CHAPTER **1**

THE SESAMOID APPARATUS POSTION IN HALLUX VALGUS SURGERY

Javier Aycart Testa, Podologo
Manuel Gonzalez San Juan, Podologo
Luke D. Cicchinelli, DPM

The correct selection of the surgical technique for the correction of hallux valgus encompasses a complete patient evaluation, which includes a thorough anatomic, biomechanic, and functional study of the foot and lower extremity. The radiologic evaluation of HAV focuses on the structural relationships and the position of its parts. In order to study the selection of the surgical technique, a number of radiologic parameters have been described, which when considered united, allow the identification of the best surgical protocols. Among these data, some serve mainly to understand the nature of the deformity and the selection of technique while others are simply interesting and anecdotal observations. By balancing the importance of these radiologic data with the clinical reality and the surgical possibilities we arrive at the techniques that are best suited for individual surgeon's hands.

The generally-considered most significant measures to evaluate the HAV can be summarized to include the angle of hallux abductus (HA), the intermetatarsal angle (IM) and the tibial sesamoid position (TSP). The position and the function of the sesamoidal apparatus are a fundamental component of the HAV. We know the advantageous position in which the fibular sesamoid and the plantar lateral capsular structures are located after the sesamoid's lateral migration. The degree of displacement of the sesamoidal apparatus can be an important indication of the dynamic component in the deformation of the HAV.

The incomplete relaxation of the plantar-lateral soft tissues of the first metatarsophalangial joint may increase the potential recurrence of the correction of the HAV. The adductor hallucis muscle is the most important dynamic force in the development and propagation of the deformity of the HAV. The contracture of this muscle and other periarticular structures causes the sesamoidal apparatus migration laterally from the metatarsal head contributing still more to the progression in the deformity. If we are incomplete in the relaxation of these lateral soft tissues, we will not be able to relocate the sesamoidal apparatus to its appropriate position under the first metatarsal head, increasing the percentage and likelihood of recurrence.

It would therefore seem normal that the importance of the position of the sesamoids before and after the surgery have due relevance in the studies that seek to determine the precise of the position of the sesamoids in relation to other anatomic structures such as, the halving of the first metatarsal or other structures of the forefoot. In those studies that have examined this it is referenced that these relationships are not altered as a result of the surgery on the first ray.

Although the intent of bunion surgery and the surgical manipulations tend to seek to place the sesamoidal apparatus underneath the first metatarsal (where it was before being developed the HAV), one is often left in doubt of how much correction, of the one observed in the radiographs, corresponds to the translation of the distal fragment of the osteotomy and how much it is a result of any other cause, causes that could be masked by the transfer of the bony portion, and by the custom to measure the TSP with the only reference of the first metatarsal halving. These considerations stimulated us to look for some point of reference within the forefoot, yet outside of the first ray from which to compare the sesamoids in the preoperative period and the postoperative period.

The intention of this study is to locate an anatomic reference in the forefoot from which to compare the preoperative situation of the sesamoids and the existing one after the intervention of the HAV, in this way we would find the degree of real displacement that takes place for the sesamoidal apparatus and its meaning in the effective correction of the HAV deformity.

MATERIALS AND METHODS

Patients affected by clinical and radiographic HAV deformity were selected from those operated in Ortocen by the authors, who took part in exclusive right and the totality of the surgeries. All the surgical techniques included modified McBride, conserving the fibular sesamoid, and first metatarsal osteotomy. The work on bone was either a modified Austin or closing wedge base osteotomy. All the patients in which some surgery had been performed on the lesser metatarsals, either during the index procedure at the time of the surgery of the HAV or at another moment, were excluded from this study. For the inclusion in the study a minimum radiologic followup of 21 days was required.

All the radiographs used in this work have been taken weight bearing, each foot separately, and in the angle and base of gait. For their study, the radiographs are placed in a negatoscope so that, for the right foot, its hallux is at the right part of the foot. In the case of the left foot, its hallux is at the left part of the foot.

Next we present the different radiographic parameters generally used to study the nature of the HAV and that associated with the selection of the surgical techniques, which serve as protocols for our surgeries. The IM angle is determined from the longitudinal bisections of the first and second metatarsals, next measuring the angle that they form.[1] The longitudinal bisection of first and second metatarsals is determined, for each bone, drawing a line that both connects the midpoint of the straight line defined between both cortex in the diafisarial-distal extension with the midpoint of the straight line defined between both cortex in the diafisarial-proximal extension. In order to measure the IM in the postoperative radiographs it is necessary to take in consideration the new longitudinal axis that is produced by the surgical correction of the first metatarsal. The new halving is described between the same proximal datum point (midpoint of the straight line defined between both cortex in the diafisarial-proximal extension), and the midpoint between both extremes of the articulating surface in the metatarsal head, corresponding with the articular projection of the first phalange base.

The HA angle is described from the longitudinal bisections of the first metatarsal and the first phalange.[1] The longitudinal bisection of the phalange is determined drawing a line that both connects the midpoint of the straight line defined between both cortex in the diafisarial-distal extension with the midpoint of the straight line defined between both cortex in the diafisarial-proximal extension.

The preoperative TSP is defined according to the description of Haas, and includes the relation to the longitudinal bisection of the first metatarsal. This axis is determined both by drawing a line from the midpoint of the straight line defined between both cortex in the diafisarial-distal extension, to the midpoint of the straight line defined between both cortex in the diafisarial-proximal extension.[2]

The postoperative TSP is defined in an analogous way to the previous one. Nevertheless, the surgical correction of the first metatarsal produces a new longitudinal axis. The new halving is determined between the same proximal datum point (midpoint of the straight line defined between both cortex in the diafisarial-proximal extension), and the midpoint between both extreme of the articular surface in the metatarsal head, corresponding with the projection to articulate of the first phalange base. Both TSP are determined in weight bearing dorsoplantar radiographs, and in angle and base of support.

We defined the "Tibial sesamoid to second metatarsal distance" as the measurement of the space located between the lateral edge of the tibial sesamoid and the halving of the second metatarsal, affecting perpendicularly to the second metatarsal bisection.

In order to measure all the described radiographic parameters fourteen points are marked in each one of the radiographs to study. These points are identified with fine tip white labeller and the aid of a negatoscope (Figures 1, 2). The radiographs were placed on the negatoscope so that for the right foot the hallux was to the right of the observer and in the case of the left foot, to the left. The fourteen points correspond to:

- Cortical left of the diafisarial distal extension of the proximal phalange of hallux.
- Cortical right of the diafisarial distal extension of the proximal phalange of hallux.
- Cortical left of the diafisarial proximal extension of the proximal phalange of hallux.

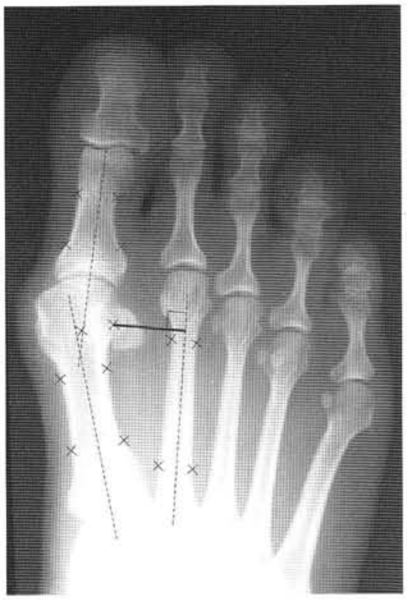

Figure 1. Preoperative dorsoplantar radiograph of a patient with a painful bunion deformity. The fourteen reference points are marked. The continuous line as drawn, demonstrates the defined "Tibial sesamoid to second metatarsal distance". Dotted lines show the metatarsals and phalangial axis.

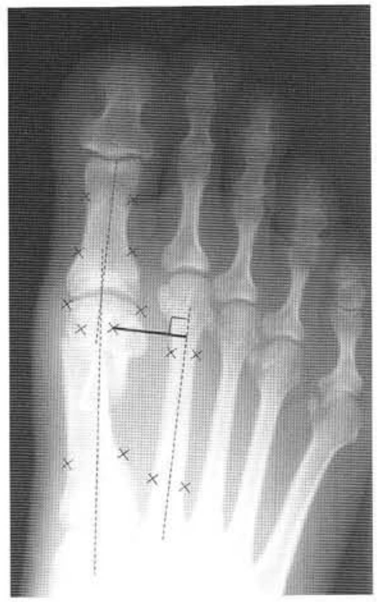

Figure 2. Eight-week postoperative radiograph of bunion deformity corrected with a modified Austin osteotomy. The fourteen reference points are marked. The axial metatarsal and phalangeal lines are drawn with dotted lines. The defined "Tibial sesamoid to second metatarsal distance" in the postoperative radiograph is shown.

- Cortical right of the diafisarial proximal extension of the proximal phalange of hallux.
- Cortical left of the diafisarial distal extension of the first metatarsal. In the postoperating radiography, left edge of the metatarsal distal articular cartilage.
- Cortical right of the diafisarial distal extension of the first metatarsal. In the postoperative radiography, right edge of the metatarsal distal articular cartilage.
- Cortical left of the first metatarsal diafisarial proximal extension.
- Cortical right of the first metatarsal diafisarial proximal extension.
- Cortical left of the second metatarsal diafisarial distal extension.
- Cortical right of the second metatarsal diafisarial distal extension.
- Cortical left of the second metatarsal diafisarial proximal extension.
- Cortical right of the second metatarsal diafisarial proximal extension.
- Tibial sesamoid medial edge.
- Tibial sesamoid lateral edge.

The reference to the right or left of the bones is necessary due to a systematization of the process of obtaining the data according the imperative of the ad hoc elaborated computer science program. The computer science program requests to know the foot that is being explored, and based on our answer transforms the concepts left or right to medial or lateral, according to how it corresponds.

The radiographs were placed on a digitizer tablet to define coordinates of the fourteen predetermined points, and following their numerical sequence. The collected data were processed by means of a created computer science program in Pascal language. The program calculates for each radiograph the angle IM, the angle HA, the TSP and the distance between the tibial sesamoid and second metatarsal, the obtained values consist in a file, or document of text, ready to be transfered to a spreadsheet.

As a previous step to the study of this current sample, the authors estimated the possibility that different explorers could mark the points with different levels from skill and that it could affect the obtained measures. In order to confirm the coincidence or discrepancy between the measures obtained by different people, three explorers (two podologos and one biologist) marked the same ten radiographs, five preoperative and five postoperative ones. The statistical analysis of the obtained results established the correlation between the variables of this distribution. In this manner the coefficient of correlation between the explorers was determined. This index informs the magnitude and the direction of the correlation. The magnitude is arrived at by the absolute value from the coefficient whereas the sign determines the direction. The value of the correlation coefficient oscillates between -1 and 1.

When the correlation coefficient is close to 1, the correlation is strong and direct, that is to say, that when increasing a variable, the increase of the other occurs in a relation that tends to be perfect.

When the correlation coefficient is close to -1, the correlation is hard and inverse, that is to say, that when increasing a variable, the diminution of the other occurs in an almost perfect relation. It would not be an acceptable result for our explorers. It had indicated that one of the explorers was significantly less precise than the others.

When the correlation coefficient is close to 0, a linear relation between the values does not exist, the correlation is very weak and the variables are very little related.

We raised three hypotheses from the measures of the radiographic parameters of our sample. In order to accept or to reject these hypotheses of work we will use a contrast of parametric hypotheses that it determines if it is sensible to reject (or to accept) the hypothesis that the value of a not known parameter is located in a certain region of the parametric space that we define. That is to say that by means of a certain test we divide the space sample (joint of all the possible samples) in two regions: a region by rejection of Ho (hypothesis by rejection), and an acceptance region of Ho.

Within this type of studies it is necessary to consider the level of meaning. This one would be defined as the maximum probability of committing an error, it is to say to reject the hypothesis when it must not be rejected. This way, as we will use a 0.01 level of meaning, the possibility of committing an error at the time of rejecting a hypothesis would be of 1% and therefore the probability that our resistance is correct would be of 99%.

The model of distribution used will be the one of a normal distribution since the used variables agree with this model and in addition the used sample size is greater than 30 in each one of the made hypotheses.

Thus, the resistance of parametric hypotheses, will allow us to determine if the following hypotheses are or non rejectable:

Hypothesis 1: "The postoperative distance of the tibial sesamoid to second metatarsal is different from the preoperative one"

Hypothesis 2 and 3: "The angles IM and HA in the postoperative time, are greater or equal to the obtained ones in the preoperative time"

The authors of this paper obtained and recorded all of data. Two groups are differentiated in the sample, the "immediate" one, that correspond to those cases with radiographic followup between the 21 and 100 days, and the "long term" one, with radiographic followup between the 21st day and the 7 years and 6 months, in this "long term" group, only the postoperative radiographs of more than 101 days were studied. This differentiation was made to define the importance and possibility that the passage of time after the surgery could contribute to the results.

RESULTS

Among the cases selected by means of clinical and radiologic evidence of HAV criteria, and operated with sesamoid apparatus relaxation and first metatarsal osteotomy, a total of 144 cases, 134 women and 10 men, were found. The patients were

Table 1

COEFFICIENT OF CORRELATION BETWEEN EXPLORERS

	*HA	IM	SES. TO 2°	TSP	GLOBAL
MEASUREMENT	0.99	0.99	0.96	1.00	0.09
PREOPERATING	0.98	0.78	0.99	1.00	0.99
POSTOPERATING	1.00	0.84	0.95	1.00	0.99

HA = hallux abductus angle; IM = intermetatarsal angle; Ses. to 2° = distance between the tibial sesamoid and the second metatatarsal; TSP = tibial sesamoid position.

between 17 and 79 years, with an average age of 57.4 years. Of the 199 feet included, 102 were right and 97 left ones.

The coefficient of correlation between the explorers, preoperative, postoperative and average for all the experiment, is reflected in Table 1.

The 199 operated feet were separated in two groups, those whose postoperative totally documented had a 100 days follow up, called "immediate", and those that had total postoperative documentation from the 101 days to the maximum follow up time, called "long term." The results of these groupings are in Table 2, cases with immediate postoperative (including 70 cases, 32 right feet and 38 left feet), and 3 cases with long term postoperative (including 129 cases, 70 right feet and 59 left feet).

In Table 2, with respect to hypothesis 1 one concludes that sufficient statistical evidence exists, at the level of 0.01 meaning, to reject the null hypothesis, that is to say, to accept that after the short term time interval (21-100 days of post-operative), a variation of the distance of the tibial sesamoid to the second metatarsal does not take place. In the same Table 2, with respect to hypotheses 2 and 3, the conclusion is that sufficient statistical evidence exists, at the level of 0.01 meaning, to reject the null hypothesis, that is to say, to accept that after the short term time interval (21-100 days of postoperative), a diminution of the angles HA and IM takes place.

Of an analogous way, in Table 3, and on hypothesis 1 one concludes that sufficient statistical evidence exists, at the level of 0.1 meaning, to reject the null hypothesis, that is to say, to accept that after the long term time interval (101-2735 days of postoperative), a variation of the distance between the tibial sesamoid and the second metatarsal does not take

Table 2

SURGICAL CASES WITH SHORT TERM FOLLOWUP, BETWEEN 21 AND 100 DAYS

	*HA	IM	SES. TO 2°	TS P
MAXIMUM PREOP RANGE	65.82	34.79	27.86	7
MINIMUM PREOP RANGE	5.73	5,15	14.33	2
MAXIMUM POSTOP RANGE	26.86	14,24	31.37	5
MINIMUM POSTOP RANGE	-17.81	-4,07	11.58	3
PREOP AVERAGE	33.89	16.54	20.79	5.03
POSTOP AVERAGE	7.23	5.20	21.64	3.31
DIFFERENCE	-26.66	-11.34	0.85	-1.71
SD	13.12	4.19	4.29	

HA = hallux abductus angle; IM = intermetatarsal angle; Ses. to 2° = distance between the tibial sesamoid and the second metatatarsal; TSP = tibial sesamoid position.

Table 3

SURGICAL CASES WITH LONG TERM FOLLOWUP, BETWEEN 101 AND 2,735 DAYS

	*HA	IM	SES. TO 2°	TSP
MAXIMUM PREOP RANGE	57.68	23.7	28.5	7
MINIMUM PREOP RANGE	1.19	5.31	15.24	3
MAXIMUM POSTOP RANGE	23.97	13.51	27.61	6
MINIMUM POSTOP RANGE	-19.81	-2.82	12.03	1
PREOP AVERAGE	32.80	15.22	20.41	5.02
POSTOP AVERAGE	7.16	4.20	20.64	3.43
DIFFERENCE	-25.64	-11.02	0.23	-1.58
STANDARD DEVIATION	11.33	3.43	2.10	

*HA = hallux abductus angle; IM = intermetatarsal angle; Ses. to 2° = distance between the tibial sesamoid and the second metatatarsal; TSP = tibial sesamoid position.

place. This same Table 3, concludes as for hypotheses 2 and 3 that sufficient statistical evidence exists, at the level of 0.01 meaning, to reject the null hypothesis, that is to say, to accept that after the long term time interval (101-2735 days of postoperative), a diminution of the angles HA and IM takes place.

DISCUSSION

There are few comparative studies of preoperative and postoperative radiographic information tending to evaluate the effectiveness of the surgical techniques of the HAV.

Luthje made a long term followup of his results with first metatarsal basilar osteotomies.[3] He operated 52 feet. The average angle of HA was 30° in the preoperative time and 24° in the postoperative time, with a reduction of 20%. IM angle means was 14° in preoperative and 10° in the postoperative one, with an average reduction of 29%. He measured the distance between the heads of the first and second metatarsals. Before the surgery his measurement average was 13 mm and after the surgery, 11 mm. Nevertheless, Luthje doubted his result understanding that the shortening of the first metatarsal due to the osteotomy invalidated his meaning that, to his understanding, was better reflected by angle IM. The position of the patients to make the radiographs was a supine position with flexed knees, for that reason it seems reasonable to wait for different results if the way to make the radiographs has been also different. In the soft tissues surgical technique he performed a plicature of the abductor muscle and a tenotomy of the adductor muscle, in the metatarsophalangial joint. The followup examination was made to the 4.6 years of average.[3] In comparison with our results, Luthje obtained a 58% of correction less than ours for HA, and a 41% less, also, for the correction of the IM.

An interesting comparative study of the HAV before and after the surgery is the one that made by Bryant and Singer in 42 cases.[4] The radiographs were obtained in weight bearing position, the postoperative ones were made to the 10 weeks on average. The surgical technique was the one of Austin with fixation by means of single buried K-wire. The cases in which a transference of the adductor tendon had been made were excluded, excepting only those that entailed a tenotomy of the same. The radiographs were taken following the habitual podiatrical patterns.[5] The results obtained for the HA angle were in preoperative 25.2° and the postoperative one, 10.9°. For the IM angle, before the surgery, 12° and after, 6.8°. The TSP changed from 4.6 in the preoperative to 2.4 in the postoperative. These results have been improved by ours in a 22% for HA and a 26% for the IM, nevertheless the correction of the TSP was superior to ours in a 14%.

In another long term study a tricorrectional distal osteotomy with a long plantar arm was made, a dorsal wedge corrected the proximal articular set angle. Fixation was obtained by means of compression screw.[6] Selner and cols operated 121 feet correcting HA from 26° to 11.6°, the IM from 14.5° to 5.7° and the TSP from 4,74 to 1.87. The radiographs were taken according to protocol in podologia and podiatric medicine, and the postoperative ones were labelled on the sixth month. The soft tissue surgery closes the capsule and centralizes the sesamoidal apparatus without explaining how. While our study improves to this one in HA in a 24% and the IM in an 8%, the TSP of the group of Selner corrects a 27% more than ours.

Judge et al have published an exhaustive investigation on the effect of the surgery of the HAV in the sesamoidal apparatus, presenting a parameter to which they have called distance between the tibial sesamoid and the second metatarsal.[7] Three investigators evaluated 25 feet each one by means of the techniques of modified McBride, and a metaphisarial, diaphisarial or basilar osteotomy of the first metatarsal. In all the cases a soft tissues lateral relaxation was made at the metatarsophalangial joint. The radiographs were taken according to the protocols of podiatric surgery, the postoperative radiographs were made between a month and 7.6 months after the surgery. They reduced the HA angle from 24.6° to 7.4°, the IM angle was lowered from 12.1° to 4.1°, the TSP diminished from 4.9 of the preoperative time, to 2.7 after the surgery, and finally, the distance from the tibial sesamoid to the second metatarsal varied one tenth of millimetre. The comparison between the work of Judge and ours shows the following results: we obtain better result for HA in 9% and for the IM in a 2.5%, their correction for the TSP in a 11% was better.

We present a work where a significant reliability of the analytical method is reached, credited by the high percentage obtained in the correlation between explorers, as expressed in table 1. The computer science program allows a precision in the taking of data for the measurements, not found in the analysed previous studies. The surgery decreases the parameters of HA, IM and TSP in 26°, 11° and 1.7. The distance between the tibial sesamoid and second metatarsal increases slightly in 0.85 mm, in the immediate pursuit, although it becomes stabilized in the long term in 0.23 mm. The statistical revision of this concept shows, in the tables 2 and 3, that the sesamoidal apparatus does not move after the surgery, and do with a level of 0.01 meaning.

Like Judge et al, we understand that the sesamoidal apparatus is shared in common to the soft plantar structures. Its shifting with respect to the longitudinal axis of the first metatarsal is due, only, to the lateral migration of the distal fragment of the metatarsal originated by the osteotomy, change showed by the alteration of the TSP, in 1.7 positions, of the seven of Hass.[2] These results demonstrate the apparent uselessness of the lateral release of soft parts. Authors such as Selner and his colleagues reached an improvement of the PST at 44% greater than ours by "closing the capsule and centralizing the sesamoidal apparatus."[6] In a similar sense, Bryant and Singer obtain resembling results to those of these authors for the postoperating PST, by means of a "standardized modification of the technique of Austin."[4]

In the samples macroscopic study we have identified some pre-existing structural anomalies and that have not been considered within the inclusion criteria, although they could well distinguish some results. For that reason, the authors study at the present time to interpolate the displayed data in this work, with the findings that can be found in the population with metatarsus adductus.

Comparing the immediate and long term followup, significant differences in the results are not noted. For that reason we consider of limited utility the radiologic determination of the more important measures in the postoperatve radiographs of the HAV, studies of more than 100 days after the surgery.

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