A comparison of bone union and complication rates between locking and non-locking plates in distal fibular fracture: Retrospective study of 106 cases

Bachar EL FATAYRI*, Yassine BULAİD, Az-Eddine DJEBARA, Eric HAVET, Patrice MERTI, Massinissa DEHL

Orthopedic surgery department, CHU Amiens – Picardie, 80480, Salouël, France

Introduction

Ankle fractures are frequent in traumatology. Their incidence of 122 to 184 per 100,000 people/year [1–3], out of which 25% in elderly over 65 [4], puts them as the third most common fracture in elderly patients [3,5]. Open reduction and internal fixation in displaced distal fibula fractures is considered as the treatment of choice [6]. The most common surgical technique nowadays is plating [7]. The advent of locking-plates has radically changed the management of long bones fractures [8–11]. This innovation using fixed-angle screws offers better angular and axial stability [12,13], particularly in metaphysis and epiphysis, independently of bone mineral density [12]. These Locking constructs have progressively changed our surgical practices, especially in cases of osteoporosis or comminuted fractures, instability and/or cortical fixation difficulties [13].

Several cadaveric studies biomechanically comparing locking plates (LP) and non-locking plates (NLP) have been conducted [14–20]. However, few studies compared bone union in distal fibula fractures treated with Locking vs. non-locking constructs [21–24].

The primary outcome of our study was to assess radiographic bone union rates in distal fibula fractures of a NLP (VIVES™, Stryker®, Mahwah, NJ, USA) vs. a LP (VariAx™, Stryker®, Mahwah, NJ, USA) at 6 and 12 weeks of follow up. Secondary outcomes included the assessment of wound complications and hardware removal rates, in addition to a comparison of each construct’s cost. Our key assumption was that Non-locking constructs are as
effective as locking constructs in the treatment of displaced distal fibula fractures.

Patients and methods

Population

We retrospectively reviewed a consecutive cohort of patients who underwent surgical fixation of closed malleolar fractures of the ankle between January 2012 and December 2013. We included patients above 18, with displaced isolated distal fibula, bi malleolar or tri malleolar fractures, treated surgically with either a LP or NLP, with a minimal 3 months follow-up period. Open ankle fractures, pilon or diaphyseal associated fractures and injuries treated with another type of osteosynthesis (isolated medial malleolar fracture treated with screws, fractures treated with external fixators, fractures treated with kirschner wires, fractures treated with isolated syndesmotic screws) were excluded. After excluding non-eligible patients, we have sent a memorandum notifying concerned patients about their participation. The memo defines the purpose of the study and its execution, in addition to their right of objection and withdrawal regarding the use of their personal information [25].

Data was collected from patient charts and electronic records of the department of orthopedic surgery and traumatology of our institution. The fracture type was defined on preoperative anterior-posterior and lateral radiographs according to AO classification [26]. The primary outcome was the radiographic confirmation of lateral malleolar fracture union at 6 and 12 weeks. We defined radiographic union as the disappearance of all fracture lines in the anterior posterior and lateral views. Two senior orthopedic surgeons, blinded to the aim and protocol of the study, determined separately the radiographic union of each case. In the event of disagreement, a third interpretation was performed by an independent radiologist to decide this issue. Wound complications were split into superficial or minor complications (delayed wound healing and wound secondary dehiscence) and deep or major infectious complications [27]. Clinical outcomes as pain, swelling and stiffness, as well as hardware removal percentage were recorded from follow-up data. The construct costs were calculated using the prices of the sales made by the corresponding trader to our institute.

Operative technique

All procedures were performed in a supine position under general or spinal anesthesia. All patients benefited from the use of a tourniquet at top of thigh and received antibiotic prophylaxis according to the institute protocol. After fracture reduction, the use of lag screws as well as the plate’s thickness was left to the discretion of the operation surgeon. When a locking or non-locking plate was placed on the lateral aspect of the fibula. Surgeons had no choice in the type of plate they would use: In 2012, there was only NLP available in our institute and as of January 2013, they were replaced with LP. The NLP used, Vives™ (Stryker®, Mahwah, NJ, USA) was a MACONOR-2 type periarticular plate characterized by its “diamond-shaped” rough deep surface and its continuous 1.8mm thickness. The LP, VariAx™ fibula locking plate system (Stryker®, Mahwah, NJ, USA), is a low profile pre-countered periarticular plate. It is 2mm thick proximally and 1.3mm distally, and it possesses the SmartLock™ polyaxial locking mechanism (Fig. 1). All proximal plate screws were non-Locking in both groups. All four distal plate screws were cancellous non-Locking in the NLP group and Locking in the LP group (Figs. 2 and 3). Medial malleolar fractures were reduced and fixed with either cancellous screws or tension band wiring. Anterior posterior screws were eventually used in case of a displaced posterior fragment. Medial collateral ligament suture and or syndesmotic repairing by a temporary screw have been undertaken when necessary. Drains were routinely used and wound closure techniques were common to both groups. All patients benefited from a plaster cast postoperatively and a pharmacological venous thromboembolic prophylaxis throughout 6 weeks of immobilization and non-weight bearing. Clinical and radiographic follow-up was routinely achieved at 3, 6 and 12 weeks postoperatively. Weight-bearing and rehabilitation began after 6 weeks. Further follow-up examinations were established in case of complication.

Statistical analysis

Statistical analysis was performed using R-Studio® version 3.4.2 for Windows® (Boston, USA). Descriptive statistics were performed to summarize demographic and clinical variables and to evaluate distributional characteristics. Continuous variables were evaluated using Student and Wilcoxon tests, and were expressed with means ± standard deviation and range. Categorical data were evaluated using Chi-square or Fisher tests, and expresses as
percentages. We used simple linear analysis studying the direct relation between the variable and the primary outcome. Multiple linear regression techniques were performed after identifying dependent variables. Data was expressed as odds ratios with their ninety-five percent confidence intervals and p-values defined at 5% (statistical significance was defined at $p < 0.05$).

**Results**

A total of 198 ankle fractures were assessed between January 2012 and December 2013. After applying exclusion criteria, there was left 128 distal fibulas that underwent fixation with a lateral plate. Twenty-two patients were lost during follow-up. After inclusion, one patient expressed his opposition to the use of his personal data by a written letter. A hundred and five patients were analyzed: 42 received a NLP and 63 received a LP (Fig. 4).

**Population and surgical characteristics**

The mean age of the population at surgery was fifty years [17; 84] and 60% of patients were female. Mean body mass index (BMI) was 26.7 Kg/m² [16.4; 46.2]. The most frequent comorbidity was smoking ($n = 44; 41.9\%$). We have found 31 dislocated ankles (29.52%) and the rate of skin blisters, before and after surgery, was 14.29%. Referring to the AO classification for ankle fractures, type 44-B was predominant ($n = 102; 97.14\%$) and sub-type 44-B2 or bi-malleolar was the most frequent ($n = 70; 66.67\%$). All the population’s data is detailed in Table 1. No significant differences were found between groups in all variables except for the AO fracture type ($p = 0.011$) and sub-type 44-B ($p = 0.024$). The use of lag screws in conjunction with the plate was significantly higher in the NLP group (65.08% vs. 40.48%; $p = 0.012$).

**Radiographic bone union rate**

Bone union rate is detailed in Table 2. We have not found a significant difference in bone union rate either at 6 or 12 weeks postoperatively between NLP and LP groups. Simple linear analysis of bone union at 6 and 12 weeks are exposed in Table 3. Odds ratios concerning multiple linear regression analysis at 6 weeks are exposed in Table 4. Multivariable analysis has not found any differences in bone union at 6 weeks after adjustment for age, gender and fracture type. However, a significant difference was found in both groups, with sub-type 44-B3 requiring longer time to bone union comparing to sub-type-B2 (OR = 0.25 [0.069–0.936]; $p = 0.035$). Concerning bone union at 12 weeks, multiple linear regression analysis have showed a statistically significant delay in bone union in case of skin blisters (OR = 0.066 [0.003; 0.762]; 0.034). Other variables were not related to bone union delay. Odds ratios concerning multiple linear regression analysis at 12 weeks are exposed in Table 5.

**Complications**

Complication rates are detailed in Table 6. Twelve wound complications were found the cohort, including four deep infections in NLP group and two in LP group. There was no significant difference in wound complications in the NLP group compared to the LP group (11.9% vs. 11.1% $p = 0.9$). This finding was similar when comparing minor and major wound complications between the study groups (respectively: 2.38% vs. 7.94%; 0.039 and 9.52 vs. 3.17; $p = 0.154$). The rates of other complications were comparable ($p = 0.138$). There were no early revisions, except for syndesmotic screws ablation at 6 postoperative weeks. One patient required a late arthroscopic artholysis in the context of ankle equinus stiffness. Multiple linear regression techniques could not be performed for complication rates.

**Hardware removal (HR)**

The overall HR rate was 36.19% (Table 7) and there was no significant difference between the groups ($p = 0.361$). All four infected sites of the NLP group have benefited of HR. On the contrary, in the LP group, only one out of two plates was removed after infection. The plate left in place was of an early infection while the fracture had not healed yet. After taking HR for infection out of count, there was 9 HR (21.42%) in the NLP group and 24 HR (38.09%) in the LP group. This difference was not statistically significant ($p = 0.071$). Plate removal was performed earlier in the NLP group independently of the infection factor (respectively: 13.5 ± 2.5 vs. 17.2 ± 7.7;
Table 1
Population and surgical characteristics.

| Characteristic                  | Total | NLP | LP  | p-value |
|--------------------------------|-------|-----|-----|---------|
| Patients (n)                   | 105   | 42  | 63  |         |
| Gender (%)                     |       |     |     |         |
| Male                           | 42 (40)|     |     | 0.625*  |
| Female                         | 63 (60)|     |     |         |
| Age *                          | 50.4 +/- 17.2 | 51.8 +/- 18.7 | 49.4 +/- 16.2 | 0.486 b |
| [17; 84]                       | [20; 84] | [17; 82] |         |         |
| BMI *                          | 26.7 +/- 5.9 | 26.1 +/- 4.5 | 27.1 +/- 6.6 | 0.347 b |
| [16.4; 46.2]                   | [17.7; 42.5] | [16.4; 46.2] |         |         |
| Smoking (%)                    |       |     |     |         |
| Y                              | 44 (41.9)| 21 (50) | 23 (36.5) | 0.169*  |
| N                              | 61 (58.1)| 21 (50) | 40 (63.5) |         |
| Alcohol (%)                    |       |     |     |         |
| Y                              | 19 (18.09)| 9 (21.43) | 10 (15.88) | 0.468*  |
| N                              | 86 (81.91)| 33 (78.57) | 53 (84.12) |         |
| Diabetes mellitus (%)          |       |     |     |         |
| Y                              | 10 (9.52) | 4 (9.52) | 6 (9.52) | 1 c     |
| N                              | 95 (90.48) | 38 (90.48) | 57 (90.48) |         |
| Peripheral arterial disease (%)|       |     |     |         |
| Y                              | 2 (1.9) | 0 | 2 (3.18) | 0.515 c |
| N                              | 103 (98.1) | 42 (100) | 61 (96.82) |         |
| Chronic renal failure (%)      |       |     |     |         |
| Y                              | 1 (0.95) | 1 (1.59) | 62 (98.41) | 1 c     |
| N                              | 104 (99.05) | 42 (100) | 62 (98.41) |         |
| Corticosteroids (%)            |       |     |     |         |
| Y                              | 1 (0.95) | 0 | 1 (1.59) | 1 c     |
| N                              | 104 (99.05) | 42 (100) | 62 (98.41) |         |
| ASA score (%)                  |       |     |     |         |
| 1                              | 32 (30.47) | 9 (21.42) | 23 (36.5) | 0.237 c |
| 2                              | 2 (1.9) | 14 (33.33) | 17 (26.98) | 0.484 c |
| 3                              | 8 (7.62)| 4 (9.52) | 4 (6.34) |         |
| 4                              | 0 | 0 | 0 |         |
| Side                           |       |     |     |         |
| Y                              | 52 (49.52) | 23 (54.8) | 29 (46) | 0.38 c  |
| G                              | 53 (50.48) | 19 (45.2) | 34 (54) |         |
| Dislocation (%)                |       |     |     |         |
| Y                              | 31 (29.52) | 14 (33.33) | 17 (26.98) | 0.484 c |
| N                              | 74 (70.48) | 28 (66.67) | 46 (73.01) |         |
| Skin Blisters (%)              |       |     |     |         |
| Y                              | 15 (14.29)| 8 (19.05) | 7 (11.12) | 0.254 d |
| N                              | 90 (85.71) | 34 (80.95) | 56 (88.88) |         |
| Fracture Type: AO Classification (%) |         |     |     |         |
| 44-A1                          | 2 (1.9)| 2 (4.76) | 0 | 0.011 c |
| 44-A2                          | 0 | 0 | 0 |         |
| 44-A3                          | 0 | 0 | 0 |         |
| 44-B1                          | 17 (16.19)| 4 (7.46) | 15 (23.8) |         |
| 44-B2                          | 70 (66.67) | 33 (78.57) | 37 (58.73) |         |
| 44-B3                          | 15 (14.28)| 5 (11.9) | 10 (15.87) |         |
| 44-C1                          | 0 | 0 | 0 |         |
| 44-C2                          | 1 (0.95) | 0 | 1 (1.59) |         |
| 44-C3                          | 0 | 0 | 0 |         |
| Lag Screw (%)                  |       |     |     |         |
| Y                              | 58 (55.24)| 17 (40.48) | 41 (65.08) | 0.012 c |
| N                              | 47 (44.76)| 25 (59.52) | 22 (34.92) |         |
| Operation time (min)           |       |     |     |         |
| Total cohort                   | 61.92 +/- 19.45 | 60.23 +/- 16.99 | 63.04 +/- 20.99 | 0.452 e |
| Bone union at 6 weeks          | No Yes | 18 (42.86) | 14 (29.6) | 12 (19.51) | 0.525 e |
| Bone union at 12 weeks         | No Yes | 3 (4.76) | 4 (59.24) | 3 (3.17) | 1 f |

p = 0.044; 10.2 ± 5.43 vs. 16.5 ± 8.1; p = 0.007. Simple linear analyses of hardware removal are illustrated in Table 3. The influential variables were age, fracture sub-type 44-B and wound complications. A multiple linear regression concerning these variables has been performed as can be seen in Table 6. It has been demonstrated that HR rates decreases with age (OR = 0.94 [0.89; 0.97]; p = 0.004). Otherwise, it was observed that fracture sub-type 44-B causes 4 times as many hardware removals as sub-type 44-B2 and 8.5 times as many as sub-type 44-B1. These results were statistically significant (respectively: OR = 4.075 [1.021; 17.455]; p = 0.048 and OR = 8.568 [1.478; 59.817]; p = 0.021). In contrast, there was no difference between sub-types 44-A1 and 44-B2.

Table 2
Radiographic bone union at 6 and 12 weeks postoperatively.

| Characteristic                  | Total cohort | NLP | LP  | p-value |
|--------------------------------|--------------|-----|-----|---------|
| Bone union at 6 weeks          | No Yes       | 18 (42.86) | 14 (29.6) | 12 (19.51) | 0.525 e |
| Bone union at 12 weeks         | No Yes       | 3 (4.76) | 4 (59.24) | 3 (3.17) | 1 f |

No: Persistency of a visible fracture line on one or more radiographic views.
Yes: complete disappearance of the fracture line on both anterior posterior and lateral views.

a Pearson's Chi-squared test.
b Fisher's Exact Test.

Constructs costs
Table 9 shows the price of each plate and different type of screws. Since they have the same price, proximal bicortical screws were not taken into account. It has been noted that a locking construct is 235.5 euros more expensive than a standard non locking construct.

Discussion
When a closed and displaced distal fibula fractures occurs, it is essential to regain the length of the fibula and maintain the stability of the ankle joint. Surgical treatment is a standard practice

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Table 3
Simple linear analysis of bone union at 6 and 12 weeks, and of hardware removal rate.

| Variables                  | 6 weeks | 12 weeks | Hardware removal |
|----------------------------|---------|----------|------------------|
| Plate (NLP/LP)             | 0.525c  | 1.000c   | 0.183c           |
| Age                       | 0.264c  | 0.811b   | < 0.001b         |
| Gender                    | 0.916c  | 0.811c   | 0.622c           |
| BMI                       | 0.249c  | 0.763c   | 0.776c           |
| Smoking                   | 0.810c  | 1.000c   | 0.520c           |
| Alcohol                   | 0.200c  | 0.454c   | 0.603c           |
| Diabetes Mellitus         | 0.200c  | 0.200c   | 0.490c           |
| Peripheral arterial disease | 0.200c | 0.200c   | 0.490c           |
| Chronic renal failure     | 0.200c  | 0.200c   | 0.490c           |
| Corticosteroids           | 0.200c  | 0.200c   | 0.490c           |
| ASA Score                 | 0.242c  | 0.645c   | 0.093c           |
| Sub-type 44-B (B1, B2 et B3) | 0.045c | 0.442c   | 0.019c           |
| Skin Blisters             | 0.284c  | 0.053c   | 0.941c           |
| Lag screw                 | 0.623c  | 0.586c   | 0.223c           |
| Wound complications       | 0.200c  | 0.308c   | 0.038c           |

a Pearson’s Chi-squared test.  
 b Welch Two Sample t-test (Student).  
 c Fisher’s Exact Test.

Table 4
Multiple linear regression analysis at 6 weeks.

| Variables                  | OR [IC95%] | p-value |
|----------------------------|------------|---------|
| LP (ref = NLP)             | 0.899 [0.263; 2.939] | 0.86  |
| Age                       | 1.016 [0.981; 1.054] | 0.384 |
| Male Gender (ref = female) | 1.253 [0.357; 4.758] | 0.729 |
| AO 44-B2 (ref = 44-B1)     | 0.743 [0.097; 6.199] | 0.741 |
| AO 44-B3 (ref = 44-B1)     | 0.186 [0.022; 11.07] | 0.082 |
| AO 44-B1 (ref = 44-B2)     | 1.345 [0.262; 10.263] | 0.74  |
| AO 44-B3 (ref = 44-B2)     | 0.25 [0.060; 0.936] | 0.035 |

Table 5
Multiple linear regression analysis at 12 weeks.

| Variables                  | OR [IC95%] | p-value |
|----------------------------|------------|---------|
| LP (ref = NLP)             | 0.538 [0.021; 7.041] | 0.644 |
| Age                       | 1.012 [0.927; 1.108] | 0.788 |
| Male Gender (ref = female) | 1.736 [0.091; 60.099] | 0.72  |
| Skin Blisters (ref = NO)   | 0.066 [0.003; 0.762] | 0.034 |

Table 6
General and wound complications.

| Wound complications (%) | LP (%) | p-value |
|-------------------------|--------|---------|
| Major complications     | 12 (12.14%) | 0.644 |
| Minor complications     | 6 (6.47%) | 0.788 |
| Skin Blisters (ref = NO) | 17 (17.14%) | 0.72  |
| Total cohort            | 30 (30.57) | 0.034 |
| Major complications     | 5 (5.11%) | 0.788 |
| Minor complications     | 4 (4.04%) | 0.788 |
| Skin Blisters (ref = NO) | 10 (10.10%) | 0.72  |
| Total All complications  | 15 (15.15%) | 0.034 |

in the young and active population which demands a quick return to their activities. In elderly patients (over 60) with unstable ankle fractures, a recent randomized clinical trial with blinded outcome assessors have showed that the use of close contact casting compared with surgery resulted in similar functional outcomes [28]. A substantial increase in the use of countered locking plates occurred in treating distal fibula fractures at our institution, whatever the age. The aim of our study was to verify the need to support such a shift in our practices. The primary outcome of our study was to assess radiographic bone union rates in distal fibula fractures of a NLP (VIVESTM, Stryker®, Mahwah, NJ, USA) vs. a LP (VariAx™ Stryker®, Mahwah, NJ, USA) at 6 and 12 weeks of follow up. It has been shown that the initial assumption is confirmed since there were no difference in bone union rate either at 6 or 12 weeks postoperatively between NLP and LP groups.

Herrera-Pérez & al. have retrospectively compared locking versus non-locking one-third tubular plates for treating osteoporotic distal fibula fractures. No statistically significant difference in time to radiographic bony union was reported between the two groups (average time of 15.27 weeks [11–16] in LP group vs. 12.58 weeks [9–13] in NLP group – p = 0.15) [22].

Likewise, while retrospectively reviewing a consecutive cohort of 145 patients, Lyle & al. have not detected significant differences in the radiographic time to bony union among three plate groups including one locked plate [23]. In another accessor blinded randomized controlled trial conducted on fifty-two patients to
Table 7

| Hardware removal rate. | Total cohort | NLP | LP | p-value |
|------------------------|-------------|-----|----|---------|
| General HRR (%)        | 38 (36.19)  | 13 (30.95) | 25 (39.68) | 0.361 |
| Time (Month)           | 14.4 ± 7.8 [2; 38] | 10.2 ± 5.43 [2; 18] | 16.5 ± 8.1 [2; 38] | 0.007 |
| HRR Without Infection | 33 (31.42)  | 9 (21.42)  | 24 (38.09) | 0.071 |
| Time (Month)           | 16 ± 6.8 [8; 38] | 13.5 ± 2.5 [10; 18] | 17.2 ± 7.7 [8; 38] | 0.044 |

HRR: Hardware removal rate.
* Means ± standard deviation and range.
† Pearson's Chi-squared test.
‡ Welch Two Sample t-test (Student).

Table 8

| Variables                  | OR [95%CI] | p-value |
|----------------------------|------------|---------|
| LP (ref = NLP)             | 2238 [0.72; 7538] | 0.173 |
| Age                       | 0.94 (0.899; 0.978) | 0.004 |
| Gender Male (ref = Female) | 0.778 [0.23; 2.51] | 0.677 |
| AO 44-B2 (ref = AO 44-B1) | 2009 [0.508; 9076] | 0.337 |
| AO 44-B3 (ref = AO 44-B1) | 8568 [1478; 59187] | 0.021 |
| AO 44-B1 (ref = AO 44-B2) | 0.642 [0.104; 1784] | 0.28 |
| AO 44-B3 (ref = AO 44-B2) | 4075 [1021; 17455] | 0.048 |
| Wound Complications (ref = NO) | 4784 [0.741; 40789] | 0.11 |

Table 9

| Cost evaluation. | NLP | LP | Difference |
|------------------|-----|----|------------|
| Plate cost (whatever the length) | 148.5 € | 168 € | 19.5 € |
| Proximal screw cost (CORTICAL) | 6 € | 6 € | 0 € |
| Distal screw cost (CANCELLOUS vs. LOCKING) | 6 € | 60 € | 54 € |
| Price of 4 distal screws within the periarticular part of the plate | 24 € | 240 € | 216 € |
| Construct cost without Proximal screws | 172.5 € | 408 € | 235.5 € |

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have concluded to the augmentation of wound complication rates along with the thickness of the used plate [27]. The same conclusion was suggested in Moss’s study, where they used LP had 1.7 and 2.8 mm thick, compared to one-third tubular 1 mm thick NLP [37]. However, Moriarty & al. have recently demonstrated that the use of locking plates for the treatment of distal fibular fractures is not associated with an increased wound complication rate. They have used low profile periarticular LP 1.3 mm thick distally, compared to one-third tubular and reconstruction NLP, respectively 1 and 3.5 mm thick [36].

Moss & al. have found a HR rate statistically higher in the thicker LP group [37]. Schepers & al. [27] reported a HR rate of 27.3% without any difference between NLP and thicker LP groups. Contrarily to the findings of our study, the latter also found that plate removal was performed 2 months earlier in the thicker LP group, without this result being statistically significant. Petrucelli & al. [34] haven’t found any difference in HR rates between Locking and non-Locking constructs. Naumann & al. retrospectively reviewed a cohort of 997 patients in the purpose of determining the risk factors for hardware removal of an internal fixation following ankle fracture surgery (lateral plate and medial / anterior-posterior screws in case of a bi malleolar or tri malleolar fracture). They have revealed that male sex, age and treatment with a syndesmosis screw were associated with a lower hazard for the removal of hardware due to complaints [38]. Inversely, an increase in the duration of the initial operation was associated with a higher hazard of experiencing hardware removal. Our study has likewise demonstrated that HR rates decreases with age. We have also observed an increase in HR rates in sub-type 44-B3 or trans-syndesmotic tri malleolar fractures. This may be related to functional limitations, discomfort and pain linked to additional implants, particularly screws fixing medial and posterior malleoli. These results should be considered as assumptions for we need further controlled trials to ensure the reliability of such findings, especially since there was no difference between sub-types 44-B1 and 44-B2 in our statistical analyses.

It is clear that a low profile construct, whether it’s Locking or non-Locking, induce a lower incidence of metal prominence, hence less wound complications and HR rates. In this study, the LP is a low profile pre-countered periarticular plate with a distal thickness of 1.3 mm, which is considerably thinner than other LP used in the mentioned studies, and slightly thinner than the periarticular NLP with a distal thickness of 1.8 mm. This could explain the similar outcomes in both wound complications and HR rates between locking and non-locking constructs in our study.

Financially wise, a typical countered locking plate construct costs $800 more than a comparable one-third tubular plate construct in the USA. Based on a calculated estimate of 60,000 locking plates used annually, Moss & al. have found that a total of $50 million can be avoided annually [37]. Our study has equally found a staggering higher price for the locking construct which is 235.5 euros more expensive than a standard non locking construct. We can easily save millions of euros on a French national scale by using non-locking constructs for non-committed distal fibula fractures with normal BMD.

Finally, the present retrospective study has limitations. The patients were not randomized for treatment with the two types of fixations. However the choice of the period of the study is linked to the fact that we have always used NLP for distal fibula fractures, until the end of 2012 when our department started using the LP. This was in the purpose of decreasing selection bias! The overall number of patients was relatively small. No significant differences were found between groups in all variables except for the AO fracture type. Sub-types A and C couldn’t be integrated in a multiple linear regression analysis because of their small numbers. Sub-type B had to be analyzed alone, which generated a selection bias. The use of lag screws in conjunction with the plate was not comparable between groups, which constituted a confounding factor. Further studies with improved design to account for these different biases are needed.

Conclusion

Locking plates are increasingly used for fractures of distal fibula and are associated with significantly increased costs. Bone union rates appear to be similar in both locking and non-locking constructs of the distal fibula, especially in case of associated mobilization. Locking plates are an interesting option in comminuted and/or osteoporotic fractures. The thickness of the plate appears to be correlated to the onset of wound complications. Measures to increase surgeons’ awareness about cost-reduction programs are needed. High-quality randomized controlled trials are needed in the future to verify the finding of this study.

Declaration of Competing Interest

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References

[1] Donken CCMA, Al-Khatreeb H, Verhofstad MHH, van Laarhoven CJHM. Surgical versus conservative interventions for treating ankle fractures in adults. Cochrane Database Syst Rev. 2012;A08 (1):CD008470.
[2] Crevoisier X, Balsalik R, Dos Santos T, Assal M. Ankle fractures in the elderly patient. Rev Med Suisse. 2014;10(Déc (455)):2420–3.
[3] Bariteau JT, Hsu RY, Moy V, Lee, Y, Digiovanni CW, Hayda R. Operative versus nonoperative treatment of geriatric ankle fractures: a medicare part a claims database analysis. Foot and Ankle Int 2015;36(6):648–55.
[4] Willert K, Keene SJ, Murley D, Nah M, Turton E, Humby R, et al. Close contact casting vs surgery for initial treatment of unstable ankle fractures in older adults: a randomized clinical trial. JAMA. 2016;316(Oct (14)):1455–63.
[5] Court-Brown CM, McBirnie J, Wilson G. Adult ankle fractures—an increasing problem? Acta Orthop Scand 1998;69(Février):43–7.
[6] Ali MS, McLaren CA, Rohulomain E, O’Connor BT. Ankle fractures in the elderly: nonoperative or operative treatment. J Orthop Trauma 1987;1(4):275–80.
[7] McKenna P, O’Shea K, Burke T. Less is more: lag screw only fixation of lateral malleolar fractures. Int Orthop 2007;31(Août (4)):497–502.
[8] Perren SM. Evolution of the internal fixation of long bone fractures. The scientific basis of biological internal fixation: choosing a new balance between stability and biology. J Bone Joint Surg Br 2002;84(Nov (8)):1093–110.
[9] Wagner M. General principles for the clinical use of the LC-IP. Injury 2003;34(Nov Suppl 2):B31–42.
[10] Haidukewych GJ, Ricci W. Locked plating in orthopaedic trauma: a clinical update. J Am Acad Orthop Surg 2008;16(Juin (6)):347–55.
[11] Anglen J, Kyle R, Marsh J, Viskus W, Watts W, Keith M, et al. Locking plates for extremity fractures. J Am Acad Orthop Surg 2009;17(Juil (7)):465–72.
[12] Miranda MA. Locking plate technology and its role in osteoporotic fractures. Injury 2007;38(Sept Suppl 3):S35–9.
[13] Justier JR. Topical review: locking plate technology in foot and ankle surgery. Foot Ankle Int 2014;35(Mai (5)):512–18.
[14] Kim T, Ayturk UM, Hasueil A, Micalu T, Puttlitz CM. Fixation of osteoporotic distal fibula fractures: a biomechanical comparison of locking versus conventional plates. J Foot Ankle Surg 2007;46(1):1–2.
[15] White NJ, Corr DT, Wagg JP, Loranic C, Buckley RE. Locked plate fixation of the comminuted distal fibula: a biomechanical study. Can J Surg 2013;56(Février (1)):35–40.
[16] Davis AT, Israel H, Cannada LK, Bledssoe JG. A biomechanical comparison of one-third tubular plates versus periarticular plates for fixation of osteoporotic distal fibula fractures. J Orthopaedic Trauma 2013;27(Sept (9)):e201–7.
[17] Bariteau JT, Fantry A, Blankenheim B, Lareau C, Paller D, Digiovanni CW. A biomechanical evaluation of locked plating for distal fibula fractures in an osteoporotic sawbone model. Foot Ankle Surg 2014;20(Mars (1)):44–7.
[18] Zahn RK, Frey S, Jakubietz RG, Jakubietz MG, Doht S, Schneider P, et al. A comparison of locking plate for distal fibular fractures in osteoporotic bone: a biomechanical cadaver study. Injury 2012;43(Juin (6)):718–25.
[19] Swital PJ, Wetzel RJ, Jain NP, Weatherford BM, Ren Y, Zhang L-Q, et al. Comparison of modern locked plating and antiglide plating for fixation of osteoporotic distal fibula fractures. Foot Ankle Surg 2016;22(Sept (3)):158–63.
[20] Nguyenat A, Camisa W, Patel S, Lagaay P. A biomechanical comparison of locking versus conventional plate fixation for distal fibula fractures in trimalleolar ankle injuries. J Foot Ankle Surg 2016;55(Février (1)):122–5.
[21] Huang Z, Liu L, Tu C, Zhang H, Fang Y, Yang T, et al. Comparison of three plate system for lateral malleolar fixation. BMC Musculoskelet Disord. 2014;15(Oct):360.

[22] Herrera-Pérez M, Gutiérrez-Morales MJ, Guerra-Ferraz A, Pais-Brito JL, Bu- 
du-Menged J, García GL. Locking versus non-locking one-third tubular plates for treating osteoporotic distal fibula fractures: a comparative study. Injury 2017;48(Nov (Suppl 6)):360–5.

[23] Lyle SA, Malik C, Oddly MJ. Comparison of locking versus nonlocking plates for distal fibula fractures. J Foot Ankle Surg 2018;57(Août (4)):664–7.

[24] Tsukada S, Otsuji M, Shiozaki A, Yamamoto A, Komatsu S, Yoshimura H, et al. Locking versus non-locking neutralization plates for treatment of lateral malleolar fractures: a randomized controlled trial. Int Orthop 2013;37(Déc (12)):2451–6.

[25] Laigneau J-F. Sécurité des patients et développement des recherches : de la loi Bertrand à la loi Jardé. Méd Drut 2012;2012(Nov (117)):163–9.

[26] Meling T, Harboe K, Enoksen CH, Aarflot M, Arthusson AJ, Søreide K. How reliable and accurate is the AO/OTA comprehensive classification for adult long-bone fractures? J Trauma Acute Care Surg 2012;73(Juill (1)):224–31.

[27] Schepers T, Van Lieshout EMM, De Vries MR, Van der Eist M. Increased rates of wound complications with locking plates in distal fibular fractures. Injury 2011;42(Oct (10)):1125–9.

[28] Wortzel RJ, Kempton LB, Lee ES, Zlowodzki M, McKinley TO, Virkus WW. Wide variation of surgical cost in the treatment of periarticular lower extremity injuries between 6 fellowship-trained trauma surgeons. J Orthop Trauma 2016;30(Déc (12)):e377–83.

[29] Hess F, Sommer C. Minimally invasive plate osteosynthesis of the distal fibula with the locking compression plate: first experience of 20 cases. J Orthop Trauma 2011;25(Fév (2)):110–15.

[30] Tornetta P, Creevy W. Lag screw only fixation of the lateral malleolus. J Orthop Trauma 2001;15(Fév (2)):119–21.

[31] Takemoto RC, Sugiyama M, Kummer F, Koval KJ, Ego K. The effects of locked and unlocked neutralization plates on load bearing of fractures fixed with a lag screw. J Orthop Trauma 2012;26(Sept (9)):519–22.

[32] Kennedy JG, Johnson SM, Collins AL, Dallovedova P, Manos WF, Hynes DM, et al. An evaluation of the weber classification of ankle fractures. Injury 1998;29(Oct (8)):577–80.

[33] Bhadra AK, Roberts CS, Giannoudis PV. Nonunion of fibula: a systematic review. Int Orthop 2012;36(Sept (9)):1757–65.

[34] Petrucelli R, Biscaccia M, Rinonapoli G, Rolilo G, Mecciariello L, Falzarano G, et al. Tubular vs profile plate in peroneal or bimalleolar fractures: is there a real difference in skin complication? A retrospective study in three level I trauma center. Med Arch 2017;71(Août (4)):265–9.

[35] Lynde MJ, Sautter T, Hamilton GA, Schuberth JM. Complications after open re- 
duction and internal fixation of ankle fractures in the elderly. Foot Ankle Surg 2012;18(Juin (2)):103–7.

[36] Moriarity A, Ellanti P, Mohan K, Fhuglu CN, Fenelon C, McKenna J. A com- 
parison of complication rates between locking and non-locking plates in distal 
fractures. Orthopedic Traumatol Surg Res 2018;104(Juin (4)):501–6.

[37] Moss LD, Kim-Orden MH, Ravinsky R, Hoshino CM, Zinar DM, Gold SM. Implant failure rates and cost analysis of contoured locking versus conventional plate fixation of distal fibula fractures. Orthopedic 2017;40(Nov (6)):e1024–9.

[38] Naumann MG, Sigurdson U, Utvåg SE, Stavem K. Incidence and risk factors for re- 
moval of an internal fixation following surgery for ankle fracture: a retro-
spective cohort study of 997 patients. Injury 2016;47(Août (8)):1783–8.