Original article

Influence of fixation with two vs. three screws on union of arthroscopic tibio-talar arthrodesis: Comparative radiographic study of 111 cases

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Background: Ankle arthrodesis is a treatment of choice for advanced tibio-talar disease unresponsive to conservative treatment. Using arthroscopy to perform this procedure minimises soft-tissue trauma while providing similar outcomes to those of open surgery. Union rates have ranged across studies from 85% to 100%. The objective of this study was to assess the potential influence on union of the number of screws used for arthrodesis fixation.

Hypothesis: The working hypothesis was that using three screws for arthrodesis produced a higher union rate than did using only two screws.

Material and methods: This single-centre retrospective comparative study included 111 cases of arthroscopic ankle arthrodesis (in 108 patients) carried out between February 1994 and October 2012. The number of screws was two in 75 cases and three in 36 cases. Union was assessed on radiographs taken 2, 6, and 12 months postoperatively.

Results: Mean age at surgery was 55.8 years. After 12 months, union was achieved in 87.4% cases overall. The non-union rate was 16% with two screws and 5.6% with three screws. Three-screw fixation was associated with a significantly higher rate of union of the medial gutter after 6 months and of the lateral gutter after 12 months.

Discussion: Our findings support the use of three screws for fixation of arthroscopic tibio-talar arthrodesis. Adding a third screw seems associated with a lower risk of non-union and a shorter time to union. These effects can be ascribed to greater stability of the construct.

Level of evidence: Level IV, retrospective study.

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1. Introduction

A distinctive feature of tibio-talar joint disease is the marked predominance of trauma as the aetiology (70% to 78%) [1–3]. Tibio-talar arthrodesis has been proven effective and reliable for advanced disease that fails to respond to conservative treatment [4,5]. Conventional open arthrodesis techniques improve both pain and function [6–8]. Nevertheless, in these patients who often have a history of multiple local surgical procedures, open surgery causes further soft-tissue trauma and can be associated with high rates of complications, including non-union, infection, and impaired healing [9–11]. With the goal of decreasing these complications, Schneider performed the first arthroscopic tibio-talar arthrodesis, in 1983. In recent studies, the arthroscopic technique was associated with less morbidity, an easier postoperative course, and shorter durations of surgery and hospitalisation compared to the open technique [9–11].

Comparative studies performed by Meng et al. [11], Nielsen et al. [12], and Myerson and Quill [13] showed that arthroscopic surgery produced a similar 1-year union rate to that seen after open surgery but with a shorter time to union. Arthroscopic tibio-talar arthrodesis, which is now a standard procedure, does not fully eliminate the risk of non-union. We started using the arthroscopic technique in our centre in 1992 [14]. Since then, we have modified the fixation method: initially, two screws were used (tibio-talar then tibio- and fibulo-talar), and a third screw was then added, with the goal of increasing the union rate.

Our main hypothesis was that the union rate was higher when three screws, instead of two, were used for tibio-talar arthrodesis fixation. We also evaluated the potential influence of the number of screws on healing of the gutters. Finally, we looked for associations linking the surgical history and arthrodesis position to the union rate.
2. Patients and method

2.1. Inclusion criteria

This was a single-centre retrospective comparative study of radiographic outcomes. Consecutive patients who underwent arthroscopic tibio-talar arthrodesis at our centre over the 225-month period between February 1994 and October 2012 were included. During this period, the arthroscopic technique was used routinely for first-line tibio-talar arthrodesis, except when autologous bone grafting was required. The only exclusion criterion was the unavailability of postoperative radiographs allowing assessment of talon dome union 1 year after surgery. All procedures were performed by three senior surgeons (OR, FS, and DM).

The patients were divided into two groups depending on the number of screws used for fixation. At our centre, two screws were used from February 1994 to January 2009 and three screws from February 2009 to October 2012.

2.2. Patients

During the inclusion period, 119 ankles in 116 patients were treated with arthroscopic tibio-talar arthrodesis. For 8 patients, the follow-up radiographs needed for the study were not available. The remaining 108 patients (111 ankles) were included in the study. Table 1 lists their main features. No significant differences were noted between the two-screw and three-screw groups.

Post-traumatic osteoarthritis was the main cause of tibio-talar disease (90/111 ankles, 81%, Table 1). A history of one or more surgical procedures on the ankle was noted for 61 (55%) ankles, with a mean of 1.6 previous procedures per ankle. Two screws were used in 75 cases and three screws in 36 cases. The causes of tibio-talar disease were not significantly different between these two groups (Table 2).

2.3. Operative technique

The procedure started with distraction of the tibio-talar joint followed by arthroscopic preparation of the joint surfaces (Fig. 1). The cartilage was removed and the underlying bone abraded using a curette and a blade (Fig. 2). The talon dome, tibial joint surface, and medial and lateral gutters were prepared to bleeding.

The second step was fixation of the arthrodesis. Short-thread, cannulated, cancellous screws 7.0 mm in diameter were inserted percutaneously. In the two-screw group, fixation was with a medial tibio-talar screw and a lateral fibulo-talar or tibio-talar screw (Figs. 3 and 4). When there were three screws, these were medial tibio-talar, lateral tibio-talar, and fibulo-talar (Fig. 5).

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Table 1

<table>
<thead>
<tr>
<th>Feature</th>
<th>2 screws n=75</th>
<th>3 screws n=36</th>
<th>Total n=111</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years) mean ± SD</td>
<td>55.0 ± 14.1</td>
<td>57.4 ± 14.0</td>
<td>55.8 ± 14.0</td>
<td>0.38</td>
</tr>
<tr>
<td>BMI (kg/m²) mean ± SD</td>
<td>27.7 ± 8.6</td>
<td>27.0 ± 3.9</td>
<td>27.5 ± 4.4</td>
<td>0.41</td>
</tr>
<tr>
<td>Males/females</td>
<td>50/25</td>
<td>27/9</td>
<td>75/33</td>
<td>0.37</td>
</tr>
<tr>
<td>Current smoking (%)</td>
<td>28.4%</td>
<td>38.2%</td>
<td>30.6%</td>
<td>0.31</td>
</tr>
<tr>
<td>Vascular disease (%)</td>
<td>17.6%</td>
<td>11.4%</td>
<td>15.3%</td>
<td>0.41</td>
</tr>
<tr>
<td>Diabetes (%)</td>
<td>6.7%</td>
<td>16.7%</td>
<td>9.9%</td>
<td>0.10</td>
</tr>
<tr>
<td>Glucocorticoid therapy (%)</td>
<td>14.9%</td>
<td>11.4%</td>
<td>13.5%</td>
<td>0.63</td>
</tr>
</tbody>
</table>

BMI: body mass index.

Table 2

<table>
<thead>
<tr>
<th>Cause</th>
<th>Number</th>
<th>2 screws</th>
<th>3 screws</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trauma</td>
<td>90 (81%)</td>
<td>58</td>
<td>32</td>
<td>0.64</td>
</tr>
<tr>
<td>Infection</td>
<td>9 (8%)</td>
<td>9</td>
<td>0</td>
<td>0.06</td>
</tr>
<tr>
<td>Primary</td>
<td>6 (5%)</td>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Neurological</td>
<td>6 (5%)</td>
<td>5</td>
<td>1</td>
<td>0.66</td>
</tr>
<tr>
<td>Rheumatic disease</td>
<td>4 (3%)</td>
<td>4</td>
<td>0</td>
<td>0.31</td>
</tr>
<tr>
<td>Avascular necrosis of the talus</td>
<td>2 (2%)</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Angiomaosis of the joint</td>
<td>1 (1%)</td>
<td>0</td>
<td>1</td>
<td>0.33</td>
</tr>
<tr>
<td>Haemophilia</td>
<td>1 (1%)</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

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Fig. 1. A. Non-invasive distraction device. B. Installation after draping. C. Intraoperative appearance (arthroscopic step).
Fig. 2. A and B. Arthroscopic appearance after bone preparation to bleeding.

Fig. 3. Two-screw fixation: one medial and one lateral tibio-talar screw.

Fig. 4. Two-screw fixation: one medial tibio-talar screw and one lateral fibula-talar screw. Right.

2.4. Methods

For each patient, we recorded the previous surgical procedures on the ankle, co-morbidities, and postoperative complications. An independent observer assessed union of the arthrodesis on radiographs taken 2, 6, and 12 months after surgery. Three joint areas were examined separately, namely, the talar dome/tibia, the medial gutter, and the lateral gutter. Union of the arthrodesis was defined as obliteration of the joint space between the talar dome and the tibia. Union rates in the two-screw and three-screw groups were compared after 2, 6, and 12 months. Union of the gutters was also assessed at the same three time points.

Arthrodesis position was evaluated on the antero-posterior radiographs by measuring the angle between the tibial axis and the line perpendicular to the talar dome. Normal valgus was defined as a value of 3° for this angle [15]. On the lateral radiograph, position was assessed based on the tibio-talar angle described by Winson et al., whose normal value is 106° [15] (Fig. 6).

The data were entered into Excel (Microsoft Corporation, Redmond, WA, USA). Statistical analyses were performed using StatView software (Optima, Mérignac, France). Comparisons were with Student’s t-test for quantitative variables, the Chi² test for qualitative variables when sample size was larger...
than 5, and Fisher’s exact test for qualitative variables when sample size was 5 or less. Values of $P<0.05$ were considered significant.

3. Results

Radiographs were available for 105 ankles after 2 months, 104 after 6 months, and 104 after 12 months. Information on whether union was achieved after 12 months was available for all patients. However, healing of the gutters was not assessed in all 111 ankles.

3.1. Complications

Within the first postoperative year, infection occurred in 5 (4.5%) ankles. A full recovery with union of the arthrodesis was achieved in 3 of these cases after early removal of the hardware and antibiotic therapy. Another patient had neuropathy of the affected limb and required amputation. Septic non-union required open revision surgery and antibiotic therapy in the remaining patient. There were no injuries to blood vessels of nerves. A previous history of local surgery was noted for all 5 ankles with postoperative infection compared to 56/106 (51.9%) of ankles without infection ($P=0.06$). Minor healing disorders that resolved with local care occurred in 5 ankles.
Table 3
Rate of union of the three joint areas at each postoperative time point.

<table>
<thead>
<tr>
<th>Union</th>
<th>2 screws</th>
<th>3 screws</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>% (union/non-union)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 months</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Talar dome/tibia</td>
<td>60% (42/70)</td>
<td>71.4% (25/35)</td>
<td>0.25</td>
</tr>
<tr>
<td>Medial gutter</td>
<td>5.5% (4/69)</td>
<td>16.7% (6/30)</td>
<td>0.08</td>
</tr>
<tr>
<td>Lateral gutter</td>
<td>1.3% (1/74)</td>
<td>5.6% (2/34)</td>
<td>0.25</td>
</tr>
<tr>
<td>6 months</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Talar dome/tibia</td>
<td>76.8% (53/66)</td>
<td>94.4% (34/36)</td>
<td>0.03*</td>
</tr>
<tr>
<td>Medial gutter</td>
<td>23.6% (17/72)</td>
<td>48.6% (17/35)</td>
<td>0.01*</td>
</tr>
<tr>
<td>Lateral gutter</td>
<td>5.3% (4/71)</td>
<td>25.7% (9/35)</td>
<td>0.01*</td>
</tr>
<tr>
<td>12 months</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Talar dome/tibia</td>
<td>84.0% (63/75)</td>
<td>94.4% (34/36)</td>
<td>0.14</td>
</tr>
<tr>
<td>Medial gutter</td>
<td>52.2% (36/33)</td>
<td>65.7% (23/35)</td>
<td>0.18</td>
</tr>
<tr>
<td>Lateral gutter</td>
<td>17.4% (12/70)</td>
<td>37.1% (13/35)</td>
<td>0.03*</td>
</tr>
</tbody>
</table>

* P-value indicating a statistically significant difference.

3.2. Radiographic outcomes

After 12 months, union was achieved for 97 (87.4%) ankles overall. Table 3 reports the results of the analysis. The 12-month union rate was 84.0% with two screws and 94.4% with three screws (P = 0.14). The final union rate was achieved within 6 months in the 3-screw group; in contrast, the union rate increased between 6 and 12 months in the two-screw group (Table 3).

Overall, there were 14 (12.6%) cases of non-union, 12 (16%) in the two-screw group and 2 (5.6%) in the three-screw group. In 10 cases of non-union, open revision surgery was performed; this procedure was consistently successful in achieving union. Good clinical tolerance made surgery unnecessary in the remaining 4 cases. One or more previous surgical procedures had been performed on 12 (85.7%) of the 14 non-unioned ankles compared to 49 (50.5%) of the 97 primarily united ankles (P = 0.02). Non-union occurred in 20.6% (7/35) of ankles in smokers compared to 9.1% of ankles in non-smokers (P = 0.06). The final union rate was not influenced by presence of a preoperative deformity, diabetes, glucocorticoid therapy, overweight or obesity, or peripheral arterial disease.

The analysis of arthrodesis position found no evidence that persistent postoperative malalignment on the antero-posterior or lateral radiographs influenced the rate of union. Postoperative malalignment of 5° or more in the coronal plane was noted for 1 (7.1%) non-united ankle and 12 (12.3%) united ankles (P = 1). The lateral radiograph showed malalignment of 5° or more for 3 (21.4%) non-united ankles and 20 (20.6%) united ankles (P = 1).

There was no evidence of a learning curve effect. Thus, within the two-screw group, non-union occurred for 4 of the 37 first arthroscopic procedures compared to 8 of the 38 remaining arthroscopic procedures.

Table 4
Data from previous reports and from our study.

<table>
<thead>
<tr>
<th>Studies</th>
<th>Year published</th>
<th>Number of ankles</th>
<th>Type of fixation</th>
<th>Follow-up</th>
<th>Union rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bresler et al. [14]</td>
<td>1994</td>
<td>7</td>
<td>2 crossed screws</td>
<td>14 weeks</td>
<td>100</td>
</tr>
<tr>
<td>Crosby et al. [19]</td>
<td>1996</td>
<td>42</td>
<td>2 crossed screws</td>
<td>27 months</td>
<td>92.9</td>
</tr>
<tr>
<td>SFA symposium</td>
<td>1998</td>
<td>116</td>
<td>2 screws or external fixator</td>
<td>87</td>
<td></td>
</tr>
<tr>
<td>Zvijac et al. [21]</td>
<td>2002</td>
<td>21</td>
<td>2 crossed screws</td>
<td>34 months</td>
<td>95.2</td>
</tr>
<tr>
<td>Pierre et al. [22]</td>
<td>2003</td>
<td>20</td>
<td>2 crossed screws</td>
<td>3.7 months</td>
<td>85</td>
</tr>
<tr>
<td>Ferkel et al. [23]</td>
<td>2005</td>
<td>35</td>
<td>2 crossed screws</td>
<td>72 months</td>
<td>97</td>
</tr>
<tr>
<td>Winson et al. [15]</td>
<td>2005</td>
<td>105</td>
<td>2 medial parallel screws</td>
<td>65 months</td>
<td>92.4</td>
</tr>
<tr>
<td>Collinan et al. [24]</td>
<td>2006</td>
<td>39</td>
<td>2 crossed screws</td>
<td>20.4 months</td>
<td>87.2</td>
</tr>
<tr>
<td>Gontoulakis et al. [25]</td>
<td>2007</td>
<td>78</td>
<td>2 or 3 parallel screws</td>
<td>21.1 months</td>
<td>97.9</td>
</tr>
<tr>
<td>Nielsen et al. [12]</td>
<td>2008</td>
<td>58</td>
<td>2 parallel screws</td>
<td>12 months</td>
<td>94.8</td>
</tr>
<tr>
<td>Dhamwii et al. [26]</td>
<td>2010</td>
<td>55</td>
<td>2 parallel screws</td>
<td>56.5 months</td>
<td>91</td>
</tr>
<tr>
<td>Our study</td>
<td>2015</td>
<td>111</td>
<td>2 or 3 crossed screws</td>
<td>12 months</td>
<td>87.4</td>
</tr>
</tbody>
</table>

SFA: French Society for Arthroscopy.

4. Discussion

In our study, the arthrodesis union rate was 84% with two-screw fixation and 94.4% with three-screw fixation. This difference seems to support an increase in the union rate when a third screw is added. That the difference is not statistically significant (P = 0.14) can be ascribed to the small sample size. According to the power estimation, with alpha set at 5% and 80% power, a sample size of 264 ankles would be needed for the observed difference to be significant. Time to union was shorter in the three-screw group, in keeping with previously published data. In a biomechanical study by Ogilvie-Harris et al. [16], compression and torque resistance were better with three-screw than with two-screw fixation. A 2004 report by Alonso-Vazquez et al. [17] clearly indicates better stability with three than with two screws. In a comparison of times to union with four different screw fixation techniques, Yoshimura et al. [18] found a significantly higher union rate when three screws were used.

A number of methodological limitations must be acknowledged. Inclusion of the learning curve for arthroscopic arthrodesis into the two-screw group was a potential source of bias. However, the rate of non-union was not higher early during the two-screw period compared to later on. Given the retrospective design, radiographs were missing for some ankles at one or more follow-up time points. This point did not affect the validity of the 1-year union rate assessment, as information was available for all ankles at this time point. Thus, the missing data affected only the assessments of time to union and gutter union. Finally, the intervals at which the radiographs were taken (2, 6, and 12 months) did not allow an accurate assessment of the time to union.

Post-traumatic osteoarthritis was the reason for arthrodesis in 81% of ankles in our study. Similarly, this aetiology was found in 70% to 78% of cases in earlier studies [1–3]. The complication rate was low (4.5%) and infection was the only complication, in keeping with results reported by Crosby et al. in 1996 [19]. This low complication rate is one of the main advantages of the arthroscopic technique.

The overall union rate in our study (87.4%) is also consistent with the literature. In a 1998 case-series study of 116 ankles by the French Society for Arthroscopy (SFA), the union rate was 87%. A meta-analysis by Abicht and Roukis [20] showed an overall union rate of 91.4%. In other studies, union rates ranged from 85% to 100% (Table 4).

The rate of medial gutter union was significantly higher in the three-screw group after 6 months, but this difference was no longer present after 12 months. We believe the medial gutter unites in conjunction with the talar dome, becoming incorporated into a tibio-talar mass. The difference noted after 6 months supports greater stability of three-screw fixation, with faster radiographic union as a result. In contrast, the rate of lateral gutter union was only 24%, in accordance with data reported by Yoshimura et al. (25%) [18]. The lateral gutter union rate was significantly higher.
in the three-screw group but remained fairly low, at 37.1%. Win-
son et al. [15] and Yoshimura et al. [18] reported that union of the
lateral gutter did not correlate with improved clinical outcomes in
ankles without major talo-fibular lesions.

A history of surgery on the ankle, particularly of open surgery,
seemed associated with a greater risk of infection and non-union,
compared to absence of previous surgery. Furthermore, current
smoking was associated with a markedly higher risk of non-union
(20.6% vs. 9.1% in non-smokers). In 1994, Cobb et al. [27] reported
that the relative risk of non-union in smokers was 3.75. Other
studies also showed higher non-union rates in smokers [15,28,29].
Current glucocorticoid therapy was not associated with the 12-
month union rate. In contrast to Yoshimura et al. and Collman et al.
[18,24], we found no association linking the body mass index to
the union rate. Neither were diabetes nor peripheral arterial dis-
ease significantly associated with union in our study, in keeping
with the report by Collman et al. [24]. In contrast, in 2013, Shibuya
et al. [30] reported a higher risk of non-union in patients with
established diabetic neuropathy. Finally, persistent postoperative
malalignment exceeding 5° in the coronal or sagittal plane did not
seem associated with a higher risk of non-union in our population.

5. Conclusion

Using three fixation screws instead of two for arthroscopic tibi-
tal arthrodesis seems to improve both the union rate and the time
to union. The high frequency of previous surgery on the ankle warn-
ants caution, however, given the increased risk in this situation of
infection and non-union. The arthroscopic technique does not elimi-
nate the risk of complications and requires scrupulous attention
to the soft tissues, quality of bone preparation, and fixation. The
patient should be informed of the risks associated with smoking.

Disclosure of interest

The authors declare that they have no competing interest.

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