The Relationship of First Metatarsal Frontal Plane Position and First Metatarsophalangeal Joint Range of Motion with Simulated First Tarsometatarsal Joint Arthrodesis: A Biomechanical Investigation

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STATEMENT OF PURPOSE

Frontal plane rotation of the first metatarsal has been described in human deformities; however, the consequences of uncorrected frontal plane deformity have yet to be fully understood. The purpose of this study is to determine if a significant relationship exists between first metatarsal frontal plane position and first metatarsophalangeal joint (MTPJ) range of motion (ROM) with first TMTJ arthrodesis.

LITERATURE REVIEW

Hallux valgus is one of the most common deformities of the foot and is present in almost 20% of adults (1). While often perceived as a bony deformity resulting from the transverse and sagittal planes, there is growing understanding of the biomechanical deformity, TMTJ increased ROM, and hypermobility. Hypermobility of the TMTJ has a statistically significant relationship (p=0.05) between frontal plane rotation and first MTPJ ROM in a simulated first TMTJ arthrodesis model with increased valgus position resulting in decreased first MTPJ ROM.

METHODOLOGY & HYPOTHESIS

An experimental biomechanical study was performed on 9 fresh-frozen adult human lower below cadaveric limbs. Age, sex, laterality, baseline deformity, and first MTPJ end dorsiflexory ROM with variable frontal plane valgus rotation on a simulated first TMTJ fusion model were evaluated. We hypothesize that with increased valgus rotation in a simulated first TMTJ fusion there will be a resultant decrease in first MTPJ ROM.

PROCEDURES

Baseline deformity of each limb was determined by clinical and fluoroscopic examination. Limbs were excluded if first MTPJ pathology was identified. After dissection of the first TMTJ, simulated first TMTJ arthrodesis was attempted by fixation of the first metatarsal base to the custom experimental loading construct thereby eliminating proximal influence (Figure 1). No dissection of the 1st MT was performed to preserve anatomic relationships and diminish distal soft tissue influence. Utilizing a 6N- applied force at a 90° perpendicularly attachment, resultant first MTPJ and dorsiflexory ROM values were recorded using the Bionix Testing Frame. Baseline examination was performed on the motion of the first metatarsal. Repeat trials at 10 degree increments of valgus frontal plane positions were conducted and the means taken (Figure 2). Data were collected and analyzed by 1-way ANOVA with Geisser-Greenhouse correction to determine if a statistically significant effect of frontal plane rotation on first MTPJ ROM exists (p≤0.05).

RESULTS

There were 5 females, 4 males; 7 left, 2 right. Mean age of limb at death was 66 years. There was no baseline deformity identified that precluded the inclusion of the limbs in the study as determined by the first transverse plane (TMTJ) arthrodesis. In vivo and in vitro investigations (2-7). The pathology of the hallux valgus frontal plane deformity has recently received increased attention with emphasis on addressing the frontal plane in surgical correction procedures (8-11).

The first TMTJ arthrodesis is indicated for moderate to severe HAV deformity with first ray hypomobility. In the absence of deformity, the TMTJ arthrodesis allows for correction at the center of rotation of angulation of the deformity. This apex of deformity allows for deformity correction within all three planes without creating secondary deformity (13). With correction of the frontal plane, radiographic evidence of improved anatomic alignment and sesamoid position has decreased the need for procedures at the MTPJ level (8-11).

Diminished motion of the first MTPJ has been found after HAV correction and has been linked to decreased patient satisfaction (14-17). Some have attributed the decreased postoperative ROM in distal soft tissue procedures such as a lateral release (18-20). While lateral release may in part be a cause for decreased ROM, we question whether retained frontal plane deformity with first TMTJ arthrodesis may be a contributing etiology for decreased ROM at the first MTPJ.

Little has been studied regarding the effects of first TMTJ arthrodesis on the first MTPJ. Meyerson and colleagues found the RMTJ ROM to average 85% of normal following first TMTJ arthrodesis, conversely Hene and colleagues found the TMTJ arthrodesis to actually result in a decreased resistance to dorsiflexion of 25% postoperatively, without negative effects to the first MTPJ (21, 22). Certainly, further works are needed.

DISCUSSION

This cadaveric investigation demonstrated a statistically significant relationship between increased frontal plane rotation and decreased first MTPJ ROM with TMTJ arthrodesis. As such, these findings assist in the overall understanding of frontal plane correction and display potential to eliminate all correction procedures. Further in vivo investigation with patient outcomes would be warranted for a better depiction of the consequences of uncorrected frontal plane deformity with first TMTJ arthrodesis.

It is our hope that this anatomic biomechanical investigation will stimulate further works on this topic due to the statistically significant relationship between first metatarsal frontal plane position and first MTPJ ROM with simulated first TMTJ arthrodesis demonstrated in our study.

REFERENCES

3. Milnes HL, Kilmartin TE, Dunlop G. A pilot study to explore if the age that women undergo hallux valgus surgery influences t