Point-Connecting Measurements of the Hallux Valgus Deformity: A New Measurement and Its Clinical Application

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Purpose: The aim of this study was to investigate new point-connecting measurements for the hallux valgus angle (HVA) and the first intermetatarsal angle (IMA), which can reflect the degree of subluxation of the first metatarsophalangeal joint (MTPJ). Also, this study attempted to compare the validity of midline measurements and the new point-connecting measurements for the determination of HVA and IMA values.

Materials and Methods: Sixty feet of hallux valgus patients who underwent surgery between 2007 and 2011 were classified in terms of the severity of HVA, congruency of the first MTPJ, and type of chevron metatarsal osteotomy. On weight-bearing dorsal-plantar radiographs, HVA and IMA values were measured and compared preoperatively and postoperatively using both the conventional and new methods.

Results: Compared with midline measurements, point-connecting measurements showed higher inter- and intra-observer reliability for preoperative HVA/IMA and similar or higher inter- and intra-observer reliability for postoperative HVA/IMA. Patients who underwent distal chevron metatarsal osteotomy (DCMO) had higher intraclass correlation coefficient for inter- and intra-observer reliability for pre- and post-operative HVA and IMA measured by the point-connecting method compared with the midline method. All differences in the preoperative HVAs and IMAs determined by both the midline method and point-connecting methods were significant between the deviated group and subluxated groups (p=0.001).

Conclusion: The point-connecting method for measuring HVA and IMA in the subluxated first MTPJ may better reflect the severity of a HV deformity with higher reliability than the midline method, and is more useful in patients with DCMO than in patients with proximal chevron metatarsal osteotomy.

Key Words: Hallux valgus, hallux valgus angle, intermetatarsal angle, measurement, reliability

INTRODUCTION

The hallux valgus angle (HVA) and first intermetatarsal angle (IMA) have been considered to be reliable indicators for the severity of a hallux valgus deformity. However, identification of the longitudinal axes of the proximal phalange, first metatarsal, and second metatarsal (which is essential for effective determination of the HVA and IMA) is subject to error. Accordingly, several studies have focused on decreasing the measuring error and increasing the reproducibility and validity of measurements for HVA and IMA. Despite these efforts, in the subluxated metatarsophalangeal joint (MTPJ), HVA measured by the conventional method do not reflect the true severity. Even though the distal metatarsal articular angle (DMAA) could adequately report the severity of deviation/subluxation of the first MTPJ, there is debate with regards to the accuracy, reproducibility, and validity of measurement of the DMAA. In the symp-
Automatic hallux valgus patients with subluxated joint, bigger HVA would be related with clinical symptoms (Fig. 1).

Hence, the aims of this study are to 1) investigate new point-connecting measurements for HVA and IMA that can reflect clinical severity (such as degrees of subluxation of the first MTPJ) and 2) compare the validities of the conventional midline method and new point-connecting method for measuring HVA and IMA.

MATERIALS AND METHODS

Of the 60 feet from 57 patients with hallux valgus who underwent hallux valgus surgery (mean age, 54.4 years; range, 21 to 74 years) between June 2007 and June 2011 at our hospital, there were 20 cases classified as ‘mild’ (HVA<20; range, 17 to 19), 20 cases classified as ‘moderate’ (20<HVA<40), and 20 cases classified as ‘severe’ (HVA>40; range, 41 to 59). Among these 60 feet also, there were 26 feet with deviation of the first MTPJ and 34 feet with subluxated joints of the first MTPJ, as described by Piggott.11 These 60 feet were classified into two groups according to the type of metatarsal osteotomy. The two groups comprised patients that underwent either distal chevron metatarsal osteotomy (DCMO) (30 feet) or proximal chevron metatarsal osteotomy (PCMO) (30 feet). Radiographic assessments involved the collection of weight-bearing dorsal-plantar (DP) radiographs. Both HVA and IMA were measured preoperatively and postoperatively using both the conventional midline method and the new point-connecting method. The results of measurements for HVA and IMA between the conventional midline method and new point-connecting method were compared according to the severity of the cases, congruency of the first MTPJ, and the type of metatarsal osteotomy. The preoperative quality of life (QOL) was evaluated by the Short Form-36 (SF-36) questionnaire. The radiographic measurements of HVA/IMA between the new point-connecting method and conventional method were correlated with the SF-36. In addition, two authors evaluated the time required to measure the HVA and IMA using the new point-connecting method and the conventional method in 60 feet. The study protocols were approved by our ethics committee.

Radiographic analysis

Digital versions of all radiographic images were obtained using the Picture Archiving Communication System (Petavision, Seoul, Korea). Weight bearing foot DP radiographs were taken at a tube-film distance of 100 cm with the X-ray beam projecting vertically and centered to the middle of the third metatarsus of the patient with the knee in full extension. For the preoperative measurement of the HVA and IMA using the conventional midline method, the longitudinal axis of the first and second metatarsal was determined by connecting the centers of the metatarsal head and base (Fig. 2A), as previously described by Miller.12 Postoperatively, a connecting line between the center of the first metatarsal head and the proximal articular surface was used as the longitudinal axis of the first metatarsal to measure the HVA and IMA (Fig. 2B), as described by Shima, et al.9 The center of the proximal articular surface was defined as the midpoint between the medial and lateral edges.

The new point-connecting method to measure the HVA and IMA

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IMA involved the use of three connecting lines for the longitudinal axes of the proximal phalanges, first metatarsal, and second metatarsal. First, the longitudinal axis of the proximal phalanges was defined as the connecting line between the most medial prominent point of the proximal phalanges in the first interphalangeal joint and most medial prominent point of first metatarsal head. Second, the longitudinal axis of the first metatarsal was defined as the most medial prominent point of the first metatarsal head and most medial prominent and sclerotic point of first metatarsal base in the tarsometatarsal (TMT) joint, both preoperatively and postoperatively. Third, the longitudinal axis of the second metatarsal was defined as most medial prominent point of the second metatarsal head and the most medial prominent and sclerotic point of second metatarsal base in the TMT joint, both preoperatively and postoperatively (Fig. 3).

Inter- and intra-observer reliabilities were obtained for HVA and IMA between the conventional midline method and new point-connecting method by three foot and ankle surgeons (JY Ahn, Dimas RB, and JH Seo). To evaluate inter-observer reliability, each surgeon measured sixty DP images with no questions or discussions allowed during radiographic measurements. Before the start of the analysis, five samples of the weight-bearing foot DP images were evaluated by these three observers to ensure that they drew angles in the same manner. For intra-observer reliability, radiographic measurements were made by each observer during the two weeks after the initial measurements in a blind manner relative to previous measurement results. These two series of sequential measurements were then compared among the three observers.

**Statistical analysis**

The distribution of variables in each group was tested for normality using the Shapiro-Wilk test. A p value of <0.05 was considered significant. Statistical comparisons of the mean HVA and IMA values obtained using the conventional midline method and the new point-connecting method were assessed with an independent t-test among patient groups divided by severity, congruity and metatarsal osteotomies, both preoperatively and postoperatively. Inter- and intra-observer reliability were assessed on the basis of the intraclass correlation coefficient (ICC). Statistical comparisons of the outcomes between 2 measurements were assessed with independent t test. The correlations between the radiographic angles and SF-36 were assessed with a Spearman correlation analysis. Statistical analyses were performed using SAS statistical software (SAS Institute, Cary, NC, USA).

**RESULTS**

The mean preoperative and postoperative values for the HVA and IMA measurements between the conventional midline method and new point-connecting method are indicated in Table 1. For both the mean HVA and IMA, there were significant differences between the conventional midline method and new point-connecting methods when used either preoperatively or postoperatively (p=0.001). The mean differences between the conventional midline method and the new point-connecting method was 9.31 degrees (95% confidence interval, 8.99 to 9.63) for the preoperative HVA measurements, 2.56 degrees (95% confidence interval, 2.35 to 2.77) for the preoperative IMA, 4.04 degrees (95% confidence interval, 3.65 to 4.43) for the postoperative HVA, and 1.32 degrees (95% confidence interval, 1.08 to 1.55) for the postoperative IMA (Table 2). The new point-connecting method showed significantly higher mean values for the pre- and postoperative HVA and IMA (p=0.001) than for the corresponding preoperative values of conventional midline method.

Reliability statistics for inter- and intra-observer comparisons between the conventional midline method and new point-connecting method are listed in Table 3. Compared with the conventional midline method, the new point-connecting method showed a higher ICC for the inter- and intra-observer reliability of preoperative HVA/IMA and a similar/or higher ICC for the inter- and intra-observer reliability of postoperative HVA/IMA.

For the DCMO group, the ICC for the inter- and intra-observer
reliability of pre- and postoperative HVA/IMA determined using the new point-connecting method was higher than that determined using the conventional midline method. The PCMO group showed similar ICC levels for the inter- and intra-observer reliability of the pre- and postoperative HVA/IMA to those determined using the conventional midline method (Table 4 and 5).

The deviated group had a preoperative mean and HVA of 29.72±5.8 degrees (range, 17 to 45) and IMA of 12.57±3.1 degrees (range, 9 to 20) with the conventional midline method, and a mean preoperative HVA of 37.27±6.2 degrees (range, 26 to 54) and IMA of 15.20±3.2 degrees (range, 8 to 24) with new point-connecting method. The subluxated group had a preoperative mean HVA of 37.59±8.2 degrees (range, 21 to 59) and IMA of 15.69±3.0 degrees (range, 9 to 23) with the conventional midline method, and a mean preoperative HVA of 47.23±8.6 degrees (range, 30 to 72) and IMA of 17.90±3.3 degrees (range, 10 to 26) with the new point-connecting method (Table 6). Significant differences were found for the preoperative HVA and IMA between the conventional midline method and new point-connecting method in two groups (p=0.001). The significant mean difference between the conventional midline method and the new point-connecting method was 7.55 degrees (95% confidence interval, 6.98 to 8.11) in the deviated group and 9.64 degrees (95% confidence interval, 9.26 to 10.2) in the subluxated group for the preoperative HVA measurements (p=0.001). There were no significant differences for either the postoperative HVA or IMA between the conventional midline method and new point-connecting method in the two groups.

In the deviated group, mean physical component summary SF-36 was 43.2±11.2 and mental component summary SF-36 was 45.4±11.1. In the subluxated group, mean physical component summary SF-36 was 39.2±10.7 and mental component summary SF-36 was 34.3±12.5. There were significant differences in SF-36 between the deviated group and the subluxated group. While our results showed no significant correlation in the 60 feet as a whole, there was a significant negative correlation (r=-0.67, p=0.001). In 26 feet with deviation of the first MTPJ, there were no significant correlation between radiographic angles and SF-36.

We checked the time required to measure HVA and IMA using the new point-connecting method and the conventional method. Mean necessary time to measure HVA with new point-connecting method was 5.9±0.2 seconds. Mean necessary time to measure HVA with conventional method was 12.3±0.6 seconds. Mean necessary time to measure IMA with new point-connecting method was 6.9±0.4 seconds. Mean necessary time to measure IMA with conventional method was 12.4±0.7 seconds. There was a significant difference in the time to measure the HVA/IMA between the new point-connecting method and the conventional method (p=0.001).

### DISCUSSION

Preoperative radiographic measurements of the HVA and IMA

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**Table 1. Comparisons of Hallux Valgus Angle (HVA) and Intermetatarsal Angle (IMA) Measurements between the Conventional and New Point-Connecting Methods**

| Method          | Preoperative | Postoperative | p value |
|-----------------|--------------|---------------|---------|
| HVA             |              |               |         |
| Conventional    | 35.2±8.3     | 10.2±6.3      | 0.001   |
| New             | 44.5±8.9     | 14.2±7.3      | 0.001   |
| IMA             |              |               |         |
| Conventional    | 14.8±3.3     | 7.8±3.0       | 0.001   |
| New             | 17.1±3.5     | 8.9±3.0       | 0.001   |

**Table 2. Comparisons of the Mean Differences between the Conventional and New Point-Connecting Methods in the Determination of the Hallux Valgus Angle and Intermetatarsal Angle in Both Preoperative and Postoperative Contexts**

| Mean difference between conventional and new method | (95% confidence interval) |
|---------------------------------------------------|---------------------------|
| Hallux valgus angle                               | 9.31 (8.99 to 9.63)       |
| Intermetatarsal angle                             | 2.56 (2.35 to 2.77)       |

| Mean difference between conventional and new method | (95% confidence interval) |
|---------------------------------------------------|---------------------------|
| Hallux valgus angle                               | 4.04 (3.65 to 4.43)       |
| Intermetatarsal angle                             | 1.32 (1.08 to 1.55)       |

**Table 3. Comparison of Inter- and Intra-Observer Reliabilities of Hallux Valgus Angle (HVA) and Intermetatarsal Angle (IMA) Values Determined Using the Conventional and New Point-Connecting Methods in Both Preoperative and Postoperative Contexts**

**Intra-class correlation coefficient (95% confidence interval)**

|                      | Inter-observer reliability | Intra-observer reliability |
|----------------------|---------------------------|----------------------------|
|                      | Conventional method       | New method                 | Conventional method       | New method                 |
| Preoperative         |                           |                            |                           |
| HVA                  | 0.89 (0.79 to 0.95)       | 0.91 (0.83 to 0.96)        | 0.95 (0.90 to 0.98)       | 0.97 (0.94 to 0.99)        |
| IMA                  | 0.82 (0.67 to 0.92)       | 0.86 (0.72 to 0.94)        | 0.87 (0.75 to 0.94)       | 0.88 (0.77 to 0.95)        |
| Postoperative        |                           |                            |                           |
| HVA                  | 0.88 (0.77 to 0.95)       | 0.94 (0.88 to 0.97)        | 0.94 (0.87 to 0.97)       | 0.98 (0.96 to 0.99)        |
| IMA                  | 0.85 (0.72 to 0.93)       | 0.86 (0.72 to 0.94)        | 0.90 (0.81 to 0.96)       | 0.91 (0.82 to 0.96)        |
have been essential for evaluating the severity of hallux valgus deformities and for the selection of an appropriate metatarsal osteotomy procedure to correct these deformities. \[1,2,3,4,5,13-20\] There have been many efforts to increase the reliability and reproducibility of the measurement for HVA and IMA using many longitudinal axes of the first metatarsal from various start points to end points. \[1,2,3,5,7,9,21-23\] Nevertheless, physicians face difficulties in selecting one long axis of the metatarsus, because the long axes of the metatarsus could be made between the center of the proximal and distal metaphyseal bone. Especially, it is difficult to determine the center point of a displaced distal fragment after DCMO with bunionectomy (Fig. 2). \[2,7,22\] Although the conventional midline method can be used to select the long axis of the metatarsus with excellent reliability, preoperative measurements of the HVA and IMA cannot show the extent of protrusion of bunions in subluxated first MTPJs (Fig. 3). Using our new point-connecting method to measure the HVA and IMA will yield higher values of HVA in a subluxated first MTPJ, because it uses the medial margin as the axis of the metatarsal.

Along with these advantages, our new point-connecting method showed higher inter- and intra-observer reliability in a preoperative context and similar inter- and intra-observer reliability in a postoperative context, when compared with conventional midline measurements.

Our new point-connecting method also showed a higher ICC for the inter- and intra-observer reliability of pre- and postoperative HVA/IMA than the conventional midline method for the DCMO group than for the PCMO group. There was difficulty determining the center of the first metatarsal head because a DCMO displaced the metatarsal head with a bunionectomy in hallux valgus deformity, even though a conventional midline method, such as the Shima method, showed excellent mea-

### Table 4. Comparison of Inter- and Intra-Observer Reliability of Hallux Valgus Angle (HVA) and Intermetatarsal Angle (IMA) Values Determined Using the Conventional and New Point-Connecting Methods in Both Preoperative and Postoperative Contexts for Patients That Underwent Distal Chevron Metatarsal Osteotomy

|                  | Interclass correlation coefficient (95% confidence interval) | Intra-observer reliability |
|------------------|---------------------------------------------------------------|----------------------------|
|                  | Conventional method   | New method     | Conventional method   | New method     |
| Preoperative     |                  |                             |                          |
| HVA              | 0.88 (0.79 to 0.95) | 0.91 (0.83 to 0.96) | 0.93 (0.90 to 0.98) | 0.96 (0.94 to 0.99) |
| IMA              | 0.82 (0.67 to 0.92) | 0.82 (0.72 to 0.94) | 0.88 (0.75 to 0.94) | 0.92 (0.77 to 0.95) |
| Postoperative    |                  |                             |                          |
| HVA              | 0.86 (0.77 to 0.95) | 0.95 (0.88 to 0.97) | 0.93 (0.87 to 0.97) | 0.97 (0.96 to 0.99) |
| IMA              | 0.82 (0.72 to 0.93) | 0.87 (0.72 to 0.94) | 0.82 (0.81 to 0.96) | 0.90 (0.82 to 0.96) |

### Table 5. Comparison of Inter- and Intra-Observer Reliability of Hallux Valgus Angle (HVA) and Intermetatarsal Angle (IMA) Values Determined Using the Conventional and New Point-Connecting Methods in Both Preoperative and Postoperative Contexts for Patients That Underwent Proximal Chevron Metatarsal Osteotomy

|                  | Interclass correlation coefficient (95% confidence interval) | Intra-observer reliability |
|------------------|---------------------------------------------------------------|----------------------------|
|                  | Conventional method   | New method     | Conventional method   | New method     |
| Preoperative     |                  |                             |                          |
| HVA              | 0.90 (0.79 to 0.95) | 0.90 (0.83 to 0.96) | 0.96 (0.90 to 0.98) | 0.99 (0.94 to 0.99) |
| IMA              | 0.85 (0.68 to 0.92) | 0.91 (0.72 to 0.94) | 0.85 (0.75 to 0.94) | 0.84 (0.77 to 0.95) |
| Postoperative    |                  |                             |                          |
| HVA              | 0.92 (0.77 to 0.95) | 0.94 (0.88 to 0.97) | 0.98 (0.87 to 0.97) | 0.98 (0.96 to 0.99) |
| IMA              | 0.84 (0.72 to 0.93) | 0.85 (0.72 to 0.94) | 0.95 (0.81 to 0.96) | 0.93 (0.82 to 0.96) |

### Table 6. Comparisons of the Mean Hallux Valgus Angle (HVA) and Intermetatarsal Angle (IMA) Values Determined Using the Conventional and New Point-Connecting Methods

|                  | Deviated group       | Subluxated group      |
|------------------|----------------------|-----------------------|
|                  | Conventional method  | New method            | Conventional method | New method |
| Preoperative     |                      |                       |                      |
| HVA              | 29.72±5.8 (17 to 45) | 37.27±6.2 (26 to 54)  | 37.59±8.2 (21 to 59) | 47.23±8.6 (30 to 72) |
| IMA              | 12.57±3.1 (9 to 20)  | 15.20±3.2 (8 to 24)   | 15.69±3.0 (9 to 23)  | 17.90±3.3 (10 to 26) |
| Postoperative    |                      |                       |                      |
| HVA              | 9.29±5.4 (1 to 19)   | 13.68±7.2 (0 to 24)   | 10.52±6.7 (0 to 30)  | 14.17±7.6 (1 to 34)  |
| IMA              | 7.33±2.7 (1 to 14)   | 8.96±2.6 (2 to 14)    | 7.91±3.1 (0 to 18)   | 8.80±3.2 (0 to 18)   |
was significant correlation between radiographic angles and SF-36, indicating that there was a significant downward trend in general health, vitality, so physical function subscales of the SF-36, indicating that there may be a confounding factor for this new method. Last, the 60 cases in our study cohort might be insufficient sample size to validate the clinical usability of the new point-connecting method for hallux valgus deformities or to compare the clinical effectiveness of the conventional and new methods. Hence, further analyses with additional cases will be useful for investigating the applicability of radiographic measurements of the HVA and IMA.

In conclusion, our new point-connecting method in measuring HVA and IMA in a subluxated first MTPJ may better reflect the severity of a hallux valgus deformity with a higher reliability than the conventional midline method. This method may also be especially useful for patients who have undergone PCMO, although it can also be used for patients who have undergone PCMO.

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