Naviculocuneiform Arthrodesis *vs.* Cotton Osteotomy for Restoration of Medial Arch Height in Flexible Flatfoot

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Statement of Purpose

Flexible flatfoot often requires medial column correction. The Medial Arch Sag Angle (MASA) has been shown to be a useful radiographic tool to assess medial column correction when concomitant procedures are performed. The purpose of this study was to compare medial column correction between the naviculocuneiform (NC) arthrodesis and the Cotton osteotomy utilizing radiographic measurements at short-term follow up.

Methodology

We identified consecutive patients of 5 surgeons in which a Cotton osteotomy or NC arthrodesis was performed from June 2013 - August 2018, at a single institution. Our primary outcome was evaluation of the medial column correction quantified by the change in MASA when comparing pre- and post-operative weightbearing lateral radiographs. Secondary outcomes included VAS pain, complications (infection, radiographic non-union, delayed union, and hardware removal). Included were all patients that underwent either NC arthrodesis or Cotton osteotomy, with available pre- and post-operative lateral weight-bearing radiographs. Patients that underwent talonavicular or first tarsometatarsal arthrodesis, which would have prevented accurate measurement of MASA, as well as those that underwent revisional surgery, were excluded. Demographics variables (Table 1) were compared between the Cotton and NC fusion groups. Adjunct therapy was defined as forefoot (FF) procedures only, rearfoot procedures (RF) only, triceps surae lengthening (TSL) only, RF procedures + TSL, FF procedures + TSL, and FF + RF procedures + TSL. Comorbidities were categorized as diabetes, seizures, cardiac history, renal disease, current smoker, and depression/anxiety. All radiographic measurements were performed by three senior foot and ankle surgeon residents. Statistical analyses included descriptive methods, tests of the null hypothesis, and logistic regression, as well as confounding and sensitivity analyses. Statistical significance was defined at the 5% level.

Results

A total of 25 feet in 22 patients were analyzed, with 17 (68%) in the Cotton group and 8 (32%) in the NC fusion group. Three (13.6%) patients underwent bilateral surgery (2 [9%] Cotton, 1 [4.5%] NC fusion), staggered at a median of 6 (6 to 12) months apart. The analyses revealed the only baseline statistically significant difference to be the absence of any comorbidities in 70.59% of the Cotton group ($p < 0.0001$) (Table1). In regard to outcomes (Table 2), only the change in MASA ($p = 0.0043$), the postoperative VAS pain ($p = 0.006$) and change in VAS pain ($p = 0.0345$), as well as the incidence of delayed union ($p = 0.007$), and hardware removal ($p = 0.001$), were statistically significant, with the Cotton group showing greater correction and fewer complications. Explanatory analyses using multiple variable logistic regression (univariate inclusion criteria, $p \leq 0.1$), with the outcome of interest being a change in MASA ≥ -5˚ (arch elevation), revealed the only statistically significant variable to be Cotton osteotomy (OR 0.03510 [95% CI 0.001341,0.919298]) (Table 3). Item analyses indicated confounding by adjunct therapy, which altered the influence of the treatment by as much as 37%, however this influence was not observed to be statistically significant. Greenland sensitivity analyses showed the treatment effect estimates to be resistant (<10% change) to the potential influence of an unmeasured hypothetical variable up to an odds ratio of 10 for the unmeasured confounder by the outcome.

Table 1 Demographic data*

Variable	Cotton (n = 17 feet)	NC Arthrodesis (n = 8 feet)	*p*-value
Age	15 (14, 22)	24 (18, 43.5)	0.0736
Female sex	13 (76.4%)	6 (75%)	0.936
Left side	9 (52.9%)	4 (50%)	0.891
Median BMI	26.36 (20.2, 29.2)	23.95 (21, 30.31)	0.304
Follow up (months)	8 (5.5, 13)	7.5 (5.25, 13)	0.505
No comorbidity	70.59%	0	< 0.0001
ASA status	I - 10 (58.8%) II - 5 (29.4%) III - 2 (11.7%)	I - 3 (37.5%) II - 5 (62.5%)	0.234
Pre Meary's (˚)	18 (11.1, 22.1)	13.5 (8.9, 21.1)	0.558
Pre CIA (˚)	12.9 (6.9, 18.9)	12.4 (10.75, 13.75)	0.478
Pre MASA (˚)	9.1 (7.31, 14.77)	6.7 (5.75, 11.1)	0.406
Pre VAS pain	7 (6, 8)	7 (6, 7)	0.156

*Median (25th,75th percentile), χ^2 or Wilcoxon rank sum

Table 2 Outcomes*

Variable	Cotton (n = 17 feet)	NC Arthrodesis (n = 8 feet)	*p*-value
Post Meary's (˚)	5.7 (2.5, 7.4)	3.75 (2.5, 13.45)	0.36
Δ Meary's (˚)	-12.2 (-14.7, -2.5)	-5.5 (-9.7, -1.9)	0.406
Post CIA (˚)	18.3 (12.2, 25.1)	14.8 (12.3, 17.05)	0.478
Δ CIA (˚)	6.4 (2.36, 8.6)	3.7 (1.55, 5.3)	0.3079
Post MASA (˚)	4 (0.4, 8)	5.4 (4.6, 9.15)	0.4663
Δ MASA (˚)	-6.34 (-11.3, -3.2)	-1.95 (-3.6, -1.85)	0.0043
Post VAS pain	0 (0, 0)	1 (0, 1)	0.006
Δ VAS pain	-7 (-8, -6)	-6 (-7, -5)	0.0345
Non-union†^	0	1 (12.5%)	0.137
Delayed union^	0	3 (37.5%)	0.007
Hardware removal	0	4 (50%)	0.001

*Median (25th,75th percentile), Wilcoxon rank sum test
†Revisional surgery undertaken, not associated with hardware removal cases
^No radiographic healing at 3 mos. = delayed union, at 6 mos. = non-union

Table 3 Multiple variable logistic regression (N = 25 feet in 22 patients)*

Exposure	Odds ratio (95% confidence interval)
Pre-operative Meary's angle (˚)	1.3826 (0.9613, 1.98864)
Treatment (Cotton or NC fusion)	0.03510 (0.001341, 0.919298)

*Outcome of interest = change in MASA ≥ 5º elevation

Figure 1 Pre-operative MASA ([+] angle indicates greater medial column sag)

Figure 2 Post-operative MASA (Cotton osteotomy)

Literature Review

The Adult-acquired flatfoot deformity (AAFD) is a complex and progressive deformity that encompasses varying degrees of compensation and symptoms. Addressing the flexible flatfoot in its totality often requires multiple soft tissue and osseous procedures to address the varying degrees of hindfoot, forefoot, and medial longitudinal arch deformity. Such procedures that address medial column instability include the naviculocuneiform (NC) arthrodesis and the Cotton osteotomy.[1,2] A paucity of literature exists when these two procedures are compared on their degree of midfoot correction. Moreover, it is difficult to ascertain the degree of medial column correction radiographically when multiple procedures are performed. Prior studies have evaluated the effect of medial column arch restoration for both procedures by evaluating Meary's talo-first metatarsal angle, however, these studies are unable to account for the effect of other concomitant procedures on medial arch restoration.[3-11] The medial arch sag angle (MASA) as defined by Aiyer et al,[4] has been shown to be a reliable measure in AAFD, and can be particularly helpful in determining medial arch height restoration as a result of a medial column procedure when other concomitant procedures are performed. It has been suggested to provide quantification of the restored medial column height that may not be detected on Meary's angle and allow for a more complete characterization of the deformity.

Discussion

The MASA is a useful radiographic tool for assessing medial column deformity, but this has only been described for the Cotton osteotomy. In our study, we compared the effectiveness of the NC arthrodesis to the Cotton osteotomy in restoration of the midfoot sag using multiple radiographic outcomes. The change in MASA was similar to the change in MASA found by Aiyer et al, which correlated MASA to a restoration of medial arch height. Interestingly, the addition of adjunct procedures in our study did not affect the change in MASA or change in VAS as it did in the study by Aiyer et al.[4] We noted 100% union in our Cotton osteotomy group. The NC fusion group had an 87.5% union rate, which was similar to Ajis et al who reported a 97% union rate.[3] Conti et al reported improved patient outcomes with restoration of the medial column arch height.[1] We found that the Cotton osteotomy had a greater change in MASA and reduced VAS scores in comparison to NC arthrodesis. To our knowledge this is the first study to assess the effect of NC arthrodesis on MASA. We concluded that the Cotton osteotomy is superior to NC arthrodesis in restoring medial arch height, and patients undergoing Cotton osteotomy experienced greater pain reduction post-operatively. Patients undergoing NC arthrodesis exhibited more post-operative complications, including hardware removal. In our practice, we do not routinely fixate Cotton osteotomies, which may explain this finding. Additionally, our results show that MASA can be used in not only evaluating the Cotton osteotomy, but also in NC arthrodesis. It is possible that our sample size was too small to thoroughly understand the influence of confounding variables such as baseline comorbidities on our results.

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