Pathogenesis of the hallux valgus: enthesis degeneration of the medial metatarsosesamoid ligament

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INTRODUCTION: We reported detailed histological structures and degenerative findings of the metatarsosesamoid ligament (MSL) which connects the metatarsal head and the sesamoid complex at last year ORS annual meeting.
It is generally accepted that failure of the medial supporting soft tissue structure of the metatarsophalangeal joint plays an important role in the development of hallux valgus. The MSL, a component of the medial soft tissue, is an important structure that connects the metatarsal head and the sesamoid complex. The sesamoid complex works as a dynamic stabilizer of the metatarsal head. We hypothesized that the failure of the medial MSL causes instability of the first metatarsal bone, which leads to hallux valgus deformities. Therefore, the present study aimed to evaluate the association between severity of the MSL enthesis degeneration and severity of valgus deformity of the hallux.

METHODS: The first metatarsal heads and sesamoid bones with soft tissue were collected from thirteen cadavers donated to University of the Ryukyus (age at death 67–96 years; male 8, female 5). Serial 4-μm thick sections, perpendicular to the articular surface of the sesamoid bones were made at 500-μm intervals and stained with toluidine blue (Fig. 1).
We evaluated degree of degeneration of MSL enthesis at metatarsal head using modified Sano score (1,2) in all specimens. Modified Sano scores include Following items: the thinning of tendon fibers, the presence of granulation tissue, incomplete tears. Grading scale consist of 4 scores: 0 = no change, 1 = slight localized change < 25% of the tendon area, 2 = multifocal change 25–50% of the tendon area, 3 = diffuse or global change> 50% of tendon area. Sections with the most severe degeneration at medial MSL enthesis were selected for scoring; theses scores were used for analysis as scores of each specimen. We also evaluated degree of hallux valgus deformity using photographic hallux valgus angle (3). Measurement was performed three times; an average was used as photographic hallux valgus angle of each specimen. We adjusted photographic hallux valgus angle by adding 5.3° to estimate the radiographic hallux valgus angle as author recommended. Then we evaluated the relationship between the degree of degeneration of the metatarsosesamoid ligament enthesis and the photographic hallux valgus angle. **[Statistical analysis]** The correlation between the modified Sano scores and photographic hallux valgus angle was evaluated by using the Spearman's rank correlation coefficient. All analyses were performed using IBM SPSS Statistics version 29 (SPSS Inc., Chicago, IL, USA), referring to the results of the Shapiro-Wilk test. Statistical significance was set at $P < 0.05$. **[Ethics and institutional review of board]** The present study was approved by the Institutional Review Board of our institution (IRB No. 1703). Consent was obtained using an opt-out option on the website of our institution (those who rejected were excluded).

RESULTS SECTION: Scores of each item of the Sano score and adjusted photographic hallux valgus angle of each specimen are shown in Table 1. The granulation tissue score ($P = 0.48$, $r = 0.556$), and the toral score ($P = 0.009$, effect size $r = 0.688$) showed significant positive correlation with photographic hallux valgus angle. All specimens with hallux valgus angle greater than 25° had grade 3 granulation tissue.

DISCUSSION: The present study demonstrated that there was significant positive correlation between the granulation score and total score of the medial MSL enthesis and photographic hallux valgus angle severity of hallux valgus. This finding indicates that the severer degeneration of the medial MSL enthesis is, the larger the hallux valgus angle is. A post hoc power analysis demonstrated that the statistical power (two-tailed alpha, 0.05) to detect the correlation between tendon thinning, incomplete tears and photographic hallux valgus angle using the Spearman's rank correlation coefficient was 0.38; and that of incomplete tears was 0.30. Therefore, we need to add more specimens to evaluate correctly. On the other hand, the presence of granulation tissue which thought to be a histological finding of incomplete healing of enthesis tear showed strong correlation with hallux valgus angle. This indicate the medial MSL enthesis tear at metatarsal head and subsequent loosening of the medial MSL can cause hallux valgus.

SIGNIFICANCE/CLINICAL RELEVANCE:
Findings from the present study help to understand the pathology of hallux valgus and may contribute to the development of effective treatment such as reconstruction of the medial MSL for early-stage hallux valgus.

REFERENCES:
1) Sano et al. J Orthop Res. 1997, 2) Ferrer GA et al. Clin Anat. 2020, 3) Yamaguchi S et al. J Orthop Sports Phys Ther. 2019

IMAGES AND TABLES:

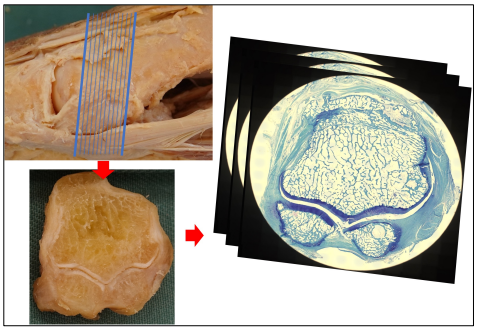

Fig. 1 Tissue preparation

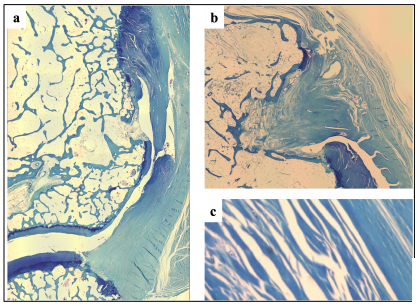

Fig. 2 Degenerative findings of the MSL
a: incomplete tear, b: granulation tissue,
c: fiber thinning

Specimen	Fiber thinning	Granulation tissue	Incomplete tear	total	Adjusted pHVA (°)
1	3	3	3	9	33.2
2	1	0	3	4	15.2
3	1	2	2	5	20.5
4	1	3	3	7	14.5
5	1	0	1	2	17.3
6	1	0	2	3	15.6
7	2	3	3	8	29.4
8	2	0	3	5	18.8
9	1	3	3	7	27.3
10	1	0	3	4	19.9
11	3	3	3	9	32.3
12	2	3	2	7	18.7
13	2	0	2	4	14.5

Table. 1 Sano score and adjusted hallux valgus angle of each specimen