Techniques

# A Simplified Preoperative Radiographic Assessment for Metatarsus Adductus Associated With Hallux Valgus

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Abstract: *Radiographic measurements for the assessment of metatarsus adductus (MTA) have a broad range of interpretation without a consensus regarding surgical indications. The "Plumbline" (PL) radiographic assessment method helps identify MTA and determines if physical space is available to align the first metatarsal to the longitudinal foot axis without the need to realign the lesser metatarsals. Forty-five neutral weight-bearing anterior-posterior (AP) radiographs of patients scheduled for surgical intervention for isolated hallux valgus (HV) or combined MTA/HV deformities were reviewed. The cohort was grouped based on the presence of MTA using a Sgarlato's angle (SA) of 15°, with 23 patients in the HV-only group and 22 patients in the MTA group. A mean preoperative SA of 8.7° (SD: 2.1; range: 5.4-13.4) and 26.6° (SD: 5.1; range: 18.2-36) were found in the HV-only and MTA groups, respectively. Subjects with an SA ≤ 15° (N = 22) were found to have a negative PL (100%) and subjects with an SA > 15° (N = 23) displayed a positive PL (100%). The PL technique provided a simple method and clear visual reference for determining the presence of MTA in HV patients without the need to measure traditional radiographic angles.*

Level of Evidence: *Retrospective, Level IV, Diagnostic*

Keywords: Metatarsus adductus; Plumbline; Hallux valgus; Sgarlato angle

## Introduction

Metatarsus adductus (MTA), is a complex multiplanar foot deformity which has approximately a 30% reported incidence in patients with symptomatic hallux valgus (HV).[1-3] Various radiographic angles have been proposed for the assessment of MTA, but these measurements can be cumbersome to perform, and difficult to explain to patients. Current MTA measurements have a broad range of interpretation among surgeons with no clear consensus regarding surgical indications.[4] We feel that an accurate but simplistic method is needed due to the high incidence of HV recurrence when MTA is present, but not recognized and addressed.[5] We present what we have termed the "Plumbline" (PL) as a more simplistic radiographic assessment method to describe MTA and to help illustrate the significance of MTA relative to correction of HV. This method determines whether enough space is available to align the first metatarsal to the longitudinal foot axis without the

> "Patients with a negative PL maintained this finding following an isolated first TMT arthrodesis, while individuals with MTA converted from a positive to a negative PL following a 3/2/1 TMT corrective arthrodesis."

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**Figure 1.**

Sgarlato's angle.

need to first realign the second and third metatarsals using a combined approach. The intent is to provide a visual radiographic reference to determine if the lesser metatarsal position will interfere with complete first ray correction by crossing the PL. Our hypothesis is that if the PL intersects the second metatarsal, it indicates a degree of MTA that would warrant correction. Conversely, if the PL remains tangential to the second metatarsal, then MTA is not present to a degree that would block first ray correction (Figure 1).[6]

## Patients and Methods

The PL, Sgarlato's angle (SA), and the intermetatarsal angle (IMA) were measured on a PACS system for 45 neutral position individual preoperative and postoperative weight-bearing anterior-posterior (AP) radiographs of patients previously scheduled for surgical intervention for either isolated HV or combined MTA/HV deformities between December 2018 and January 2022. Retrospective radiographic data were collected and recorded upon receipt of a letter of exemption from the Western Institutional Review Board. The cohort was grouped based on the presence of MTA using an SA of 15°, with 23 patients in the HV-only group and 22 patients in the MTA group. Intermetatarsal angle measurements were recorded in both populations, and the preoperative True IMA was calculated in the MTA group using the formula: True IMA = IMA + (MAA – 15°).[7]

The IMA was defined as the angle between the longitudinal anatomic axis of the first and second metatarsals on AP radiographs. The SA was identified using the following method: tangential reference lines are drawn connecting points placed at the first tarsometatarsal (TMT) joint to the medial talonavicular joint and from the distal and proximal cuboid articulations with the fourth metatarsal base and calcaneus, respectively. The reference line midpoints are linked with a line crossing the midfoot from which a 90° line is subtended. The longitudinal axis of the second metatarsal is bisected, and the SA is formed between this and the 90° subtended line (Figure 1).[8]

The PL is determined by using the following method: the medial cuneiform axis line is drawn by identifying and linking two individual points marked at the medial aspects of the first TMT joint and the medial naviculo-cuneiform (NC) joint (Figure 2A).[9] A third point is marked at the lateral apex of the first TMT joint (Figure 2B). The medial cuneiform axis line is translated in a parallel fashion to the third point at the first TMT joint (Figure 2B and C). This line is then extended distally to the level of the second metatarsal head resulting in the formation of the PL (Figure 2C). If this line intersects the second metatarsal head, it is considered a positive PL and indicates the presence of MTA which may interfere with complete first ray correction (Figure 3B). A negative PL will not intersect the second metatarsal head or shaft; indicating that there is sufficient space to align the first metatarsal to the axis of the midfoot without additional lesser ray corrections (Figure 4B). The goal of the PL is to mimic the longitudinal anatomic axis of the foot and provide a reference to which the first metatarsal should theoretically be corrected (Figures 3A-C and 4A-C).

There is no formal sample size calculation for this cohort as this is a single-arm study that is primarily descriptive in nature. All analyses were based on available data, without imputation for values. All variables were summarized using the following descriptive statistics: n, mean, standard deviation (SD), median, and range. The frequency and percentages of observations were reported for all pertinent categorical measures.

## Results

A mean preoperative SA measurement of 8.7° (SD: 2.1; range: 5.4-13.4) and 26.6° (SD: 5.1; range: 18.2-36.0) were found in the HV-only and MTA groups, respectively. All subjects with an SA ≤ 15° (N = 22) were found to have a negative PL (100%) and subjects with an SA > 15° (N = 23) displayed a positive PL (100%). The HV-only group with a SA ≤ 15°, and a negative PL, all underwent successful radiographic correction of the IMA via an isolated instrumented triplanar TMT arthrodesis with a final mean IMA value of 5.4° (SD: 2.7; range: 0.6-12.5) and with a mean reduction of 7.2° from baseline. The patients in the MTA group with an SA > 15°, and a positive PL, all underwent successful correction of the True IMA and SA via an instrumented triplanar 3/2/1 TMT arthrodesis with a final mean IMA value of 4.2° (SD: 2.2; range: 9.7-0.0) and a mean preoperative True IMA to postoperative IMA angle reduction of 18.9°. A mean SA value of 7.0° (SD: 4.9; range: 0.0-15.1) was found postoperatively with an overall mean SA reduction of 19.6°. The intersection of the PL at the second metatarsal identified the presence of MTA in 23 of the 45 (51%) pre-operative AP radiographs examined and indicates a positive correlation with an SA greater than 15° in 23 of 23 (100%) radiographs (Table 1).

**Figure 2.**

Plumbline radiographic assessment method. (A) cuneiform axis line is drawn linking two points marked at the medial aspect of the first TMT joint and the medial NC joint; (B) a third point is marked at the lateral apex of the first TMT joint; (C) the medial cuneiform axis is translated in a parallel fashion to the third point at the first TMT joint. This line is then extended distally toward the second metatarsal head resulting in the formation of the Plumbline.

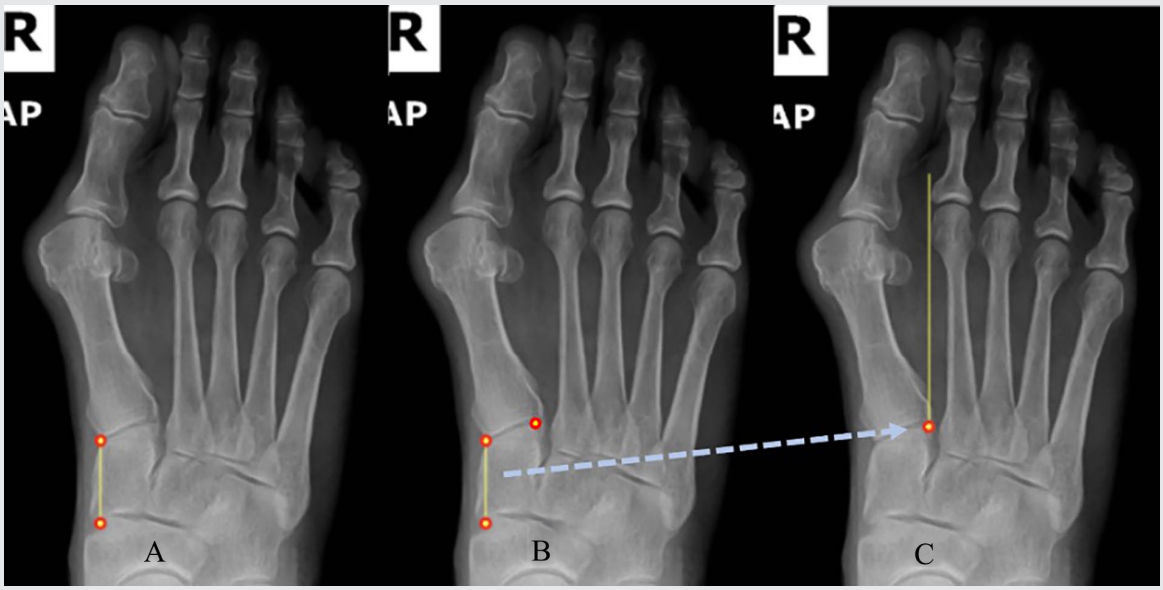


**Figure 3.**

Positive plumbline: 3/2/1 tarsometatarsal corrective arthrodesis. (A) medial cuneiform axis line; (B) plumbline crossing the second metatarsal (positive result) indicating the presence of metatarsus adductus; (C) 3/2/1 corrective tarsometatarsal arthrodesis with normalization of the plumbline.

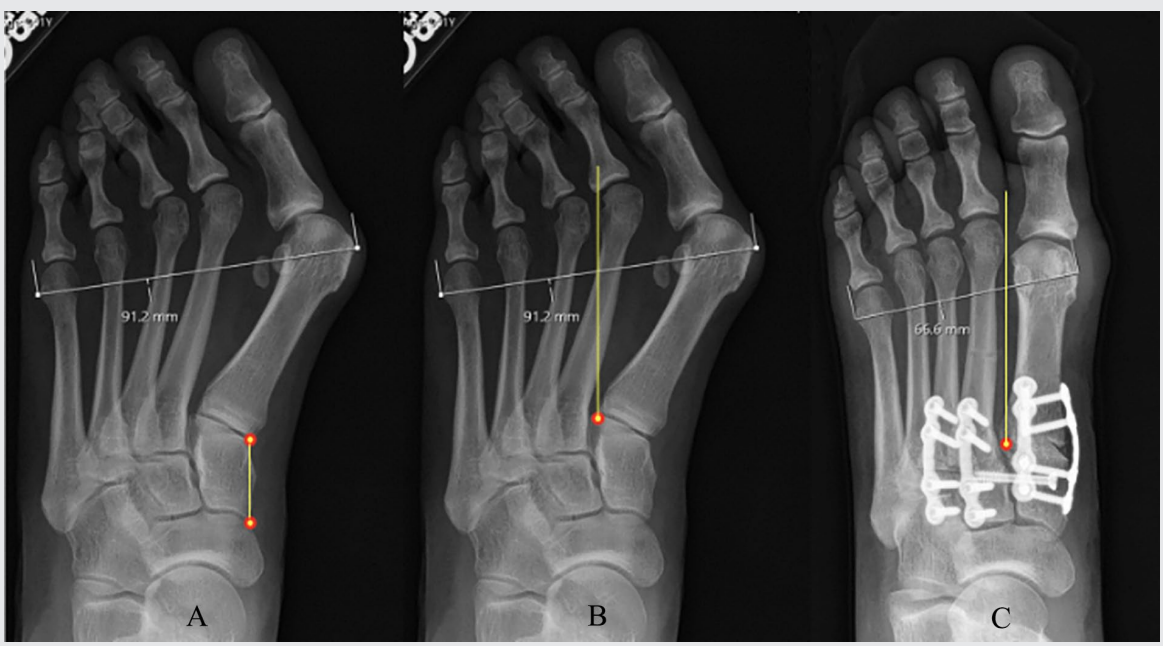

**Figure 4.**

Negative plumbline: isolated first tarsometatarsal corrective arthrodesis. (A) medial cuneiform axis line; (B) plumbline tangential to the second metatarsal (negative result) indicating the absence of metatarsus adductus; (C) isolated corrective first tarsometatarsal arthrodesis with maintenance of a negative plumbline.

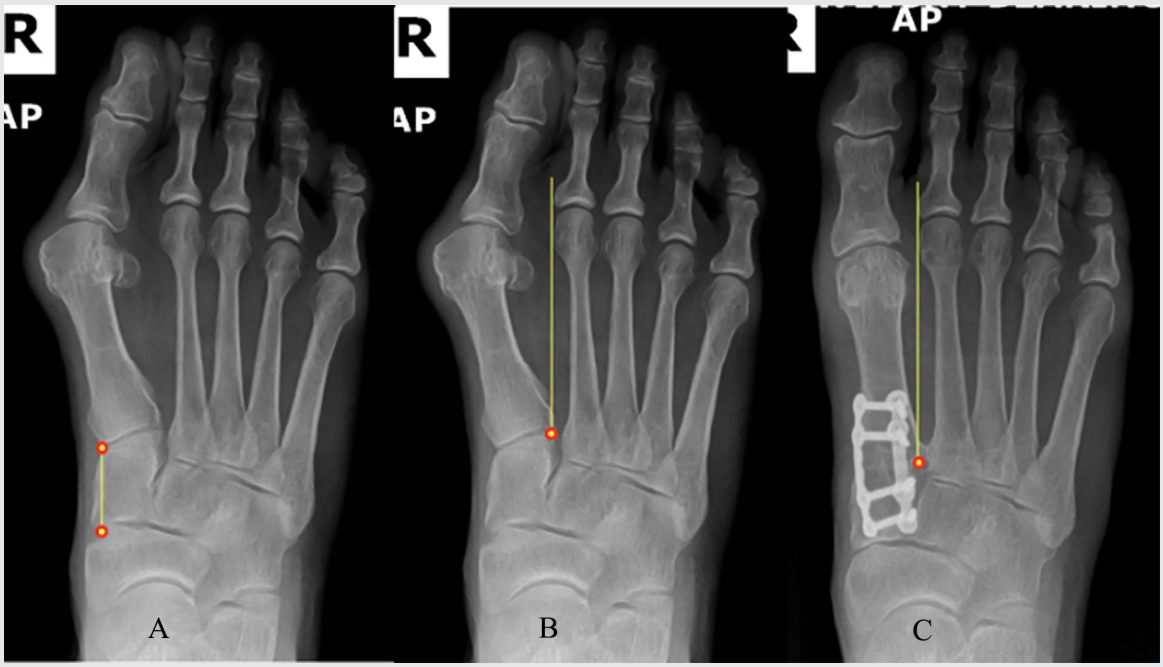


**Table 1.**

MTA Prediction Using Plumbline Technique.

| | Metatarsus adductus group | Hallux valgus only group |
|---|---|---|
| Subject group | SA > 15° (N = 23) | SA ≤ 15° (N = 22) |
| Mean preoperative SA (SD; range) | 26.6° (5.1; 18.2-36.0) | 8.7° (2.1; 5.4-13.4) |
| Mean postoperative SA (SD; range) | 7.0° (4.9; 0-15.1) | 9.6° (3.6; 2.8-16.3) |
| Mean preoperative TRUE IMA (SD; range) | 23.1° (5.8; 12.2-33.0) | N/A |
| Mean preoperative IMA (SD; range) | 11.4° (4.3; 5.7-24.8) | 13.2° (2.1; 10.3-19.2) |
| Mean postoperative IMA (SD; range) | 4.2° (2.2; 0.0-9.7) | 5.4° (2.7; 0.6-12.5) |
| Preoperative plumbline | 23/23 (100%; positive) | 22/22 (100%; negative) |
| Postoperative plumbline | 23/23 (100%; negative) | 22/22 (100%; negative) |
| Mean follow-up in months | 14.3 | 12.0 |

## Discussion

The PL technique describes a simplified method for MTA assessment. In our limited case series, we found that a negative PL indicated that HV was amenable to correction in isolation. The longitudinal mechanical foot axis[6] is referenced to assess the degree of MTA deformity and helps the patient and surgeon interpret whether correction in addition to the first ray is needed. A positive PL finding indicated that the second and/or third metatarsals would physically obstruct the first metatarsal from being completely reduced to the midline axis of the foot, possibly leaving the patient with a lack of complete correction. We observed in this cohort that patients with a negative PL maintained this finding following an isolated first TMT arthrodesis, while individuals with MTA converted from a positive to a negative PL following a 3/2/1 TMT corrective arthrodesis.

The SA measurement, a commonly used method to determine the presence of MTA, is described as having a high degree of intraobserver and interobserver reliability.[4] However, there is no consensus on the value of the measurement as it pertains to surgical planning and practical clinical application in patients with MTA and HV. Measurement of the SA does not define when surgical intervention for MTA is warranted which may result in surgeon frustration. The IMA measured following an isolated first TMT arthrodesis in patients with unaddressed MTA may appear normal, but the calculated True IMA will indicate a residual deformity. The lesser metatarsals will have not been corrected to the normal longitudinal axis of the foot and an adducted position of the first and lesser metatarsals will persist.

These claims regarding traditional radiographic evaluation of MTA have been supported in the literature and are reflected in the inconsistent surgical correction outcomes of HV when MTA is present.[10,11] Residual radiographic deformity and higher rates of recurrence are often noted postoperatively in MTA subjects that have undergone an isolated first TMT arthrodesis.[12] A retrospective study of 15 MTA subjects undergoing isolated HV surgery reported a 40% patient dissatisfaction with a "striking under correction" following Scarf, Akin, and medial eminence resection procedures.[13] Failure to realign the lesser metatarsal malposition to the longitudinal foot axis has been reported to result in a 30% radiographic recurrence of HV.[14] This raises concern as the SA may identify the presence of MTA but gives no guidance as to whether the MTA needs to be addressed to achieve complete reduction (or correction) of the first metatarsal. In addition, the exact angular value used to define MTA is not universally agreed upon.

Our report primarily serves to assess the utility of the PL as a valuable alternative radiographic assessment technique to evaluate the presence of MTA and establish if the lesser metatarsals need to be addressed when surgical correction is being considered. Radiographic acknowledgment of the lesser metatarsal pathology and subsequent correction via a 3/2/1 TMT realignment arthrodesis has been found to yield acceptable results.[2] Our authors currently perform an instrumented triplanar modification of this arthrodesis to correct MTA and HV clinically and radiographically when a positive PL finding is present.[5] Anecdotally, we have found this technique to be successful in addressing both the radiographic and clinical features of HV and MTA.

Limitations present in our study include those inherent to retrospective radiographic evaluation bias. We attempted to control for this by having experienced foot and ankle surgeons read standardized weight-bearing radiographic images positioned in normal angle and base of gait with each foot imaged individually. We recognize that an assessment of intraobserver and interobserver reproducibility would provide further validation of the method and additional study is warranted.

## Conclusion

The PL is a novel technique used to determine when MTA needs to be surgically addressed in conjunction with HV correction. This technique was studied in a subset of patients specifically undergoing an instrumented TMT arthrodesis for HV, but its utility may be predictive for other indications or procedures. The technique is a quick and simple method that provides a clear visual reference without the need to measure traditional radiographic angular relationships. It indicates the proximity of the metatarsal segments to determine whether the first metatarsal is amenable to reduction in isolation or if correction will be blocked by the adducted lesser metatarsal bones. The visual simplicity of the measurement can aid in patient education and surgeon clarity when describing the surgical approach to this complex three-dimensional anatomic pathology.


### Declaration of Conflicting Interests

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### Ethical Approval

Not applicable.

### Informed Consent

Not applicable.

### Trial Registration

Not applicable.



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