bone graft technique in cases of nonunion with displaced lateral end fractures.

Matchstick shaped bones that are firmly tied with periostea have a strut bone effect, although somewhat weaker than actual strut bone graft. Our results were comparable with those of other studies reporting a 91% to 100% union rate with autologous bone graft and plate fixation. The factors that contributed to superior outcomes (100% union) compared with other research would have been the usage of matchstick shape bone graft as well as the cerclage which was performed using suture material. Wu et al. reported that wire cerclage could be a risk factor for clavicle nonunion, thus suture material should be used in place of wire.

This study had several limitations. First, the sample size was small. A larger sample size would facilitate a definitive conclusion. Second, we included no control group of plate fixation with autologous iliac bone chip graft alone. Third, the mean follow-up period was short. However, because this disease was associated with fracture, the results provided limited meaning regarding the healing of nonunion. And fourth, morbidity of the donor site including pVAS, and postoperative symptom duration was not evaluated. Although there were no complications requiring specific postoperative management, prospective evaluation of the donor site would be helpful in advancing this technique.

 concludes that matchstick shape autologous iliac bone grafting in clavicle nonunion showed a high union rate which might have contributed to the healing with an appropriate surgical technique.

References

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