Biomechanical Evaluation of 4th Generation Minimally Invasive Distal First Metatarsal Osteotomy Akin Osteotomy Technique on First Ray Articular Contact Properties

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INTRODUCTION: Hallux valgus is a common deformity encountered, but remains a complex clinical entity. Fourth generation minimally invasive (MIS) techniques consisting of a percutaneous distal metatarsal transverse osteotomy combined with an Akin osteotomy have been utilized to address mild to severe hallux valgus deformities. Benefits of a MIS approach include improved cosmesis, faster recovery, lower opiate requirement, immediate weight-bearing, and favorable outcomes relative to a traditional, open procedure. An understudied area with respect to hallux valgus correction is the effect that osteotomies can have on the articular contact properties of the first ray following correction.

METHODS:

Sixteen paired cadaveric specimens were dissected to include the first ray and tested in a customized apparatus. Specimens were randomized to receive a distal transverse osteotomy translated either 50% or 100% of the width of the first metatarsal shaft. The osteotomy was performed with either a 0^0 or 20^0 distal angulation of the burr relative to the shaft in the axial plane. Specimens were tested in the intact state and following the distal first metatarsal osteotomy for peak pressure, contact area, contact force, and center of pressure at the first metatarsophalangeal joint (MTP) and first tarsometatarsal joint (TMT). An Akin osteotomy was then performed on each specimen and peak pressure, contact area, contact force, and center of pressure were recalculated.

RESULTS:

There was a notable decrease in peak pressure, contact area, and contact force across the TMT joint with greater shifts of the capital fragment. However, at 100% translation of the capital fragment, distal angulation of the osteotomy by 20^0 appears to improve loading across the TMT joint. Addition of the Akin osteotomy at 100% translation also aids in increasing the contact force across the TMT joint. The MTP joint is less sensitive to changes in shifts and angulation of the capital fragment. The Akin osteotomy also leads to increased contact force across the MTP joint when the capital fragment is translated 100%.

DISCUSSION AND CONCLUSION:

While the clinical significance is unknown, larger shifts of the capital fragment lead to greater load alterations at the level of the TMT joint than the MTP joint. Distal angulation of the capital fragment and the addition of an Akin osteotomy can aid in reducing the size of those changes. The Akin can lead to increased contact forces at the MTP joint with 100% translation of the capital fragment.

Tables

Table 1: Intact Specimen Data

Group	Peak pressure (MPa)		Contact area (mm²)		Center of pressure (mm)				Contact Force (N)	
	MTP	TMT	MTP	TMT	MTP		TMT		MTP	TMT
Group 1 Intact (In1)	2.7(1.1)	3.0(1.2)	67.4(37.8)	88.3(26.1)	6.1(3.8)	6.9(1.8)	5.4(2.2)	5.8(2.1)	76.4(50.9)	83.6(19.5)
Group 2 Intact (In2)	3.8(1.9)	4.5(2.9)	69.6(21.2)	80.5(14.7)	8.4(2.9)	6.8(2.1)	7.1(3.2)	6.8(2.5)	92.1(41.5)	127.0(74.6)
Group 3 Intact (In3)	3.6(0.9)	2.2(1.8)	55.6(19.8)	58.8(30.7)	8.3(4.1)	7.0(1.9)	7.5(3.2)	8.0(3.6)	79.1(36.9)	61.7(56.8)
Group 4 Intact (In4)	3.6(2.0)	2.8(1.8)	52.3(23.5)	68.5(41.7)	8.1(3.7)	8.3(2.5)	8.4(3.1)	6.4(2.6)	72.8(51.4)	70.7(45.2)

SD included in parentheses

Table 2: Data following Capital Fragment Osteotomy

Group	Peak pressure (MPa)		Contact area (mm2)		Center of pressure (mm)				Contact force (N)	
	MTP	TMT	MTP	TMT	MTP		TMT		MTP	TMT
Group 1 (50%,0^0)	3.2(1.2) [p1=0.25]	3.0(1.9) [p1=0.98]	73.5(28.5) [p1=0.61]	60.6(21.9)# [p1=0.003]	5.6(2.6) [p1=0.13]	9.4(2.0) [p1=0.02]	6.1(3.0) [p1=0.26]	7.4(2.4) [p1=0.07]	80.9(27.2) [p1=0.73]	65.9(31.9)# [p1=0.03#]
Group 2 (50%,20^0)	2.4(1.3)# [p1=0.05#, p2=0.24]	2.3(1.1)# [p1=0.03#, p2=0.36]	63.3(25.6) [p1=0.44, p2=0.46]	56.6(26.3)# [p1=0.05, p2=0.75]	7.4(3.7) [p1=0.43, p2=0.30]	7.6(1.8) [p1=0.37, P2=0.09@]	8.4(2.8) [p1=0.67, p2=0.14]	8.4(2.9) [p1=0.30, p2=0.47]	69.7(32.3)# [p1=0.02#, p2=0.46]	57.3(47.8)# [p1=0.01#, P2=0.68]
Group 3 (100%,0^0)	4.5(3.3) [p1=0.51, p2=0.30]	1.4(0.7)@ [p1=0.22, p2=0.05@]	51.6(20.4) [p1=0.74, p2=0.10]	33.3(27.4)#,@ [p1=0.008#, p2=0.04@)	6.8(3.7) [p1=0.68, p2=0.50]	8.3(2.9) [p1=0.22, p2=39]	7.8(4.7) [p1=0.44, p2=0.42]	8.5(3.3) [p1=0.78, p2=0.45]	76.9(37.5) [p1=0.91, p2=0.81]	23.4(19.6)#,@ [p1=0.06#, p2=0.01@]
Group 4 (100%,20^0)	2.5(2.0) [p1=0.60, p2=0.88, p3=0.19]	3.1(2.2) [p1=0.56, p2=0.36, p3=0.11]	41.9(23.7) [p1=0.44, p2=0.11, p3=0.40]	58.5(23.1)* [p1=0.41, P2=0.88, P3=0.07*]	6.5(4.2) [p1=0.19, p2=0.66, p3=0.90]	7.6(2.9) [p1=0.68, p2=0.99, p3=0.67]	5.8(2.7)@ [p1=0.51, P2=0.08@, p3=0.32]	7.6(2.7) [p1=0.20, p2=0.61, p3=0.85]	57.6(51.2) [p1=0.54, p2=0.58, p3=0.40]	68.3(40.9)* [p1=0.79, p2=0.62, p3=0.01*]

Standard deviation included in parentheses; P values included in brackets

p1: Denotes p value relative to the intact state for each respective group

p2: Denotes p value as indicated below:

- For Group 2: p2 denotes p value relative to Group 1 (50% translation, 0^0 angulation)
- For Group 3: p2 denotes p value relative to Group 1 (50% translation, 0^0 angulation)
- For Group 4: p2 denotes p value relative to Group 2 (50% translation, 20^0 deg angulation)

p3: Denotes p value as indicated below

- For Group 4: p3 denotes p value relative to Group 3 (100% translation, 0^0 deg angulation)

# Denotes statistical significance/trend for p1

@ Denotes statistical significance/trend for p2

* Denotes statistical significance/trend for p3

Table 3: Data following Capital Fragment and Akin Osteotomy

Group	Peak pressure (MPa)		Contact area (mm2)		Center of pressure (mm)				Contact Force (N)	
	MTP	TMT	MTP	TMT	MTP		TMT		MTP	TMT
Group 1 (50%,0^0+ Akin)	3.3(0.7) [p1=0.63]	2.8(1.1) [p1=0.76]	63.3(21.2) [p1=0.31]	69.3(31.7) [p1=0.34]	4.8(2.7) [p1=0.52]	6.6(2.5) [p1=0.03]	5.8(2.4) [p1=0.41]	7.1(2.8) [p1=0.81]	77.9(19.9) [p1=0.73]	76.4(40.0) [p1=0.38]
Group 2 (50%,20^0+ Akin)	2.6(1.4) [p1=0.77, p2=0.19]	3.5(2.4)# [p1=0.07#, p2=0.48]	61.4(22.1) [p1=0.82, p2=0.86]	65.5(31.2) [p1=0.60, p2=0.81]	8.5(3.6)@ [p1=0.88, p2=0.03@]	6.1(2.2) [p1=0.15, p2=0.68]	8.6(1.6)@ [p1=0.52, p2=0.01@]	10.4(2.2)@ [p1=0.19, p2=0.02@]	58.8(47.2) [p1=0.43, p2=0.31]	76.1(45.7) [p1=0.25, p2=0.99]
Group 3 (100%,0^0+ Akin)	4.9(2.5) [p1=0.57, p2=0.10]	2.0(1.4) [p1=0.29, p2=0.24]	77.6(28.8)# [p1=0.03#, p2=0.27]	40.9(33.1) [p1=0.49, p2=0.10]	7.0(3.4) [p1=0.73, p2=0.16]	7.1(2.1) [p1=0.25, p2=0.67]	5.5(4.3) [p1=0.91, p2=0.88]	9.4(3.2) [p1=0.32, p2=0.15]	127.5(26.2)#,@ [p1=0.005#, p2=0.001@]	35.7(33.5)@ [p1=0.26, P2=0.04@]
Group 4 (100%,20^0+ Akin)	4.5(2.2)# [p1=0.06# p2=0.05, p3=0.76]	3.5(2.5) [p1=0.52, p2=0.98, p3=0.17]	68.9(32.3)# [p1=0.03#, p2=0.59, p3=0.57]	57.4(30.0) [p1=0.89, p2=0.59, p3=0.30]	6.4(4.6) [p1=0.54, p2=0.32, p3=0.76]	7.3(1.7) [p1=0.70, p2=0.26, p3=89]	6.0(3.1)@ [p1=0.59, p2=0.05@, p3=0.79]	7.5(2.4)@ [p1=0.88, p2=0.02@, p3=0.20]	104.6(63.5)# [p1=0.01#, p2=0.12, p3=0.36]	82.2(58.0)* [p1=0.16, p2=0.82, p3=0.07*]

Standard deviation included in parentheses; P values included in brackets

p1: Denotes p value relative to the non-Akin state for each respective group (ie 50%,0^0+ Akin vs 50%,0^0 no Akin)

p2: Denotes p value as indicated below:

- For Group 2: p2 denotes p value relative to Group 1 (50% translation, 0^0 angulation, + Akin)
- For Group 3: p2 denotes p value relative to Group 1 (50% translation, 0^0 angulation, + Akin)
- For Group 4: p2 denotes p value relative to Group 2 (50% translation, 20^0 deg angulation, + Akin)

p3: Denotes p value as indicated below

- For Group 4: p3 denotes p value relative to Group 3 (100% translation, 0^0 deg angulation, + Akin)

# Denotes statistical significance/trend for p1

@ Denotes statistical significance/trend for p2

* Denotes statistical significance/trend for p3