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HALLUX VALGUS SURGERY
– EPIDEMIOLOGICAL ASPECTS AND CLINICAL
OUTCOME

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**Karolinska
Institutet**

Stockholm 2007

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Published and printed by Universitetservice US-AB

SE- 171 77 Stockholm, Sweden

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ISBN 978-91-7357-233-0

Institutionen för klinisk vetenskap,
intervention och teknik (CLINTEC)
Enheten för ortopedi
Karolinska Institutet

Hallux valgus surgery - epidemiological aspects and clinical outcome

av

Carlos Saro M.D.

AKADEMISK AVHANDLING

som för avläggande av medicine doktorsexamen vid Karolinska Institutet offentligen
försvaras på svenska språket i Föreläsningssal B 64, Karolinska Universitetssjukhuset
Huddinge, fredag 8 juni 2007, kl. 09:00



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Stockholm 2007

I would like to dedicate this work to my mother Carmen for always being there when needed and to the memory of my father Manuel Justo who I owe among several things, the gratitude to introduced me in the pathology of the foot, when at that time most general orthopaedic surgeons had little interest in taking care of problems of the foot and ankle.

When the shoe fits, the foot is forgotten

Zhuang-Zhou or Chuang-tze, c.369–c.286 B.C.,

The "affection" that "not only deforms the foot in a most clumsy way but also makes the gait uncertain and continuous walking painful" has not received from surgeons the attention it deserved

Volkman 1856

ABSTRACT

Hallux valgus is a common condition that accounts for a significant number of visits to foot and ankle specialists. Surgery is the standard treatment but there is insufficient evidence from randomized trials to determine which method of treatment is the most appropriate. Furthermore the prevalence of forefoot and hallux valgus surgery has not been well documented.

We have investigated the prevalence of forefoot surgery in Sweden (Study I) and obtained data for the surgical treatment of hallux valgus in a geographically defined population. We also determined (Study II) the reliability of radiographic measurements, used as criteria for the choice of procedures and surgical failure or success. Moreover, we used a system to evaluate the appearance of the hallux. We tested, in a prospective randomized controlled trial (Study III) the hypothesis that the differences between the surgical procedures would affect the outcome. The quality of life (Study IV) before and after hallux valgus surgery was evaluated. Finally, the plantar pressure distribution and pain after two distal first metatarsal osteotomies were assessed (Study V).

In study I, the investigated population included patients of any age and sex who underwent forefoot surgery in both ambulatory (2000) or inpatient settings (1997-2000). Epidemiologic data was retrieved from the National Swedish Patient Register (NSPR). Clinical data was extracted from medical records of hallux valgus surgery in the Stockholm region. In studies II, III and IV, 100 prospective randomized cases were included. In study II, radiographs and photographs from 100 patients undergoing hallux valgus surgery were evaluated by two independent observers. In study III, 100 hallux valgus patients were randomized to a Lindgren (n= 50) or a distal chevron osteotomy (n= 50). We employed measures such as the American Orthopaedic Foot and Ankle Society (AOFAS) clinical rating for the hallux, EuroQol (EQ-5D) for health-related quality of life and visual analogue scales (VAS) for pain in addition to radiographic and clinical parameters. In study IV, the measures used were the quality of life (QoL) according to SF-36, a disease specific score (AOFAS), the severity of the deformity, the possibility of wearing the preferred choice of shoes and satisfaction with the treatment. The pre- and postoperative QoL scores were compared with the score in the general population. In study V, twenty-two patients randomly assigned to either a distal chevron or a Lindgren first metatarsal osteotomy were evaluated prospectively with dynamic plantar pressure measurement, quality of life scores, clinical and radiographic measurements.

Study I, provides comprehensive data on the prevalence of forefoot surgery in Sweden. The number of operations in relation to the population was not evenly distributed in the 6 major regions in Sweden. The procedures were more common in urban areas than in rural regions. We also found that in-patient surgery was more common in private clinics than in community hospitals. Study II showed that the intraobserver reliability was higher than the interobserver reliability for the intermetatarsal distance, the appearance of the hallux and the sesamoid positions. Angular measurements were more accurate than linear measurements. Evaluation of appearance was less reliable than the radiographic measurements except for the sesamoid position measurements. In study III, the clinical outcome of the two procedures was similar but patients operated with Lindgren's osteotomy showed better correction as judged by radiological measurements. Loss of correction was noted in

both groups after 3-6 years. Neither osteotomy was recommended for patients with a HVA $> 30^\circ$ and/or an IMA $> 15^\circ$. Study IV showed that pain affected the quality of life in these patients. Surgery produced a significant improvement. The severity of the deformity did not influence the quality of life; however a free choice of shoe ware and satisfaction with the surgery was associated with a better quality of life. SF-36 is a relevant instrument for evaluating outcome in hallux valgus surgery. Study V demonstrated that both surgical techniques used resulted in significant clinical and radiographic improvement and reduced the level of pain, although the foot pressure recordings demonstrated no biomechanical effect of the treatment.

Keywords: Hallux valgus; Osteotomy; Plantar pressure; Prevalence; Quality of life; Randomized controlled trial; Surgery

LIST OF PUBLICATIONS

This thesis is based on the following papers, which will be referred to by their Roman numerals (Papers I-V).

I. Surgical treatment of hallux valgus and forefoot deformities in Sweden: A population based study of 6956 patients

Saro C, Bengtsson AS, Lindgren U, Adami J, Blomqvist P, and Felländer-Tsai L.

Submitted.

II. Reliability of radiological and cosmetic measurements in hallux valgus

Saro C, Johnson DN, Martínez de Aragón J, Lindgren U and Felländer-Tsai L.

Acta Radiologica 46: 843-851.

III. Outcome after distal metatarsal osteotomy for hallux valgus: A prospective randomized controlled trial of two methods

Saro C, Andrén B, Wildemyr Z and Felländer-Tsai L.

Foot and Ankle International, Accepted for publication, Dec 2006.

IV. Quality-of-life outcome after hallux valgus surgery

Saro C, Jensen I, Lindgren U and Felländer-Tsai L.

Qual Life Res, In press (2007), doi: 10.1007/s11136-007-9192-6.

V. Plantar pressure distribution and pain after distal osteotomy for hallux valgus. A prospective study of 22 patients with 12-months follow-up

Saro C, Andrén B, Lindgren U, Felländer-Tsai L and Arndt A.

The Foot, In press (2007), doi:10.1016/j.foot.2006.11.002.

LIST OF ABBREVIATIONS

AOFAS	American Orthopaedic Foot and Ankle Society
CI	Confidence interval
COR	Coefficient of repeatability
DMAA	Distal metatarsal articular angle
EQ-5D	EuroQol
HVA	Hallux valgus angle
IMA	Intermetatarsal 1-2 angle
IMD	Intermetatarsal 1-2 distance
MTP	Metatarsophalangeal
QoL	Quality of life
VAS	Visual analogue scale

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INTRODUCTION

HISTORICAL PERSPECTIVE AND BACKGROUND

One of the most fundamental structural specializations which distinguish *Homo sapiens* from other species is found in the anatomy of the foot, especially in that of the hallux¹⁰⁶.

The term “hallux valgus” means a turning outward of the big toe. It was introduced by Hueter⁴² in 1871 and has come to define the lateral deviation and subluxation of the first metatarsophalangeal (MTP) joint with medial deviation of the first metatarsal. It is now accepted, mostly in the juvenile patient, that a hallux valgus deformity can result from lateral deviation of the articular surface of the metatarsal head without subluxation of the first MTP joint¹⁹. The deviation of the hallux occurs primarily in the transverse plane and often also involves rotation of the toe in the frontal plane causing the nail to face medially (i.e., pronation).

In 1951, Hardy and Clapham³⁵ published an important study comparing a group of patients with hallux valgus with a control group (people with normal feet). This study became the basis for the present practice of the preoperative measurement of the hallux valgus angle (HVA) and intermetatarsal angle (IMA); a HVA is defined as the angle between the longitudinal axes of the first metatarsal bone and the proximal phalanx of the big toe and an IMA is defined as the angle between the longitudinal axes of the first and the second intermetatarsal bones (Fig. 1A). These authors established a physiological mean HVA value of 15.7 ° and a physiological mean IMA value of 8.5 °.

In 1960 Piggot⁷³ studied the congruency of the first MTP joint and the development of the hallux valgus related to this congruity. In the normal foot the proximal phalanx is centered on the metatarsal head. If one line is drawn along the base of the proximal phalanx and another along the articular surface of the metatarsal head, they will be parallel to one another. When these lines are parallel, the joint is considered to be congruent. Once lateral subluxation of the proximal phalanx occurs, the parallelism between the base of the proximal phalanx and the articular surface is lost, and varying degrees of subluxation occurs (Fig. 2). Once the proximal phalanx begins to deviate laterally off the metatarsal head, instability of the first MTP joint occurs, and with time the hallux valgus deformity will probably progress, as compared with the congruent joint where the first MTP joint is stable²¹.

Pelet⁷² emphasized the importance of the angulation of the distal articular surface of the first metatarsal (Fig. 1B). The relationship between the distal articular surface of the first metatarsal head and the long axis of the metatarsal was designated as the distal metatarsal articular angle (DMAA). The DMAA may be changed during the performance of an osteotomy. However, a proximal osteotomy that does not correct the angulation of the DMAA, may aggravate the deformity. With distal osteotomies, it may be possible to correct and realign the DMAA.

Fig. 1. (A) Hallux valgus angle and intermetatarsal angle. (B) distal metatarsal articular angle (DMAA)

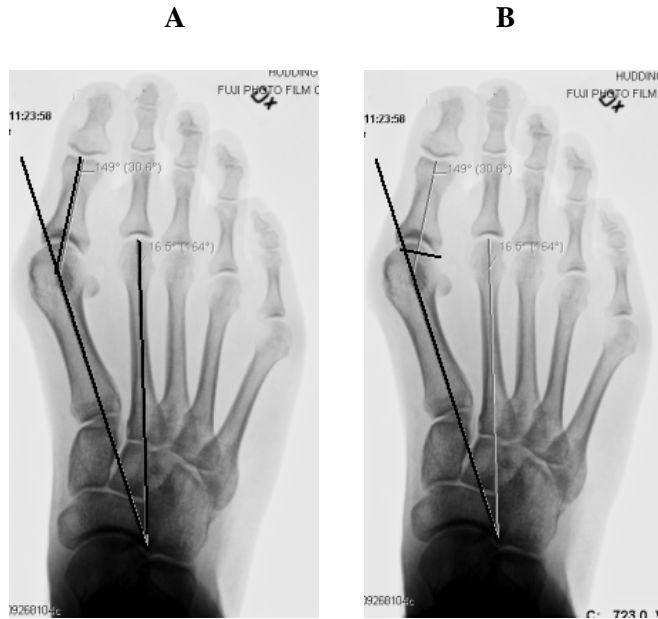
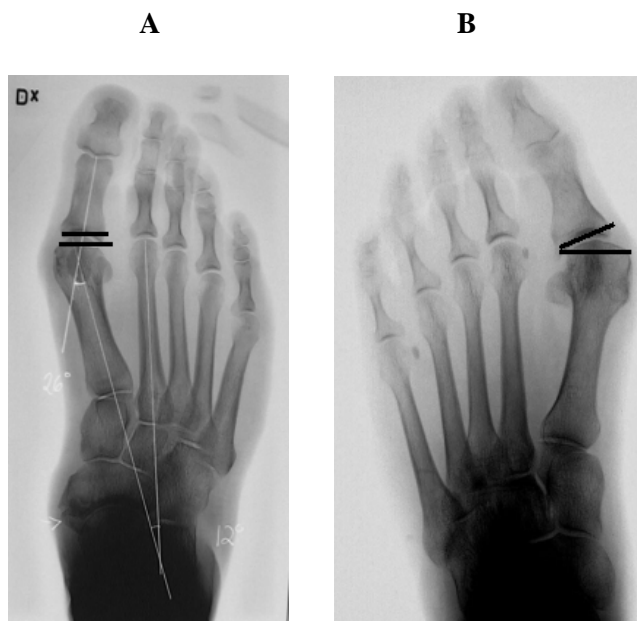


Fig. 2. (A) Congruent and (B) incongruent metatarsophalangeal joint



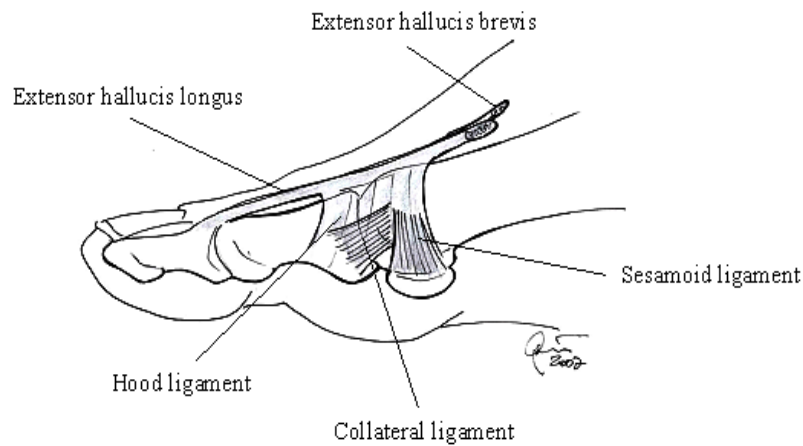
ANATOMY

The first metatarsal located on the most medial portion of the foot, has three regular articulations, the proximal phalanx and sesamoids distal and the medial cuneiform proximal. In some cases, however, the first metatarsal articulates laterally with the second metatarsal. The first metatarsal is the shortest and broadest.

On the base there are two small tubercles; one medial for the insertion of the tibialis anterior tendon and on the opposite side, lateral, for the insertion of the peroneus longus tendon. The remaining surfaces are rough to facilitate the attachment of ligaments. A fan-shaped ligamentous band (Fig. 3) originates from the medial and lateral metatarsal epicondyles and constitutes the collateral

ligaments of the first MTP joint.

Fig. 3. Organization of ligaments and tendons in the region of metatarsophalangeal joint



The head of the first metatarsal presents with a crista that begins on the anterior aspect of the articular cartilage and continues plantarly. On each of the plantar condyles there is a groove for the articulation with the sesamoids. Normally the groove on the medial plantar condyle is larger than the groove on the lateral plantar condyle (Fig. 4).

Fig. 4. Coronal section of the forefoot at the level of the sesamoid bones



Sesamoids are fibrous, cartilaginous, or osseous structures that are almost always contained within a tendon. Although the precise functions of sesamoids are uncertain, it has been suggested that they alter the pull of a tendon, decrease friction at articular surfaces, and decrease pressure within a tendon to allow circulation to the tendon².

These sesamoids are contained in each tendon of the flexor hallucis brevis muscle proximal to the MTP joint and articulate only with the head of the first

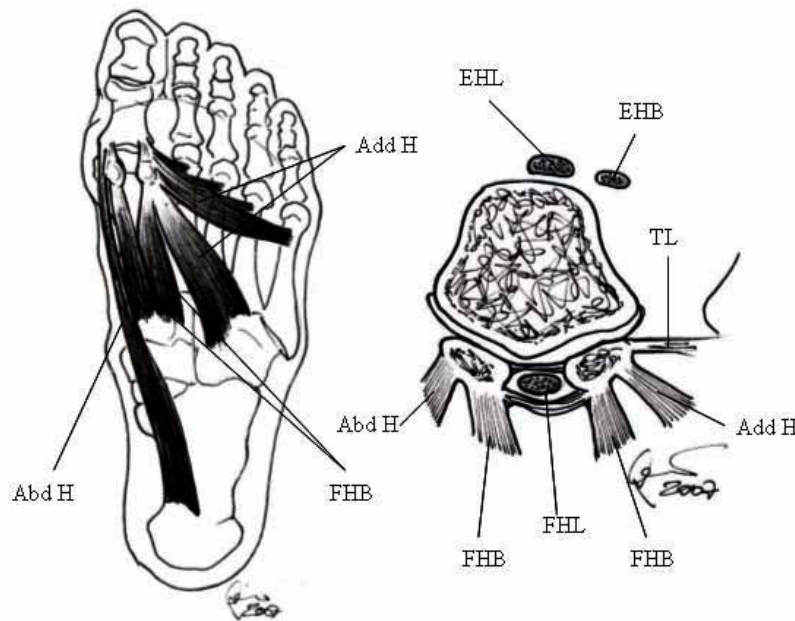
metatarsal. It is rather common to see these two sesamoids present as bipartite sesamoids².

The base of the phalanx is concave to enable articulation with the metatarsal head. Tubercles are also present on the inferior side of the base and dorsal side of the head of the phalange for the attachment of collateral ligaments.

The tendons and muscles that move the big toe may be arranged around the MTP joint in four groups²¹:

- A. Dorsal: the extensor hallucis longus and brevis pass dorsally and centrally. The extensor hallucis longus is anchored medially and laterally by the hood ligament and inserts into the distal phalanx. The extensor hallucis brevis inserts beneath the hood ligament into the dorsal aspect of the base of the proximal phalanx (Fig. 3).
- B. Plantar: the long and short flexor tendons pass across the plantar surface, with the tendon of the flexor hallucis longus coursing through a centrally located tendon sheath on the plantar aspect of the sesamoid complex and inserts into the distal phalanx. The medial and lateral heads of the flexor hallucis brevis insert into the medial and lateral sesamoids (Fig. 5). Distally, the sesamoids are attached to the base of the proximal phalanx by the plantar plate.
- C. Medial: the tendon of the abductor hallucis passes medially and inserts into the medial sesamoid and medial plantar tubercle of the proximal phalanx.
- D. Lateral: the tendon of the adductor hallucis pass laterally and inserts into the lateral sesamoid (transverse head) and base of the proximal phalanx (oblique head).

Fig. 5. Tendons and muscles that move the big toe (plantar view and cross section)



Abd H= Abductor hallucis; Add H= Adductor hallucis; EHB= Extensor hallucis brevis; EHL= Extensor hallucis longus; FHB= Flexor hallucis brevis; FHL= Flexor hallucis longus; TL= Transverse ligament

The stability of the first metatarsophalangeal (MTP) joint is maintained by a combination of static and dynamic stabilizers. The strong capsuloligamentous sling of the first MTP joint (Fig. 3) and the bony shape of the first MTP joint (since flat surfaces being more inherently stable than round surfaces) form the static stabilizers, providing a good compromise between stability and suitability for weight transfer on one hand and motion on the other. Medial and lateral stability of the first MTP joint is also provided by the collateral ligaments.

A further contribution to stability is the sesamoid ligaments, which connect the metatarsal head to the sesamoids, and the hood ligament, which stabilizes the extensor tendons dorsally (Fig. 3). Plantarly, the sesamoids are stabilized by the bony configuration of their articulation with the undersurface of the metatarsal head and by the sesamoidal ligament, the plantar plate, and the transverse metatarsal ligament (Fig. 4).

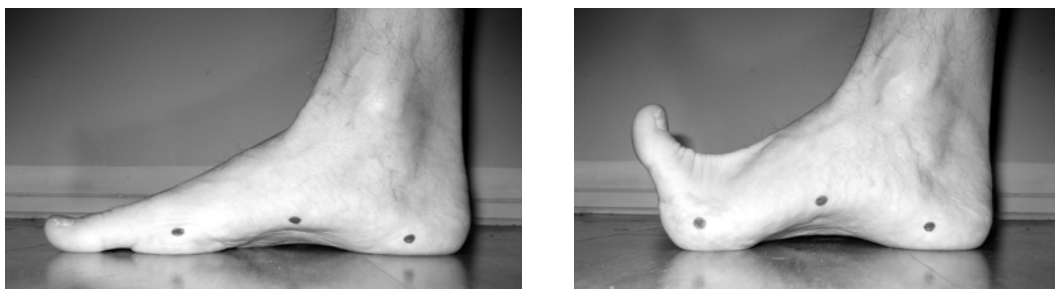
Dynamic stabilizers include the abductor hallucis, whose tendinous insertion blends with the medial slip of the flexor hallucis brevis to insert medially on the proximal phalangeal base, and the two heads of the adductor hallucis (transverse and oblique) whose tendinous insertions blend with the lateral slip of the flexor hallucis brevis to insert on the lateral proximal phalangeal base as the conjoined tendon.

Additional functional stability of the forefoot is provided by the plantar aponeurosis via the windlass mechanism. The plantar aponeurosis arises from the tubercle of the calcaneus and passes distally to insert into the base of the proximal phalanx. As the plantar aponeurosis passes the plantar aspect of the metatarsophalangeal joint it combines with the joint capsule to form the plantar plate. The function of the plantar aponeurosis has been described by Hicks³⁹, who demonstrated that mechanically it is a windlass mechanism. The windlass mechanics is an engineering concept that has been used for thousands of years to help move heavy loads. The windlass mechanism is the coordinated action of the layers of muscle, tendon, ligament and bony architecture, to maintain arch height and foot rigidity. Without correct windlass function, the foot will not act as an efficient lever, and an effective push off power cannot be achieved.

As the proximal phalanxes move upwards (dorsiflexes) when the body shifts across the fixed foot, the plantar fascia is drawn tightly around the metatarsal heads, developing tension. This tension within the plantar fascia packs all the joints of the foot tightly together, which results in a depression of the metatarsal heads and hence an elevation of the longitudinal arch and converts the foot to a rigid structure, in preparation for the forward thrust of propulsion. This increased foot rigidity is reflected by the increase in arch height, as the forefoot is drawn down and closer to the rear foot. It is very important to understand that for the windlass to function properly, the first metatarsal must be allowed to plantar flex (Fig. 6).

This is a somewhat passive mechanism since no muscle function per se brings about this stabilizing mechanism, which is the most significant stabilizer of the longitudinal arch. The plantar aponeurosis is most functional on the medial side of the foot, and becomes less functional as one moves laterally toward the fifth metatarsophalangeal articulation.

Fig. 6. The Windlass Mechanism



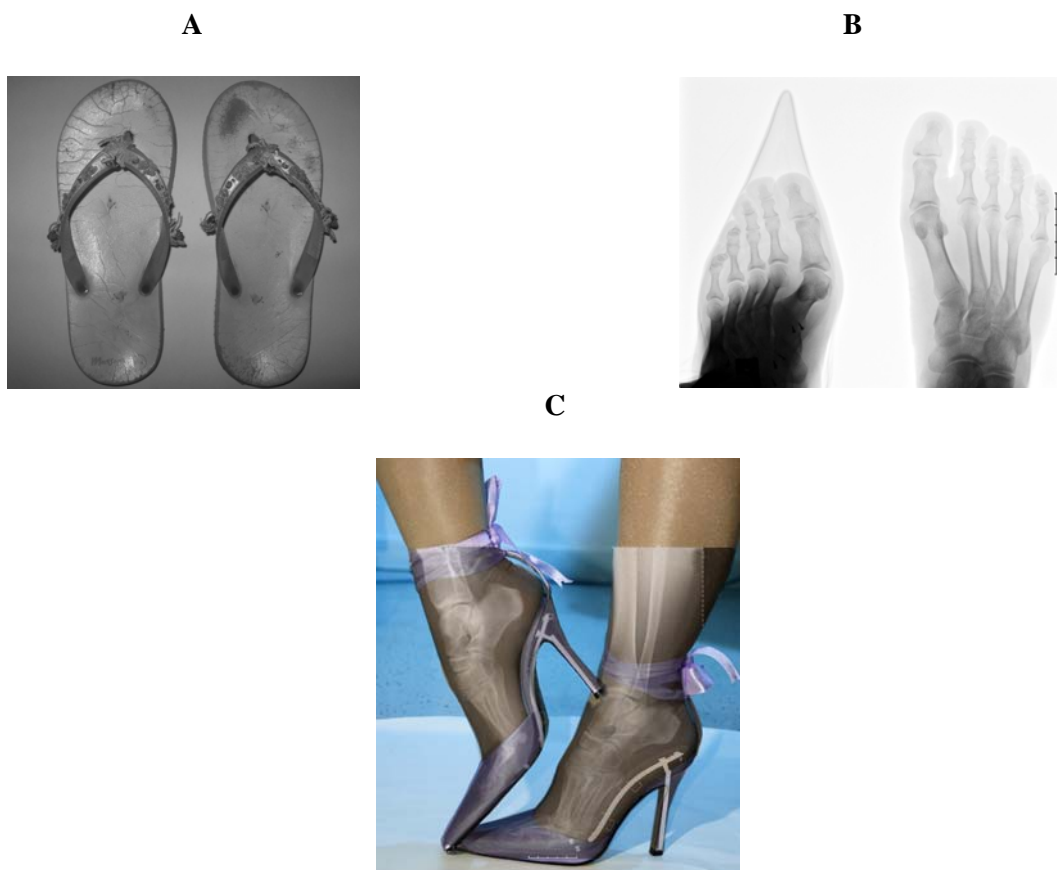
ETIOLOGY

Hallux valgus is known to have controversial etiologies. Extrinsic forces (poorly fitting footwear), hereditary, as well as arthritic/metabolic conditions, neuromuscular diseases, joint hyper elasticity, biomechanical and traumatic causes have been advocated.

Since no muscle inserts into the metatarsal head the big toe is vulnerable to extrinsic forces, in particular, footwear with narrow, pointed shoes.

In a study from China, approximately 33 per cent of individuals in shoe-wearing populations had some degree of hallux valgus in contrast to 2 % of persons who had never worn shoes⁸⁷. In Japan, the traditional Japanese footwear was missing in modern life (Fig. 7 A). Since the late 1970s the sales of western shoes increased the number of operations for hallux valgus in women⁴⁶.

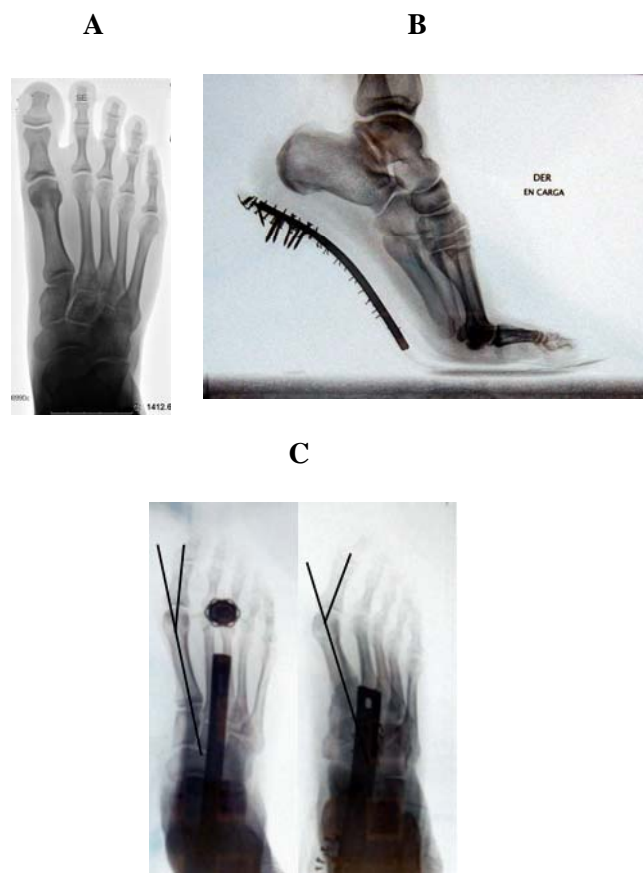
Fig 7. (A) Traditional Japanese like footwear, (B to the left and C) high-fashion footwear



The long term wearing of poorly fitting shoes, usually shoes with a narrow, pointed toe box that squeezes the toes into an unnatural position and high heels (Fig 7 B and 7 C) are particularly problematic⁹³, which is one reason why hallux valgus can be estimated to be nine times more common in women than in men.

In general, the outline of a man's foot is comparable to the outline of a man's shoe. As a result, the typical man's shoe does not constrict the foot. In contrast, the typical woman's high-fashion shoe (Fig. 8) does not conform to the outer dimensions of a woman's foot⁹³. Frey et al.³¹ found that 88 per cent of 356 women wore shoes that were on average 1.2 centimeters narrower than the foot. These authors concluded that the deforming effects of improper shoes on a normal foot frequently can lead to hallux valgus and other problems. Certainly, shoes worn by women are generally less physiological than those worn by men, and shoes of any type may lead to hallux valgus in susceptible persons²¹.

Fig. 8. The same foot in all three radiographs. (A) Woman foot during weight bearing without shoes, (B) with typical woman's high-fashion shoe and (C) to the left comfortable shoe and to the right high-fashion shoe



On the other hand, many individuals who wear fashionable footwear do not develop this deformity. Therefore some intrinsic predisposing factors must make some feet more vulnerable to the effect of footwear and likewise predispose some unshod feet to develop hallux valgus. Those intrinsic factors that could play a role are pes planus, an increased angle between the first and second metatarsals, contracture of the Achilles tendon, generalized joint laxity, hypermobility of the first metatarso-cuneiform joint, neuromuscular disorders, amputation of the second toe (Fig. 9) and cystic degeneration of the medial capsule of the first MTP joint²¹.

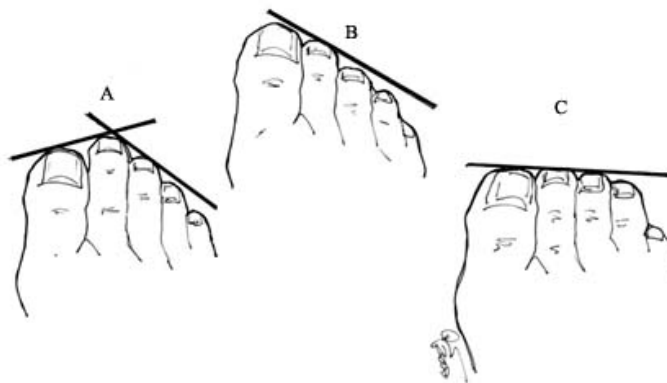
Fig. 9. Hallux valgus after amputation of second toe



Different types of feet are considered to play an etiological role in the development of hallux valgus. Viladot¹⁰⁴ distinguished three types: Egyptian foot, in which the big toe is the longest; Greek foot, in which the second toe is the longest, and squared foot, with equal length of the first and second toe (Fig. 10). In addition with respect to the metatarsals, three types can be distinguished: index plus with a long first metatarsal; index minus, with a short first metatarsal, and index plus-minus, with equal length of the first and second metatarsal. The metatarsus index minus type is believed to predispose to the development of a hallux valgus deformity, in particular with an Egyptian big toe and shoe wearing.

Heredity is also considered to influence the development of hallux valgus in many individuals. Some authors noted that fifty-seven (63 per cent) of the ninety-one patients in their series had a parent who had hallux valgus³⁵ and others reported that a bunion was identified in twenty-nine (94 per cent) of thirty-one mothers of children who had hallux valgus¹⁹.

Fig. 10. Types of foot. (A) Greek, (B) Egyptian and (C) squared

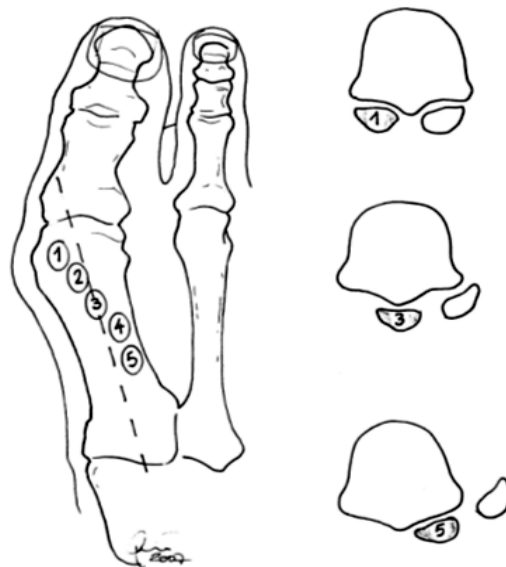


PATHOGENESIS

Hallux valgus is a complex progressive deformity in which the big toe is angled towards the second toe, or even moves all the way under it, causing the joint at the base of the big toe to stick out slightly. To correct the deformity, one needs to understand its pathogenesis.

In this deformity, there is a disruption of the intricate balance previously described. No muscle inserts into the metatarsal head, therefore, once the big toe becomes destabilized and begins to move laterally, the muscles, which previously acted to stabilize the joint, develop into a deforming force since their pull is lateral to the long axis of the MTP joint²¹. The metatarsal head migrates not only medially, resulting in metatarsus primus varus, but often also dorsally, while the proximal phalanx becomes laterally deviated and eventually displaced. The medial capsule and supporting structures become attenuated, and the lateral structures contract. With progressive deformity, the sesamoids may become laterally positioned relative to the first metatarsal head (Fig 11), since they remain attached to the second metatarsal (through the intermetatarsal ligament and the adductor hallucis muscle) (Fig. 5) and to the proximal phalanx. The crista (which normally acts to stabilize the sesamoids) may flatten as they keep on lateral to the medially displaced metatarsal head. The big toe may become pronated (Fig. 12), with the abductor hallucis coming into a more plantar position, where it is less effective in preventing further lateral deviation of the proximal phalanx. The laterally deviated proximal phalanx may push the metatarsal head medially, further accentuating the deformity.

Fig. 11. With progressive deformity, the sesamoids may become laterally positioned relative to the first metatarsal head. One to five represents progressive lateral location of the medial sesamoid as observed with increasing hallux valgus deformity



The plantar aponeurosis and the windlass mechanism also contribute significantly to the progression of the deformity. As this dynamic joint deformity is occurring, the medial eminence often progressively enlarges. The medial bursa develops in response to the excessive pressure of shoes over this prominence. The resultant reduction in plantar pressure under the first ray leads to insufficiency of

the first ray and overload of the lesser rays. As a result, the second toe may claw and eventually the second metatarsophalangeal joint will dislocate⁷⁷.

Fig. 11. Hallux valgus deformity with pronation of the big toe



DIAGNOSIS AND PATIENT EVALUATION

Hallux valgus is a common problem encountered by the orthopaedic surgeon. This condition is often associated with pain or discomfort, especially in women⁴⁶. The primary symptom of hallux valgus is pain over the medial eminence. Pressure from footwear is the most frequent cause of this discomfort. Bursal inflammation, irritation of the skin, and even breakdown of the skin may be noted¹⁸. Pain may also be felt in the distribution of the dorsal cutaneous nerve, due to pressure. At times there may be a dislocated second toe that is sitting on top of the big toe, or a large callus beneath the second metatarsal head as a result of a transfer lesion due to instability of the first MTP joint. Synovitis of the second metatarsophalangeal joint with pain and swelling is particularly painful⁷⁷. Deformities of the lesser toes such as corns and calluses are often a source of symptoms and are largely due to insufficiency of the first ray and overcrowding. It is important to obtain the patient's expectations of what a surgical procedure will accomplish so that the patient will not be inadvertently misled³⁴. The physical evaluation should be carried out while the patient is standing as well as sitting. The neurovascular status, callus formation in the plantar aspect of the foot under the lesser metatarsal heads (transfer lesions), degree of pronation of the big toe, and range of motion, especially of the first MTP joint should be observed. Furthermore, the lesser toes should be examined for associated deformities and callosities. The patient's age and co-morbidity should also be considered.

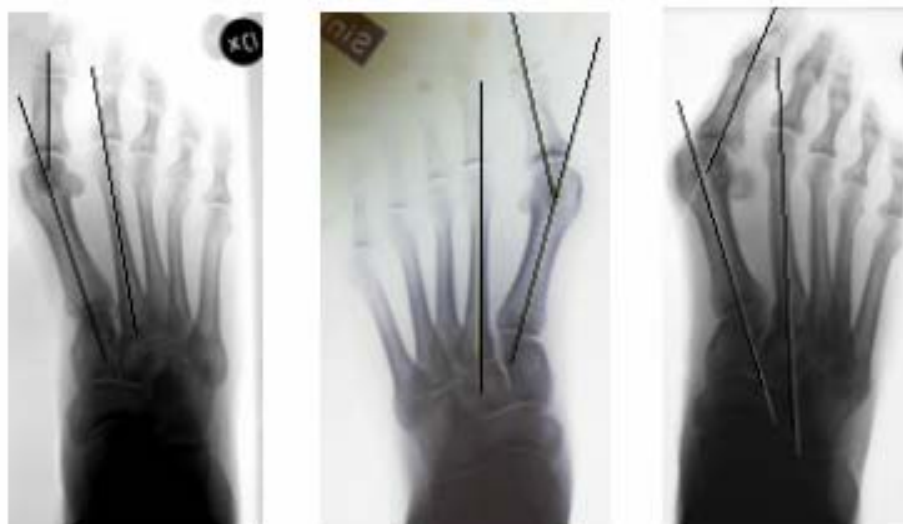
The radiographic examination (Fig. 12) should include a weight-bearing, anteroposterior and lateral radiograph and the following measurements should be recorded:

- A. The degree of hallux valgus angle
- B. The degree of intermetatarsal angle.
- C. The congruency of the MTP joint.
- D. The distal metatarsal articular angle (DMAA).
- E. The degree of arthritis of the MTP joint, if any.
- F. The degree of interphalangeal angle.

The relationship of the first metatarsal head to the sesamoids, and the size of the medial eminence should also be recorded.

In order to help and simplify the decision-making process, using radiological criteria, Mann²¹ found it useful to divide the severity of the deformity into three main classifications: (1) a congruent joint, (2) an incongruent joint, or (3) a joint with degenerative joint disease.

Fig. 12. Different degrees of hallux valgus deformity



NON-OPERATIVE TREATMENT

Hallux valgus can in many cases be treated with accommodative footwear. The provision of a soft leather shoe with extra width and depth of the toe box can alleviate the symptoms in many patients. This may be the treatment of choice in the elderly and those with neurological or vascular compromise.

Only a few studies have considered conservative treatment^{51,97}. The evidence from these suggested that orthoses and night splints are not more beneficial in improving outcomes than no treatment at all. There is neither any evidence to show that orthoses prevent progression of hallux valgus²⁸.

SURGICAL TREATMENT

If the hallux valgus has progressed to the point where the patient has difficulty in walking, or experiences pain despite properly fitting shoes, surgery may be indicated. The aim of surgery is to correct the hallux valgus and to prevent recurrence. Failures and complications occur more often in feet with severe deformities⁵³.

Surgical treatment has been shown to be superior to conservative treatment or no treatment²⁸. Osteotomies of the first metatarsal to correct a painful hallux valgus deformity are among the most common surgeries done on the foot.

In the past, patients with hallux valgus were relegated to barbers to have their calluses trimmed, or to boot makers to have their shoes adjusted. Hallux valgus was considered as belonging to a "low class of surgery"⁴⁸.

One of the first attempts to treat the hallux valgus by surgeons was given by Boyer⁷. Resection of the joint was later reported by Pancoast⁶⁹, Hilton⁴⁰, and

Butcher¹⁰. Hueter⁴² described an excision arthroplasty. Rose⁷⁸ removed the sesamoids in addition to the resection of the head of the first metatarsal and the base of the proximal phalanx. Nelaton⁶⁵ recommended tenotomy of the extensor hallucis longus.

Reverdin⁷⁶ removed the medial eminence and in addition did an osteotomy in which, a wedge-shaped portion of bone was resected proximal to the articular surface of the head of the first metatarsal. This procedure resulted in correction of the DMAA. Broca⁸ performed an arthrodesis of the first metatarsophalangeal joint.

Keller⁴⁹ performed resection of the proximal part of the proximal phalanx of the big toe. Mayo⁶¹ removed the head of the first metatarsal. Thereafter, excision arthroplasty has been reported by Girdlestone in 1937, Stone and Kelikian⁴⁸. Hohmann⁴¹ and Helal³⁸, combined a first metatarsal osteotomy with removal of a medially based wedge. Peabody⁷¹ performed the osteotomy more proximal than Reverdin did. In the United States, Hawkins³⁷ and Mitchell⁶³ popularized osteotomy of the first metatarsal.

The chevron osteotomy was first used by Austin and Leventen³, who already in 1967 read a paper on his osteotomy, although in 1976 Corless¹⁶ described it as a modification of the Mitchell method⁶³. A few years later it was popularized by Johnson et al.⁴⁵.

Lindgren and Turan in 1983⁵⁶ described a method whereby the deformity could be corrected by a distal osteotomy followed by internal fixation.

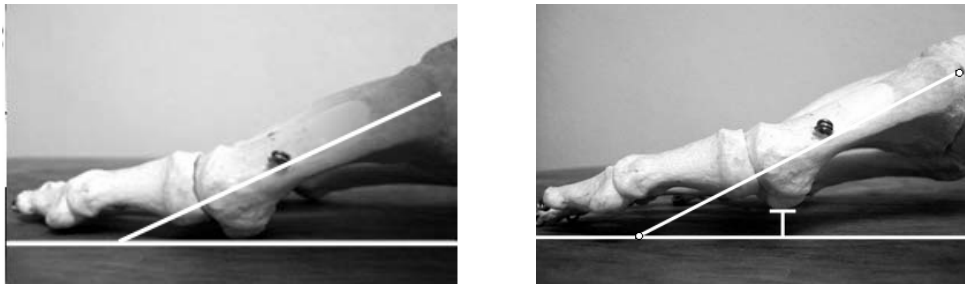
Modification in all planes of the first metatarsal can take place after such osteotomies; antero-posterior (shortening or elongation), sagittal (elevation or depression) and rotation (pronation or supination).

Shortening occurs owing to the thickness of the saw cut and the amount of compression and displacement while inserting the screw for fixation. Shortening also elevates the metatarsal head owing to the declination angle (Fig. 13).

Usually, elevation is due to technical problems or early full weightbearing⁵⁹. In theory, depression should decrease transfer metatarsalgia. Despite the fact that more clinical studies are needed to evaluate it, there is general consensus in the orthopaedic literature that feet with hallux valgus have decreased weight bearing of the big toe and the first metatarsal, causing transfer of weight bearing pressure to the adjacent second metatarsal^{1,13,25,60,68,98,101,103,107}. Numerous authors cite pressure-related topics under the first metatarsal head, the big toe, and second metatarsal head as measures of judging failure and success of bunion surgery. These include transfer metatarsalgia under the second metatarsal^{1,18,25,54,98,101,103}, elevation of the first metatarsal^{6,13,25,60,68,98,101}, and decreased weight bearing on the big toe and/or first metatarsal as sources of failure^{1,13,25,54,60,98,101}. Conversely, plantar flexion of the first metatarsal^{24,60} increased weight bearing pressure under the big toe and first metatarsal head²⁴, and improvement of second metatarsalgia are cited as proof of surgical success²⁴.

Rotational changes (pronation) occur frequently in patients with hallux valgus. In a mathematical model study Kay et al⁴⁷ have shown that if a 15 ° corrective angle and a proximal to distal direction of the saw of 20 ° is used, the head of the first metatarsal is supinated by 5.27 °.

Fig. 13. The declination angle is determined by bisection of the first metatarsal shaft in reference to the weight-bearing surface



When choosing the correct procedure, the length of the first metatarsal has to be considered. In short first metatarsal, base angular osteotomies lead to further shortening of the metatarsal. Displacement osteotomies are preferred. Only a base angular osteotomy and distal rotation osteotomy can correct high levels of DMMA in severe intermetatarsal angle⁶⁷.

The selection of the surgical procedure for hallux valgus depends on a number of factors, such as, the patient's age, physical examination and radiographic evaluation.

The ideal hallux valgus repair must achieve the following results:

- A. Correction of the HVA, the IMA and the DMAA
- B. Attain a congruent MTP joint
- C. Realignment of the sesamoid bones
- D. Adequate range of motion of the MTP joint
- E. Stability so that re-displacement does not occur.
- F. Maintenance of the length of the first metatarsal to prevent the development of transfer lesions and metatarsalgia. Similarly, dorsiflexion, with the resultant elevation of the metatarsal head, should be avoided.

The different kinds of procedures that can be used to correct the hallux valgus deformity can be grouped into:

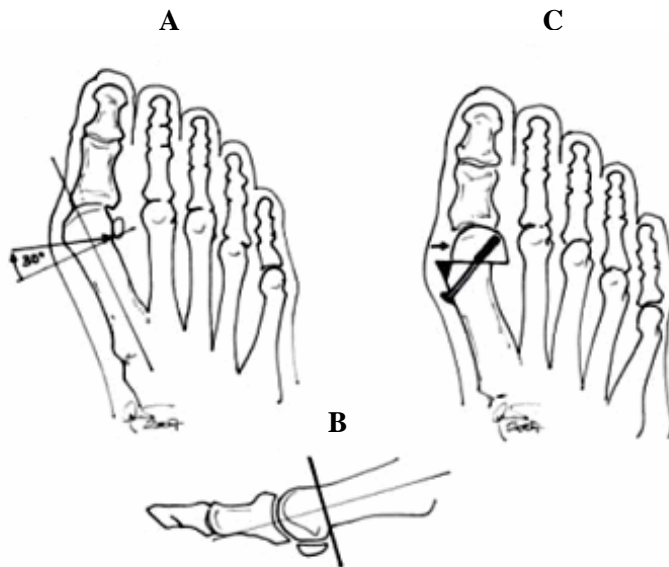
- A. Osteotomy of the proximal phalanx of the big toe
- B. Osteotomies of the first metatarsal, which can be done proximally, in the shaft or in the distal part of the bone.
- C. Osteotomy of the first cuneiform bone
- D. Arthrodesis of the first MTP joint
- E. Resection arthroplastic
- F. Distal soft tissue procedure
- G. Arthrodesis of the cuneiforme-first metatarsal joint
- H. A combination of two or more of these mentioned procedures

The two distal procedures used in the prospective randomized trial in this thesis, the Lindgren⁵⁶ and the chevron osteotomy³, are described in detail below.

Lindgren osteotomy

The Lindgren osteotomy was performed as described by Lindgren and Turan⁵⁶ (Fig. 14). The osteotomy is sub-capital and extra-articular. A dorsomedial incision over the distal part of the first metatarsal was made. The skin incision was straight and placed medial to the extensor hallucis longus tendon. The dissection was carried out to bone and the saw blade was aligned half way in-between the perpendicular long axis of the first metatarsal and the plantar aspect of the foot. A transverse osteotomy was performed at a 30° angle from the long axis of the metatarsal shaft (Fig. 14). The distal fragment was then displaced laterally, and slightly plantar wards to correct the deformity. The amount of lateral displacement was determined by the correction needed and could be as far as 8 to 10 mm (depending of the size of the metatarsal bone and the IMD). The distal fragment was fixed with a 2.7-mm lag screw, its head countersunk. The residual medial bony prominence of the proximal fragment was excised. No release of the adductor tendon, or the lateral or medial capsular structures was done.

Fig. 14. A diagram of the Lindgren procedure is shown (A to C). The osteotomy is performed at a 30° angle from the long axis of the metatarsal shaft (A) in a transverse direction (B). The distal fragment is fixed with a 2.7-mm lag screw (C)



Chevron osteotomy

The chevron osteotomy was performed as described by Austin³ (Fig. 15) however the incision over the MTP joint was placed straight medially and a tenotomy was not done. The distal fragment was then displaced laterally approximately 4 to 6 mm, depending on the width of the metatarsal head, and the osteotomy site was impacted on itself. No additional holes were placed through the cortex of the proximal metatarsal to anchor the capsular flap. Instead the plantar and dorsal aspect of the flap was tightly closed before the U-shaped capsular flap was placed and reattached. Thus the risk for displacement was minimized. No internal fixation was used.

Fig. 15. The chevron osteotomy is performed at 60° angle (A), lateral translation of the distal fragment 4 to 6 mm (B) and the osteotomy site is impacted on itself. The residual medial bony prominence of the proximal fragment is excised (C)

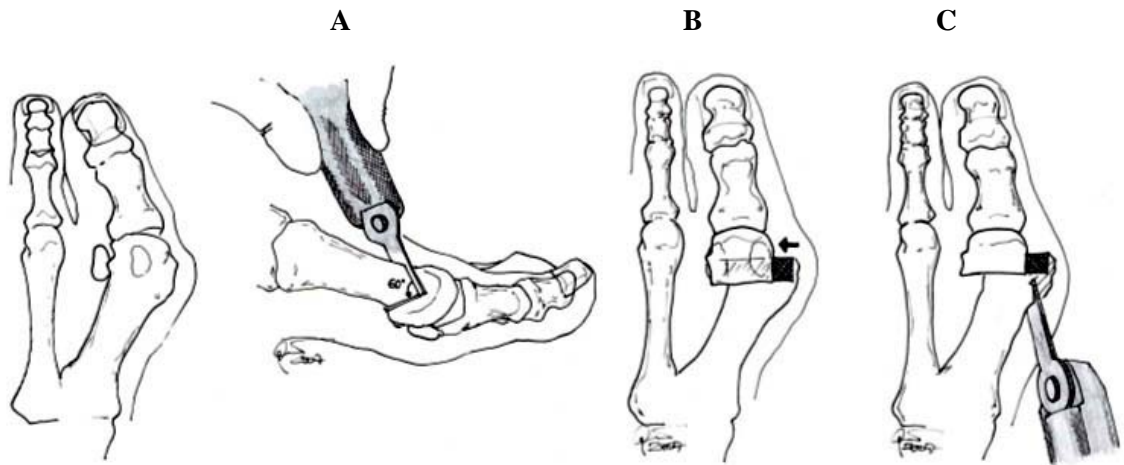


Fig. 16. Postoperative radiographs after (A) Lindgren and (B) distal chevron osteotomy



SURVEY OF THE LITERATURE ON RANDOMIZED TRIALS

According to a systematic review by Ferrari et al.²⁸ surgery (chevron osteotomy) was shown to be beneficial compared to orthoses or no treatment, but when compared to other osteotomies, none of the techniques was shown to be superior. Only one trial has compared osteotomy to arthroplasty¹⁰⁰. There was limited evidence to suggest that the osteotomy resulted in a better outcome. It was notable that high numbers of participants in some trials remained dissatisfied at follow-up (25 to 33 %), even when the hallux valgus angle and pain had improved. A few of the more recent trials used assessment scores that combine several aspects of the patients' outcome. These scoring systems are useful to the clinician when comparing techniques but are of dubious relevance to the patient if they do not address their main concern and such scoring systems are frequently invalidated. Only one study simply asked the patient if they were better than before the treatment²⁸.

Table 1a. Six randomized trials in which chevron osteotomy has been compared with other operative procedure

Author	Trials	Number of patients	Women	Age range	Mean follow-up	HVA	IMA	Complication
(Klosok 1993)	Wilson osteotomy / chevron osteotomy	51	44	23-77	6 m -3 y	W †	X	n.s.
(Resch 1993)	Proximal osteotomy/ chevron osteotomy	79	61	16-78	2 y	PO †	PO †	n.s.
(Easley 1996)	Proximal crescentic osteotomy/proximal chevron osteotomy	75	63	25-73	1 y- 32 m	n.s.	n.s.	n.s.
(Partio 1998)	Proximal osteotomy/ chevron osteotomy	47	44	16-59	3 y	X	X	n.s.
(Basile 2000)	Akin with DSTR/ chevron-Akin	32	29	20-55	1 y	n.s.	X	n.s.
(Ruaro 2000)	Proximal osteotomy/ proximal chevron osteotomy	24	24	21-60	X	n.s.	n.s.	n.s.

HVA= hallux valgus angle; IMA= intermetatarsal 1-2 angle; X= No reported; W= Wilson osteotomy; PO= proximal osteotomy; †= statistically significant improvement; n.s. = no statistically significant.

Table 1b. Continued from above

Author	Trials	ROM	AOFAS	Pain	Patient satisfaction	Footwear	Limited walking
(Klosok 1993)	Wilson osteotomy/ chevron osteotomy	W †	X	X	X	n.s.	n.s.
(Resch 1993)	Proximal osteotomy/ chevron osteotomy	n.s.	X	n.s.	n.s.	n.s.	n.s.
(Easley 1996)	Proximal crescentic osteotomy/proximal chevron osteotomy	X	n.s.	X	X	X	X
(Partio 1998)	Proximal osteotomy/ chevron osteotomy	X	X	X	X	X	X
(Basile 2000)	Akin with DSTR/ chevron-Akin	n.s.	X	n.s.	n.s.	X	X
(Ruaro 2000)	Proximal osteotomy/ proximal chevron osteotomy	X	n.s.	X	X	X	X

ROM= Range of motion; AOFAS= American Orthopaedic Foot and Ankle Society clinical rating for the hallux; W= Wilson osteotomy; †= statistically significant improvement; n.s. = no statistically significant; X= Not reported.

AIMS

To document the prevalence of forefoot surgery in Sweden accompanied with a more detailed clinical characterization based on medical record review on a population sample (Paper I).

To evaluate the reliability of radiographic measurements (angular, linear and sesamoid positions), used generally before and after hallux valgus surgery and appearance (Paper II).

To compare in a prospective randomized trial two distal first metatarsal osteotomies for the treatment of a painful hallux valgus. The hypothesis was that the differences between the surgical procedures would affect the outcome (Paper III).

To assess the quality of life before and after hallux valgus surgery in 100 cases operated on with two distal first metatarsal osteotomies (Paper IV).

To assess whether there was a difference in pain and plantar pressure distribution parameters after correction of the deformity by two distal metatarsal osteotomy techniques (Paper V).

PATIENTS AND METHODS

Detailed descriptions of the patients and methods used can be found in Paper I-V.

Paper I

Patients

All consecutive persons of any age, living in Sweden, who underwent forefoot procedures for any indication between 1997 and December 2000, were included in the study. 214 cases were excluded because of missing record of the procedure leaving 6956 patients in the study population, 5776 (83 %) being women and 1180 (17 %) men.

The median age of all patients in ambulatory surgery was 56 years (SD 16.1 years, range 8-96 years). The median age for women and men was 56 years (SD 16 years) and 55 years (16.3 years), respectively. Regarding in-patient surgery the median age of all patients was also 56 years (SD 18.5 years, range 3-94 years). The median age for women and men was 56 years (SD 18.6 years) and 55 years (18.4 years), respectively.

In the medical records survey 680 patients were included in the study. 363 cases were excluded because the diagnosis was other than hallux valgus (Table 2).

Table 2. Summary of patient's accountability in studies I-V

	Paper Ia ^a	Paper Ib ^b	Paper II	Paper III	Paper IV	Paper V
Assessed for eligibility	7170	1043	100	115	100	25
Did not meet inclusion criteria	-	363	-	8	6	-
Excluded from the study	214	363	-	15	6	3
Included	6956	680	99	100	94	22/13
Lost to follow-up	-	-	-	9 (4.7 y)	2	1
Re-operation	-	-	1	1	-	35
Available for the analysis	6956	680	99	99 (1 y)/90 (4.7 y)	92	35 (6m)/34(1y)

^a Paper Ia= All patients undergoing forefoot surgery registered in the National Swedish Patient Register during 1997-2000; ^b Paper Ib= Patient from a defined population sample (Stockholm) where medical records were analyzed; y= year;

Methods

Data on both ambulatory surgery (2000) and in-patient surgery (1997-2000) were collected. The data were processed to quantify the frequency of different surgical methods as well as the regional distribution.

Regarding hallux valgus surgery (2000), clinical and radiographic data were extracted from patient records in a population sample (Stockholm). A chart was designed to include demographic data, with an emphasis on the patients' co-morbidities, choice of the procedure and time to return to work.

Particular questions addressed satisfaction (yes or no), asymptomatic gait, complications and re-operation. Independent examiners made hospital visits and completed the charts.

Paper II

Patients

One hundred patients randomized to Paper III were included in a retrospective study to evaluate the reliability of angular, linear and sesamoid position measurements as well as the cosmetic outcome in hallux valgus surgery.

The study population included ninety-four females and six males with a median age of 51 years (range 16-76 years). One patient in the chevron group was re-operated at six months after the initial surgery and therefore excluded from the one year analysis. This was not commented in Paper II; however the statistical calculation and results at one year were performed on 99 patients (Table 2). Consequently in Fig 1 page 845 n= 200 should be 199 in both radiographs and photographs and n= 100 postoperative should be 99 correspondingly.

Methods

Two independent observers reviewed the radiographs and photographs from one hundred patients, after surgery (two different first distal metatarsal osteotomies).

Radiographs were taken preoperatively and one year postoperatively following one of two first distal metatarsal osteotomies. Fifty patients (50 radiographs) following a Lindgren osteotomy⁵⁶ and forty-nine patients (49 radiographs) after a distal chevron osteotomy without a soft tissue procedure³.

The observers measured the hallux valgus angle according to Miller⁶², used two different methods to make linear measurements on the intermetatarsal distance⁷⁴ and also compared two different systems to record the position of the sesamoid bones⁸⁸. In addition, the two observers viewed black and white copies of the photographs for each patient and the photographs were evaluated in two ways.

All measurements were done on two separate occasions with at least one week interval between them.

Paper III

Patients

Between January 1999 and February 2002 one hundred fifteen consecutive patients referred to our clinic were assessed for eligibility. Fifteen patients were excluded from the primary analysis because of rheumatoid arthritis (n=4), previous surgery (n=4) or refusal to participate (n=7). One hundred patients were randomized to a prospective study where two distal first metatarsal osteotomies for the treatment of a painful hallux valgus were compared to test the hypothesis that the differences between the surgical procedures would affect outcome. The mean age of the study population was 48 years (16-76 years). The sex distribution was the same as in Paper II.

Criteria to enter the study included patients between 16-80 years of age, hallux valgus angle of 20° up to 44°, intermetatarsal 1-2 angle (IMA) up to 20°, distal metatarsal articular angle (DMAA) up to 25°, no radiographic evidence of degenerative metatarsophalangeal (MTP) arthritis, and persistent symptoms.

Patients were excluded if they had had previous operation on the affected foot or suffered from diabetes, peripheral vascular disease, peripheral neuropathy, rheumatoid arthritis or other inflammatory diseases.

Of the one hundred patients included in the study (Table 2), fifty were randomized to a Lindgren osteotomy and fifty to a distal chevron osteotomy without a soft tissue procedure. Ninety-nine patients were available at one year (50 in the Lindgren group and 49 in the chevron group) and ninety at 4.7 years (44 in

the Lindgren group and 46 in the chevron group).

Methods

The procedure for Lindgren or distal chevron osteotomies were unilateral in all patients and were done on an outpatient basis; mostly with an ankle-block (88 %) performed by one surgeon (C.S.) responsible for all procedures.

Outcome measures such as the American Orthopaedic Foot and Ankle Society (AOFAS) clinical rating for the hallux,⁵² EuroQol (EQ-5D) for health-related quality of life⁹ and visual analogue scales (VAS) for pain¹⁴ were employed in addition to radiographic parameters. Also, a questionnaire concerning satisfaction with the outcome of the surgical treatment, the patients' perception of the cosmetic appearance, pain relief and the ability to wear preferred shoes, was collected at each follow-up assessment.

One physical therapist, examined the patients preoperatively and at the follow-up.

At 3 to 6 years, the patients were asked by an independent examiner whether they would choose the same procedure again, whether they would recommend the surgery to a friend.

Standardized weight bearing radiographs were taken preoperatively, at one year and at the last follow up an average of 4.7 years postoperatively. Measurements of the HVA, the IMA, the reduction of the IMA (intermetatarsal 1-2 distance-IMD-), the position of the sesamoids and the DMAA were performed on all cases at a later date in random order by one trained independent observer.

Under-correction was judged as a final hallux valgus angle greater than 16°³⁵. For the determination of joint congruency⁷³, the relationship of the articular surface of the base of the proximal phalanx to the metatarsal head articular surface was considered.

Paper IV

Patients

One hundred patients randomized to Paper III were included in this study. Rather than measuring the differences between the groups, we focused on the quality of life of patients with hallux valgus. We analyzed only the female population (n= 94) since SF-36 is sex specific and a sub analysis of the remaining six patients (males) was precluded due to the small sample size.

The inclusion and exclusion criteria were the same as in Paper III. Two patients were lost to follow-up (Table 2). Ninety-two patients were left for analysis. Of these, ninety-one were included in the analysis of the HVA (mild and moderate deformities) and eighty-eight for the IMA (moderate and severe cases).

Methods

Assessments were made preoperatively and at twelve month postoperatively. Measures used were the quality of life (QoL) according to SF-36⁹⁰, a disease specific score the American Orthopaedic Foot and Ankle Society's (AOFAS) clinical rating system for the hallux⁵², the radiographic severity of the deformity, the possibility of wearing the preferred choice of shoes and satisfaction with the treatment (questionnaire and also a visual analogue scale).

The pre- and postoperative QoL scores were compared with the score in the general population.

The radiographic measurement of the degree of the deformity (HVA and IMA)

was done by an independent observer⁸². The preoperative data on the HVA and IMA was divided into groups with different degrees of deformity. The postoperative data was split into corrected angle vs. under-corrected angle.

Paper V

Patients

The last twenty-five patients (mean age 49 years, range 20-67 years) previously randomized to distal chevron or Lindgren first metatarsal osteotomy were assessed for eligibility to evaluate prospectively whether there was a difference in pain and plantar pressure distribution after correction of the hallux valgus deformity by two first distal metatarsal osteotomies. All patients were women. The inclusion and exclusion criteria were the same as in Paper III.

Three patients, all from the chevron group were excluded because they did not appear for the appointment (n=2) or refused to participate (n=1), leaving twenty-two patients in the study population. Of these, all returned for the full follow-up except for one in the Lindgren group failing to appear for the twelve month examination. Only the analysis of the plantar pressure data at twelve month follow-up was excluded in this patient.

The feet of thirteen age matched control subjects with a mean age of 50 years (range 23-62), with no foot deformity and no foot complaints were compared with the feet of operated patients. These healthy subjects were asked to answer a verbal questionnaire screening for lower-extremity surgeries or chronic pain. Subjects were also asked about history of neuropathy, diabetes or other systemic disease and were screened for hallux rigidus, hallux valgus, severe pes planus, severe pes cavus and other deformities. Subjects who passed the questionnaire and the physical examination were admitted to the study after signing a volunteer consent form.

Methods

Plantar pressure data were recorded using Pedar system insoles (Novel GmbH, Munich, Germany) (Fig 16). Subjects were instructed to walk along a 10 m walkway at a self-selected speed and the middle 6 m were designated for data collection to minimize the effect of acceleration and deceleration.

Two trials were conducted for each patient or subject at each examination and the second trial was used in the analysis in all cases. The following regions were considered: heel, midfoot, lateral forefoot, central forefoot, medial forefoot, toes II-V, big toe and total foot (Fig. 17).

Data was collected pre-operatively, at six and 12 months after surgery. Results of the combined operated group were compared with the age-matched control group.

The pre- and 12 months postoperatively range of motion of the operated foot in the first MTP joint as well as pain on motion was assessed and compared with the unoperated contralateral foot as well as with the feet of the healthy subjects. The American Orthopaedic Foot and Ankle Society (AOFAS) clinical rating for the hallux⁵² and the visual analogue scale (VAS) for pain¹⁴ during different activities were also applied.

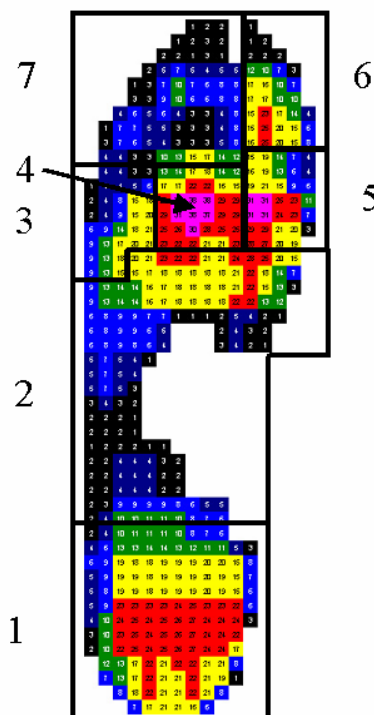
The health status of the patients was measured before, at six and 12 months after the operation using a general-health questionnaire (SF-36)⁹¹. The SF-36 scores were also compared with the healthy group.

Standardized weight-bearing radiographs were taken preoperatively and 12 months postoperatively. Measurements of the HVA and the IMA were repeated in random order by an independent experienced observer.

Fig. 16. The insoles are 2.5 mm thick and consist of an array of 99 capacitive pressure sensors distributed across the insole



Figure 17. Anatomical masks, 1: heel, 2: midfoot, 3: lateral forefoot, 4: central forefoot, 5: medial forefoot, 6: hallux: 7: toes II-V.



Randomization (II, III, IV, V)

Using a computer-generated list, randomization was guaranteed by preparing numbered sealed envelopes (one for each patient) containing the name of the procedure to be followed (Lindgren or chevron) before the start of the study. Neither the patients, nor the members of the study team, were aware of treatment assignment until after clinical and radiographic examination of the patient, the relevant envelope was opened and the randomized operation to be performed was communicated to the patient. The same patients randomized in Paper III (prospective trial) were examined in Paper II (reliability) and Paper IV (quality of life). The last 25 consecutive patients from Paper III were included in Paper V (plantar pressure distribution).

Statistical methods (I – V)

In all Papers the data was analyzed using SPSS/PC software version 11.0 (Chicago, IL) for Paper II, III and V, version 14.0 for Paper IV and version 15.0 for Paper I. In all tests a p value of less than 0.05 was considered statistically significant. All tests were two-sided. Power analysis was performed for Paper III and V.

In Paper II the limits of agreement⁵, the intraclass correlation coefficient⁸⁶ and weighted Kappa statistic were used²⁹.

In Paper III, normally distributed independent samples were tested for differences with Student's t test and non-normally distributed continuous data with the Mann-Whitney U test, which was also used for ordered categorical data. Paired t -tests and Wilcoxon signed-rank test (for nonparametric variables) were used to compare pre- and postoperative data within the groups. Categorical variables were compared with the X^2 test. The position of the tibial sesamoid was tested for differences with the chi-square test, and Fisher's exact test when the groups contained small numbers (< 5). Multiple regressions analysis, analysis of variance (ANOVA), and analysis of covariance were used as well.

In Paper IV, the raw scores on the SF-36 scale were calculated for all patients and converted to a 0–100 scale using the formula specified in the scoring manual for SF-36.⁹⁰ Means for the study population were compared to normative data from the general female population in Sweden. Confidence intervals for mean differences were also calculated. Associations between health-related QoL, AOFAS, and possibility to wear the preferred choice of shoes and HVA and IMA correction were calculated with Kendall's tau-b. X^2 - tests were performed to assess whether the proportions of patients satisfied with the choice of shoes were different in corrected and under-corrected angle categories (HVA and IMA), AOFAS categories and in satisfied and dissatisfied patients. To determine whether the postoperative freedom of choice of shoes was associated with the QoL, analyses of variance (ANOVA) was performed. Differences in QoL in the groups according to the degree of the HVA and IMA (mild, moderate and severe) were also analyzed using ANOVA.

In Paper V, data was also analyzed using the SAS statistical package. The parameters analyzed for each of the different foot regions were contact area, peak pressure, maximum mean pressure and contact time. Results were analyzed using a three-way repeated measures ANOVA with one between group factor *method* (chevron or Lindgren) and two within-group factors *foot* (operated, unoperated) and *time* (pre-operative, six or 12 months). Correlations were calculated for pressure distribution parameters compared to the two VAS factors "pain at rest" and "pain during barefoot walking" for the chevron and Lindgren patients pre- and postoperatively (12 months).

Ethics

The entire project was approved by the Ethical committee at Karolinska University Hospital, Huddinge (Dnr: 146/02 paper I, Dnr: 398/98 paper II, Dnr: 04/459 and 398/98 paper III, Dnr: 04/607 and 398/98 paper IV and Dnr: 398/98 paper V).

The studies were performed in accordance with the Helsinki Declaration. All patients in Paper II, III, IV and V as well as the healthy group in Paper V gave voluntary written consent before participating in the studies.

RESULTS

The results presented in this thesis are based on studies of patients at our institution (II, III, IV and V), as well as on patients in the Swedish population (I).

Paper I

In the whole country 4.409 procedures for forefoot deformities were reported in ambulatory surgery in 3360 (82 %) women and 779 (18 %) men. 2.547 procedures were performed in inpatient settings in 2146 (84 %) women and 401 (16 %) men. The age distribution in both sexes was characterized by a peak in the fifth decade. The mean age was 54.4 years in ambulatory surgery and 52.7 years in hospitalized patients.

There was a substantial variation regarding the amount of forefoot surgery performed in each region for both ambulatory and inpatient surgery. The pattern was the same when analyzing only hallux valgus surgery.

The number of forefoot and also hallux valgus surgeries per 100.000 inhabitants was lower in rural regions. Hallux valgus surgery was by far the most common procedure regarding forefoot surgery.

The number of hospital days (1.8 for the whole country) also differed between the different regions.

Forefoot surgery was statistically more common in private clinics than in community hospitals ($p < 0.001$).

Regarding the clinical and radiographic survey of the patients with hallux valgus deformity in the area of Stockholm, 680 patients distributed between 12 hospitals (six major hospitals) were available. The vast majority of the patients underwent a distal procedure (69 %), in ambulatory setting (96 %) and ankle block (52 %).

In 47 % of the medical record the indication for surgery was missing. There was also a documented weakness regarding radiographs.

Paper II

The interobserver and intraobserver agreements for the hallux valgus angle using coefficient of repeatability measures were 4.4° and 3.7° (Table 3). Intraclass correlation coefficient measures within and between agreements were 0.97 for the HVA. Measuring the intermetatarsal distance from the midline of each metatarsal was superior to measuring the distance from the cortices. Using the visual analogue scale (VAS) to evaluate the aesthetic appearance, the interobserver and intraobserver agreement was 0.59 and 0.79.

Interobserver and intraobserver kappa values for preoperative and postoperative evaluations of sesamoid position with two established methods (Mann or Smith) were 0.47 and 0.70 or 0.65 and 0.75, respectively.

Table 3. Coefficient of repeatability and intraclass correlation coefficients for HVA and IMD

	COR			ICC	
		Preop	Postop	Total	
HVA	Inter	3.2°	5.3°	4.4°	0.97
	Intra	3.4°	4.0°	3.7°	
IMD ^a (midlines)	Inter	2.7°	3.3°	3.0°	0.90
	Intra	2.1°	2.7°	2.4°	
IMD ^b (cortex)	Inter	4.0°	4.2°	4.2°	0.75
	Intra	3.3°	2.7°	3.0°	

Data given for the interobserver and intraobserver coefficient of repeatability (COR). ICC= Intraclass correlation coefficients; HVA= hallux valgus angle; IMD= intermetatarsal distance (measuring from midlines^a or cortex^b).

Paper III

AOFAS score and VAS, demonstrated significant improvement in both groups at one-year follow-up (Table 4). Statistical analysis failed to demonstrate any significant difference between the two groups even when the VAS results were dichotomized into VAS < 30 mm (no pain) and VAS > 30 mm (pain).

It was surprising that patients in both groups had more preoperatively pain when walking barefoot than when wearing their usual shoes (Table 5). There was a statistically significant reduction ($p < 0.001$) in the degree of passive plantar flexion at one-year follow-up in the chevron group. The degree of the big toe pronation improved significantly in both groups ($p < 0.001$); however it did not differ between the groups.

There was no significant difference within or between the two groups regarding the presence of metatarsalgia and callosities postoperatively.

There was no difference in results between the two procedures regarding patient satisfaction and health-related quality of life measured using EuroQol (EQ-5D) at the 3-6 years follow-up.

Patients with limitations in shoe ware or who were not satisfied with the cosmetic result had a lower EQ-5D. Hallux valgus angles < 30° and intermetatarsal 1-2 angles (IMA) < 15° improved considerably as a result of both operations. The postoperative improvement of HVA, IMA and intermetatarsal 1-2 distance was greater in the Lindgren group. A remaining postoperative HVA of >16° was more common in the chevron group. Regardless of the methods used to evaluate the position of the tibial sesamoid at one year follow-up; it was significantly more medial in the Lindgren group (Fig. 18).

Other general radiological characteristics are presented in table 7.

At the one year follow-up forty-one of the 50 patients (82 %) in the Lindgren group and forty-one of the 49 patients (84 %) in the chevron group stated that they would choose to undergo the procedure again. At 3-6 year follow-up, 88 % of the patients were satisfied with the procedure in both groups.

The average time for return to work was 5 ±2.4 weeks in the Lindgren group and 4 ±3 weeks in the chevron group (n.s.). Asymptomatic gait was possible after 7 weeks in both groups (± 4.8 in the Lindgren group, and ± 4.3 in the chevron group).

Table 4. Clinical and radiological data in Lindgren and chevron group

	<u>Lindgren</u>		<u>chevron</u>		<i>p</i> -value
	Preop	Postop	Preop	Postop	
AOFAS	42	85	47	85	0.001
VAS	32	3	21.5	2	0.001
Big toe pronation	1.04	0.1	1.06	0.2	0.001
HVA (degrees)	29	15	30	17	0.001
IMA (degrees)	14	8	14	10	0.001
IMD (mm)	30	26	30	27	0.001
Loss of correction (degrees)		2		4	0.001

Mean values shown; ^a *p*-values given for differences between preoperative and postoperative data

Table 5: Pre- and 1 year postoperative VAS score ^a (0-100)

	<u>Lindgren</u> ^b			<u>chevron</u> ^c		
	Pre-op	Post-op	<i>p</i> (pre-post) ^d	Pre-op	Post-op	<i>p</i> (pre-post) ^d
^a Pain at rest	37 (19.3-53.5)	3.5 (1-9.5)	< 0.001	27.5 (11.3-50)	2 (1-4)	< 0.001
^a Pain during barefoot walking	43.5 (20.8-65)	3.5 (2-13)	< 0.001	25 (5-53.8)	2 (1-8)	< 0.001
^a Pain at work	18 (5-50)	2 (1-12)	< 0.001	12 (2.5-48.5)	2 (0.5-3.5)	< 0.001

^aThe 100-mm long visual analogue scale (VAS) anchored by “no pain”= 0 and “worst pain imaginable” =100; The median and interquartile range (P_{25} - P_{75}) shown; ^b N= 50 patients, 50 feet; ^c N= 49 patients, 49 feet; ^d P-values given for differences within groups.

Table 6: Health-related quality of life according to EuroQol (EQ-5D) at 3-6 year follow-up

Variable	Lindgren	chevron	<i>p</i> -value ^a
EQ-5D index score ^b	0.87 (0.21)	0.92 (0.16)	0.1
EQ-5D sub-dimensions ^c			
Mobility	1.09 (0.28)	1.04 (0.20)	0.3
Self-care	1(0)	1 (0)	1
Usual activities	1.17 (0.48)	1 (0)	0.01
Pain/discomfort	1.39 (0.53)	1.27 (0.49)	0.2
Anxiety/depression	1.28 (0.62)	1.19 (0.49)	0.4

Mean values (SD) shown; ^a *p*-values given for differences between groups; ^b EQ-5D index score: range 0.00-1.00, were 1.00 is optimal health; ^c EQ-5D sub-dimension scores: 1= no problem, 2= some problem, 3= extreme problem.

Fig. 17. Postoperative changes in the position of the tibial sesamoid (Fisher's exact test $p= 0.004$)

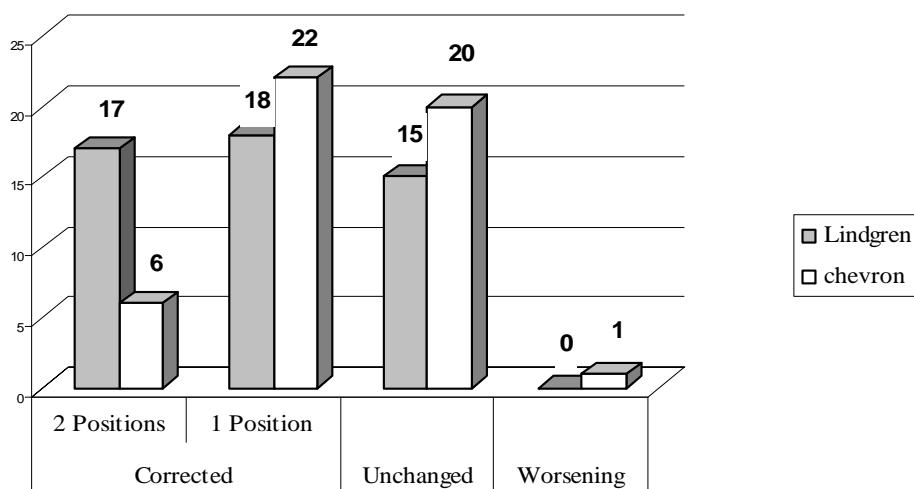


Table 7. General preoperative radiographic parameters found in 100 patients (100 feet)

Variable	n= 100
HVA (degrees)	
- Congruent joints	27 (4)
- Subluxated joints	33 (5)
DMMA (degrees)	
- Congruent joints	17 (5)
- Subluxated joints	12 (4)
Metatarsus adductus angle (number of patients)	
- normal (0–15°)	23
- mild (16–20°)	56
- moderate (21–25°)	14
- severe (greater than 25°)	7
Length of the first and second metatarsals (number of patients)	
- long first metatarsal	25
- equal length	39
- short first metatarsal	36
Pes planus (number of patients)	24
Average pes planus (degrees)	18 (2)

Mean values (SD) shown , unless otherwise stated; HVA= hallux valgus angle; DMMA= distal metatarsal articular angle;

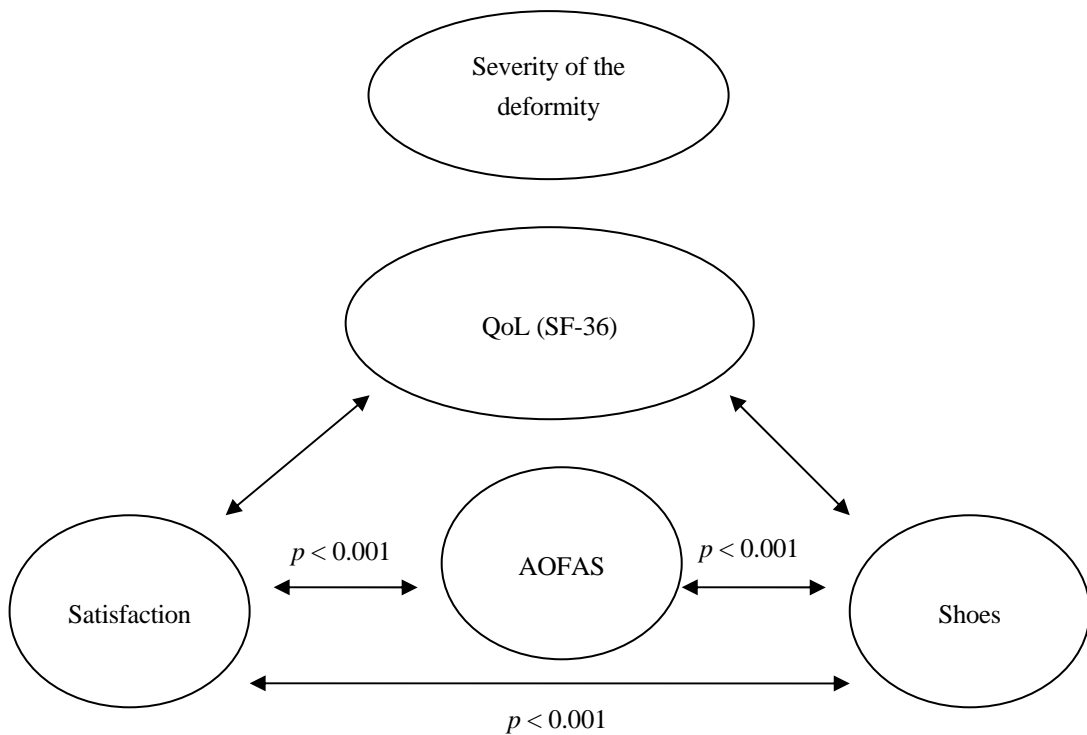
Paper IV

The patient group rated their quality of life lower on several scales preoperatively compared to the general population. The most significant difference noted preoperatively was in bodily pain ($p < 0.001$). No significant difference in this respect was found postoperatively.

QoL outcomes improved significantly postoperatively regarding bodily pain, vitality, mental health and mental component summary. The correction of the deformity did not affect the QoL (Fig. 18). There was no association with the health-related QoL when comparing patients with corrected HVA ($< 15^\circ$) and those with an angle of 15° or more, nor when comparing patients with corrected IMA with those with an angle of 10° or more. Regardless of the extent of correction, the possibility of a free choice of shoe ware and the degree of satisfaction with surgery were associated with a better QoL.

The clinical rating system for the hallux of the American Orthopaedic Foot and Ankle Society's (AOFAS) was not significantly associated with QoL (SF-36). However, the AOFAS showed a high association with the postoperative measurement of the type of shoes ($X^2_{df=1} = 37.9, p < 0.001$), as well as with the degree of satisfaction with the surgical treatment ($X^2_{df=1} = 26, p < 0.001$). At the one-year follow-up, 81 of the 92 patients (88%) stated that they would choose to undergo the procedure again and 87% would recommend the procedure to a friend.

Fig. 18. Illustration showing the associations found in this study



Paper V

The results of this study showed that both osteotomy techniques improved the AOFAS score, reduced the level of pain during different activities, improved the quality of life on several scales and corrected the alignment. However corresponding differences in plantar loading after 12-months follow-up were not seen.

There were no significant differences in plantar pressure distribution parameters between the two operated groups at any occasion. At six months the peak pressure was significantly less under the lateral forefoot in the operated feet compared to the non-operated feet and significantly greater under the central forefoot than in the control group and the medial forefoot than under the non-operated feet, although the operated group had normalized after 12 months.

DISCUSSION

Hallux valgus is a common condition and surgical correction has remained a challenge over the last 100 years with more than 150 procedures being described⁴⁸. Orthopaedic surgeons have attempted to find the perfect osteotomy, and thus developed several surgical procedures, which include modifications as well as modifications of modifications.

The key to understanding hallux valgus is to appreciate that there are both static and dynamic deformities occurring simultaneously in a given person.

Modern orthopaedic surgical techniques aim to correct deformity at the site of origin and recognize the biomechanical abnormality within the weight-bearing foot, with the intention of restoring normal forefoot loading⁸⁹.

For mild and moderate deformities, distal osteotomies of the first metatarsal joint such as the chevron³, or Mitchell techniques⁶³ are used. In Sweden, since the late 1970s the Lindgren⁵⁶ osteotomy is frequently used.

The chevron and the Lindgren osteotomy allow:

- a) Lateral displacement of the distal bone fragment thus reducing the IMA,
- b) Plantar displacement, in an attempt to increase the load of the first ray,
- c) Elongation in cases of a short first metatarsal,
- d) Shortening in cases of a long first metatarsal.

In addition, both osteotomies avoid the complication of metatarsus elevatus associated with proximal metatarsal osteotomies.

The patients in our series were allowed to bear weight on the heel in a postoperative shoe and then immediately return to full weight-bearing when the first dressing was removed at three weeks, without any significant complications.

Paper I

The prevalence of hallux valgus is unknown, and appears to vary between different populations, but in all studies females are affected more often than males²⁸. In unshod populations, the prevalence is around two per cent^{58,87}. In shod adult populations the prevalence in women has been reported as up to 44 per cent²⁶ and in men the prevalence is up to 22 per cent^{23,43}.

Each year, at least 24.000 foot surgeries are done in Sweden⁶⁶. The Swedish National Inpatient Register has a complete set of data on all admissions and a high validity⁶⁴.

The study underlines the significantly higher prevalence of foot problems in women. The choice of footwear is a major contributing factor to forefoot pathology such as hallux valgus, and lesser toe deformities^{22,30}. Wearing shoes substantially narrower than the foot has been associated with corns on the toes, hallux valgus deformity and foot pain, whereas wearing shoes shorter than the foot was associated with lesser toe deformity. In this study, more than half of reported ambulatory surgical procedures for forefoot deformities were done because of hallux valgus.

The indication for hallux valgus surgery is persistent symptoms despite conservative measures. In the Stockholm region this was documented in only 44 % of the records. Benvenuti et al⁴ found significant associations between foot pain and the presence of big and lesser toe deformities, Leveille et al⁵⁵ found no relationship between severe foot pain and toe deformities. An explanation for this disparity may lie in the different definitions of foot pain used in each of the studies³².

The survey of the medical records showed a serious documentation weakness.

Many of the patient charts comprised only a few lines and lacked information regarding important items like the prescription used, patient's degree of satisfaction with the treatment, time to return to work and complications. Surprisingly, in many records preoperative radiographic evaluations which are important for preoperative planning in order to decide the level of the osteotomy were missing. Postoperative radiographs essential for evaluation of the results were also missing in many cases. To assure the quality of care it is important not to underestimate the complexity of the hallux valgus deformity and the importance of radiographs in order to detect possible complications.

The study showed that forefoot surgery is most frequently done in ambulatory settings using an ankle block.

There was a considerable variation between the different regions regarding forefoot surgery, which was more common in urban than in rural regions. One possible explanation is that the availability of surgeons with an interest in foot surgery is better in metropolitan areas; another explanation could be that people in rural areas prefer comfortable and wider shoes.

Forefoot surgery was more frequent in private clinics than in public hospitals ($p < 0.001$) which are in line with their different treatment profiles. Probably the number of foot surgeries in private clinics is even higher since procedures registered in the private health system comprise, in the vast majority of cases, only procedures performed by county council assignment. Operations performed on insurance patients or patients paying the full charge themselves are not recorded in the National Swedish Patient Register⁶⁶.

Our results support the idea that differences in footwear characteristics may be at least partly responsible for the sex difference, as women wear shoes that are smaller relative to their foot size compared to men. Hallux valgus surgery was by far the most common procedure. The prevalence of forefoot- and hallux valgus surgery differed between the 6 major regions in Sweden. It was more common in urban than in rural regions as well as in private clinics than in community hospitals.

Paper II

Radiographic parameters are the main criterion used for selecting procedures. As proof of surgical failure or success, the inter-intrareliability of angular, linear and sesamoid positions measurements was assessed.

In many clinical research studies of hallux valgus surgery, three important measurements have been used as primary outcome measures: the hallux valgus angle^{37,62,63,84,102}, the intermetatarsal I-II angle^{75,81} and the sesamoid position^{18,35,60,81,88,92}. In addition, the distal metatarsal articular angle^{11,18,73} and the joint congruency^{17,73} have often been considered.

The use of these quantitative measurements in assessing hallux valgus deformities is based on reliability, and providing a constant value for comparison of different studies⁸⁰. On the other hand, the cosmetic appearance of the foot, obviously an important factor for patient satisfaction^{12,36,45,85}, was often overlooked and there were no objective outcome parameters for the cosmetic result.

Studies have evaluated radiological interobserver and intraobserver reliability in hallux valgus surgery^{11,15,20,75,84,105} but none with the two first distal metatarsal osteotomies. In contrast to other procedures for cosmetic enhancement, e.g. breast reconstruction⁵⁷ there are no reports of reliable methods to evaluate cosmetic results in hallux valgus surgery.

Hallux valgus outcomes in the literature are difficult to assess because

physicians use different methods. Caution should be exercised in the interpretation of the data because of potential errors. The radiographic measurement of HVA and IMA has poor reproducibility with regard to the X-ray beam angle, foot placement and choice of bony landmarks resulting in difficulty with inter- and intraobserver reliability. Strict standardized procedures would have to be adhered to in order to ensure an accurate assessment of the difference between pre-operative and post-operative measurements. The radiological methods used in the measurement of forefoot surgery must be correctly applied. The accurate assessment of the outcomes depends on the use of reliable and valid outcome instruments. Our study showed that the measurement of the hallux valgus angle according to Miller⁶² and the linear measurement of the intermetatarsal distance (between midlines) meet these criteria with excellent reliability preoperatively and postoperatively. This was not the case for cosmetic evaluation. The visual analogue scale used to evaluate the aesthetic result was equally reliable as two common methods used for grading of the sesamoid location.

Paper III

More than 150 operations for correction of hallux valgus have been described in the literature, however despite the high number of surgical methods, according to a recent review²⁸ only a few comparative randomized studies have been published.

Many of the procedures for hallux valgus are adaptations of a core set of basic operations. Even so, most of the most frequently used basic operation types have not been compared with each other within randomized trials.

There is also a paucity of validated assessment criteria in many published articles. This makes it difficult to draw conclusions from their results.

We have prospectively compared two types of distal metatarsal osteotomies, with or without internal fixation for hallux valgus irrespective of the degree of deformity, for the treatment of a painful hallux valgus. In theory, the final position of the metatarsal head should be easier to predict with a distal procedure than a proximal one. Reports of hallux varus and postoperative osteoarthritis are more common with proximal osteotomies⁶⁰. Patients tended to experience less morbidity with distal osteotomy compared with proximal osteotomy³³. Malunions can be more forgiving in the distal location than proximal. Jahss et al.⁴⁴ pointed out that a 15° dorsal elevation of a distal procedure elevated the weight bearing metatarsal head 2.8 mm. Proximally, however, a 15° dorsal elevation cause a greater than 5 times worse elevation of the metatarsal head, totaling 15.2 mm and this situation increases the risks of a transfer metatarsalgia. Distal procedures have been associated with lower degrees of correction, but on the other hand the risk of transfer metatarsalgia is minimized.

There are some controversies in the orthopaedic literature concerning proximal osteotomies and the effect of the procedures on second metatarsalgia. Mann et al.⁶⁰ reported that 63 % of transfer lesions resolved and no new painful transfer lesions developed after surgery; however, in other studies^{96,103} the incidence of new transfer lesions postoperatively varied from 5 % to 30 %. In our series the risk of transfer metatarsalgia has been minimized.

The general current consensus is that an IMA of 15° should be used to decide the level of the osteotomy. Nevertheless, in earlier publications many authors^{16,45,79} have included high IMA in the treatment with distal procedures with good results.

We consider the IMA as an important guideline but we do not believe that an IMA $> 15^\circ$ alone precludes a distal procedure. The inability to obtain good correction can also have other reasons; one being that the sesamoids can cause difficulties for a straight lateral displacement of the distal fragment.

Resch et al.⁷⁴ have previously shown that although proximal osteotomy gives a slightly better correction of the hallux valgus angle and the IMA than chevron osteotomy, the outcome, i.e. the patients' subjective rating, after both procedures is the same. Furthermore, Thordason et al.⁹⁴ recently found that the degree of deformity, amount of correction, or type of operation did not determine the outcome. The same author⁹⁵ has also stated that the severity of the deformity as measured radiographically did not correlate with any of the outcome scores measured. We found that despite the use of distal osteotomies in patients with high IMA, the clinical and subjective outcomes were still good. No differences between the procedures regarding clinical outcome, patient satisfaction or quality-of-life were found.

The deformities included in this study were higher than those usually recommended. However, it is a well-known clinical experience of foot surgeons that at times, the correction achieved is less than the expected, despite the use of general commonly accepted norms. On the other hand, one may be surprised that just only one measure can correct the whole deformity without an additional procedure. Thus, other factors could play an important role in facilitating or complicating the correction. On the other hand we have previously demonstrated⁸² that there is a reliability error in the measurement of the HVA of 4.4° for the inter- and 3.7° for the intra- agreements. The choice of the method is dependent on such measurement and consequently there is always some inherent uncertainty regarding exact measurements.

Persistent symptoms despite shoe modification were the major inclusion criteria, however three patients in our study had missed to fill in the pain score in the questionnaire but they had pain detected by VAS (visual analogue scores). Our trial showed no significant difference between the two procedures regarding the AOFAS score for the hallux. The comparison of pre- and postoperative pain during different activities, demonstrated obvious improvement.

We found a statistically significant reduction ($p < 0.001$) in the degree of passive plantar flexion at one-year follow-up in the chevron group. This finding is in accordance with studies by Trnka et al.⁹⁹.

Patients operated with Lindgren's osteotomy showed better radiological correction, as well as fewer patients with a postoperative HVA greater than 16° . However, in contrast with other series^{83,99}, this study demonstrated a significant loss of correction of the HVA in both groups at 4.7 years after the operation. We speculate that the reason for this result might be the use of distal osteotomies in cases of increased IMA but when comparing patients with preoperatively normal and elevated IMA:s, there was an equal loss of correction in both groups, i.e. the high IMA values exclude this possibility. Probably one explanation is to have ignored the need of soft tissue surgery. On the other hand, the lateral displacement of the distal osteotomies may tend to relax the adductor tendon and lateral structures⁴⁴. At present we focus more in combining the osteotomies with soft tissue surgery if needed, in an attempt to correct the complexity of the hallux valgus deformity.

Regardless of the type of osteotomy this study has showed that patients with a preoperative HVA $< 30^\circ$ and an IMA $< 15^\circ$ had a statistically significant better correction of the HVA ($P < 0.001$), and the IMA ($P < 0.01$) at one and 4.7 years. Therefore, at present we do not recommend the genuine Lindgren or distal chevron osteotomies for patients with HVA deformities $> 30^\circ$ or IMA $> 15^\circ$. Reciprocally, we believe that those osteotomies can work in larger deformities (HVA deformities $> 30^\circ$ or IMA $> 15^\circ$.) with the addition when needed of soft tissue surgery or a medial closing wedge.

The main design when we conceived this study was to compare two original methods without modifications. The chevron method was first described without internal fixation. We agree with the fact that the addition of internal fixation, actually very accepted, can allow a more lateral displacement of the distal fragment without putting the healing at risk. This study is already done; nevertheless, it is rational to think that if we should use internal fixation in the chevron group, more lateral displacement could theoretically be allowed which would thus better achieve correction. 42 patients in the Lindgren group required hardware removal. A second surgical procedure could represent a challenge with the potential possibility of complications. However this should be considered in the light of the benefits that a stable screw fixation allows. This is also reflected by the current preferred method of osteotomy fixation as observed in up-to date literature.

One may wonder how the “pronation of the hallux was corrected if needed” (Paper III). How is this done with the Lindgren osteotomy and without malrotating the distal metatarsal head? Since the first metatarsal is known to deviate about its longitudinal and vertical axes, pronation and varus deviation of the first metatarsal are linked²⁷. Because the Lindgren procedure is extra-articular there is soft tissue integrity between the proximal phalanx and the head of the first metatarsal. In the cases where we found a “pronation of the hallux“ we performed a de-rotation maneuver. We have not found complications after this procedure. Probably this was the reason why the DMAA could be reduced in the Lindgren group. Vittetoe et al.¹⁰⁵ have showed that longitudinal rotation and varus deviation of the first metatarsal had a significant effect on the radiographic determination of the DMAA.

Twenty per cent of patients stated they needed wider shoes postoperative and one may wonder if they wouldn't have needed surgery if they would have wider shoes preoperatively. When we look closer at their data they had a preoperative HVA 29° (SD 5°) and IMA 13° (SD 2°). Postoperatively they had a HVA 16° (SD 5°) and IMA 9° (SD 3°). The measurement of the largest circumference of the forefoot (usually over the first and fifth metatarsal head) was preoperatively 251 mm (SD 13 mm) and postoperatively it decreased to 248 mm (SD 13 mm). Neither the radiograph nor the physical measurement can explain the need of wider shoes. A possibility could be if transfer lesions are present before or after the operation, it may be necessary to wear cushioned shoes or even insoles following operation. In our study 9 of the patients needing wider shoes postoperatively had new callosities under the second metatarsal head and 5 had metatarsalgia. The high expectations of some patients could also play an important role.

Paper IV

Most research on patients with hallux valgus has focused on complications and reduction of the deformity, but patients are also similarly concerned with the repercussions of surgery in their daily life. Nevertheless, measurements of the general health status and quality of life in relation to foot and ankle surgery have been largely ignored to date⁷⁰. In our study the short Form-36 (SF-36)⁹⁰, was used.

We chose to only include women in this study because it is a well known clinical fact that most patients seeking treatment for hallux valgus are females. One common cause of hallux valgus is the prolonged wearing of poorly fitting shoes, usually shoes with a narrow, pointed toe box that squeezes the toes into an unnatural position. A study by the American Orthopaedic Foot and Ankle Society found that 88 percent of women in the U.S. wear shoes that are too small and 55 percent have hallux valgus³¹. That is why hallux valgus has been estimated to be nine times more common in women than men.

With the use of SF-36 significant differences between the pre- and post-surgery situations were noted, i.e., the health-related QoL of the patients improved significantly over time regarding bodily pain, vitality, mental health and mental component summary.

We used a disease specific score; the AOFAS (the American Orthopaedic Foot and Ankle Society's clinical rating system for the hallux), in an attempt to find an association with the other parameters studied, i.e., the severity of the deformity (HVA and IMA), the possibility of wearing the preferred choice of shoes and satisfaction with the treatment. The AOFAS was not significantly associated with QoL (SF-36). However, the AOFAS showed a high association with the postoperative measurement of the type of shoes, as well as with the degree of satisfaction with the surgical treatment. No association was found between the AOFAS rating and the pre- or postoperative severity of the deformity.

The results of this study confirmed that surgery produces an improvement in the bodily pain domain of general health-related QoL outcomes. Furthermore, the degree of the HVA and IMA corrections, which have been considered important issues in the literature, did not seem to affect the quality of life in this group of patients. Rather, the possibility of wearing the preferred choice of shoes appears to influence the patient's perception of the quality of life. The SF-36 appears to be a relevant tool for evaluating outcome in hallux valgus surgery.

Paper V

Patients with hallux valgus usually develop metatarsalgia as a result of splaying of the foot with displacement of the first metatarsal in a medial and dorsal direction, therefore apart from the hallux valgus correction, the goal of a hallux valgus operation should be the approximation of the first metatarsal head to the original plane of contact¹⁰¹.

In this study in-shoe pressure measurement was used as an objective indication of the biomechanical status of the foot after distal osteotomy surgery. The fact that the clinical assessment showed no significant difference between the two surgical techniques was supported by the pressure distribution results.

Plantar pressure data showed no significant differences between the two surgical methods but significant differences between these groups and the matched healthy subject group, the contralateral unoperated foot and over time. A number of plantar pressure results indicated significant changes six months postoperatively, which were normalized after 12 months. The only parameter significantly different in the combined operated group at 12 months compared to the control group was a smaller contact area underneath the big toe.

The postoperative AOFAS hallux scores showed improvement over the preoperative scores in terms of pain, functional outcome, and clinical alignment. Furthermore, the comparison of pre- and postoperative pain during different activities, measured with the VAS also showed obvious improvements. This result is in accordance with those of a previous study⁵⁰.

In theory, the final position of the metatarsal head should be easier to predict with a distal procedure than a proximal one. There are some controversies in the orthopaedic literature concerning proximal osteotomies and the effect of the procedures on second metatarsalgia. Mann et al.⁶⁰ reported that 63 % of transfer lesions resolved and no new painful transfer lesions developed after surgery; however, in other studies^{96,103} the incidence of new transfer lesions postoperatively varied from 5 % to 30 %. In this study, no new callosities developed under the second metatarsal. Wanivenhaus et al.¹⁰¹ found that the incidence of metatarsalgia declined from 18.6 % preoperatively to 10.9 % postoperatively after a distal metatarsal osteotomy. In the present study we found an increase of metatarsalgia from 18 % to 22 %. A possible explanation could be a minor plantar displacement of the metatarsal head indicated by greater peak pressure under the central forefoot after six months and no significant reduction after 12 months. Conversely, a comparison of the preoperative presence of metatarsalgia or the callosities beneath the second metatarsal with the postoperative findings showed no significant difference.

The quality of life in patients with hallux valgus was significantly lower than in the healthy group.

In contrast with other series⁵⁰ no increase was found in post-surgical first MTP joint plantar flexion. In fact, analysis of the passive range of motion of the first MTP joint revealed a postoperative decrease in plantar flexion in both groups, but maintenance of adequate extension. This finding is partially in accordance with those of Trnka⁹⁹, who reviewed the results of the chevron osteotomy in 43 consecutive patients (57 feet) two and five years postoperatively and found that the passive range of motion of the first MTP joint decreased between the preoperative assessment and the two years follow-up.

The loss of motion after the Lindgren osteotomy was surprising, because the integrity of the joint was maintained. A previous report⁵⁴ demonstrated that stiffness was less frequent after the Wilson osteotomy possibly related to the soft-tissue dissection around the joint. Further studies comparing intra- and extraarticular procedures with a larger number of patients should be performed to investigate this hypothesis. In the present series, the correction of the hallux valgus angle and intermetatarsal angle did not alter the loading pattern.

The results of this study show that both osteotomy techniques improved the AOFAS score, reduced the level of pain during different activities and corrected the alignment but corresponding differences in plantar loading after 12-months follow-up were not seen. The present surgical treatment of hallux valgus with these distal metatarsal osteotomies must be regarded as only partially effective in terms of modifying plantar pressure distribution and in that regard no preference can be given to either of the two methods investigated.

CONCLUDING REMARKS

Hallux valgus is a complex disorder that must be objectively studied and surgically individualized.

Surgery for hallux valgus, while technically demanding, has a high rate of success in appropriately selected patients. However, a small number of patients have poor outcome following surgery.

No single osteotomy can address the wide range of deformity of hallux valgus

This thesis shows that:

- The prevalence of forefoot- and hallux valgus surgery was not evenly distributed in the 6 major regions in Sweden. It was more common in urban than in rural regions. Furthermore, forefoot surgery was more frequent in private clinics than in community hospitals despite common financial sources.

The survey of the medical records in one defined region showed a serious documentation weakness e.g. lack of preoperative and postoperative radiographs and no given indication for surgery in approximately 50 % of the patients.

- Intraobserver reliability was higher than interobserver reliability for intermetatarsal distance, cosmetics, and sesamoid position. Angular measurements were more accurate than linear measurements. Esthetic evaluation was less reliable than radiographic examination, except when compared to sesamoid position measurements.

- There was no difference in clinically outcome between the procedures. Patients operated with Lindgren's osteotomy showed better radiological correction at one year and 3-6 years postoperative. Loss of correction was noted in both groups after 3-6 years. Neither of the osteotomies are recommended for patients with a HVA > 30° and/or an IMA > 15°.

- Hallux valgus patients were in greater pain than the general population. Surgery produced a significant improvement in the quality of life. The severity of the deformity did not influence the QoL, however; the free choice of shoe ware and the degree of satisfaction with the surgery had a positive effect on the QoL outcome. SF-36 is a relevant tool for evaluating outcome in hallux valgus surgery.

- Both surgical techniques resulted in significant clinical and radiographic improvements and reduced the level of pain, although the foot pressure recordings demonstrated no biomechanical effect as measured by plantar pressure distribution.

Strengths and limitations

The strength in this study lies in its prospective and randomized design; that the patients had no history of previous foot surgery or systemic illnesses; a low level of drop out, and that one experienced surgeon performed all operations. Furthermore the follow-up measurements were performed and documented by independent observers not involved in the treatment of the patients.

The weakness of this study is that AOFAS and clinical examination could not be performed by the same observer in the 3-6 year follow-up. In order to avoid the challenges of interobserver variations we instead chose EQ-5D and a questionnaire at this follow-up.

In Paper V the numbers of patients in the Lindgren and chevron groups were not equally distributed. Due to technical problems with the Pedar system we had to limit the time frame of inclusion to the last 25 patients already randomized in Paper III.

Based on the findings of this thesis, future studies of patients with hallux valgus could focus on:

- Randomized, controlled trials with strict study design to elucidate the factors which determine a good outcome.
- Good validated outcome score (standardized assessment criteria)
- Quality of life
- Patient-focused outcome (patient's perception of footwear and satisfactions with the surgery, etc)
- Longer surveillance periods

SAMMANFATTNING PÅ SVENSKA

Trots att hallux valgus är ett vanligt förekommande tillstånd, som står för stor vårdkonsumtion där kirurgi är den etablerad behandlingen, är det vetenskapliga underlaget för behandlingen av hallux valgus kvantitativt litet och av måttlig kvalitet. Det finns bristande evidensbaserade data från randomiserade studier för att man skall kunna välja rätt operationsmetod. Dessutom är prevalensen av framfots- och hallux valguskirurgi inte dokumenterat.

I delarbete I har vi utforskat prevalensen av framfotskirurgi i Sverige. Dessutom har vi utfört en journalstudie i Stockholms Läns Landsting, avseende kliniska och röntgenologiska data för behandling av hallux valgus. I delarbete II har vi utvärderat tillförlitligheten av vissa verktyg som används vid röntgenmätningar, före och efter operation, eftersom dessa parametrar avgör valet av operationsmetod, samt delvis utgör kriterier för om kirurgen var lyckad eller misslyckad. Dessutom användes ett system för utvärdering av kosmetiken efter hallux valguskirurgi. Därefter (delarbete III) har vi utvärderat två olika operationsmetoder för att se om skillnaden mellan metoderna kunde påverka utfallet, i en prospektiv randomiserad studie. Dessutom har livskvaliteten (delarbete IV) före och efter hallux valguskirurgi utvärderats. Slutligen, (delarbete V) har vi utvärderat fördelningen av tryckmönster samt smärta efter de två olika operationsmetoderna.

Delarbete I, en populationsbaserad studie, omfattar patienter inom alla åldersgrupper som genomgick framfotskirurgiska ingrepp utförda i dagkirurgi (2000) eller slutenvård (1997-2000). Epidemiologiska data har extraherats från den nationella patientdatabasen. Kliniska data för patienter som genomgick hallux valguskirurgi extraherades från journalerna i Stockholms Läns Landsting. I delarbete II, III och IV har 100 konsekutivt randomiserade patienter inkluderats. I delarbete II, har röntgenbilder samt fotografier från 100 patienter som genomgått hallux valguskirurgi utvärderats av två opartiska observatörer. I delarbete III, randomiserades 100 patienter till operation enligt Lindgren (n= 50) eller chevron (n= 50) osteotomi. I uppföljningen ingick bland annat American Orthopaedic Foot and Ankle Society (AOFAS) clinical rating for the hallux, livskvalitet i form av EuroQol (EQ-5D), VAS, samt mätning av olika röntgenologiska och kliniska parametrar. I delarbete IV, registrerades livskvalitet enligt SF-36. Andra parametrar som studerades var AOFAS, graden av felställning, skoval samt tillfredsställelse med behandlingen. Före och efter operationen jämfördes patientens livskvalitet med den normala befolkningens. I delarbete V, inkluderades tjugotvå patienter, som skulle genomgå Lindgren eller chevron osteotomi, ut ur den prospektivt randomiserade studien. Dessa studerades preoperativt, vid 6 månader samt 1 år med dynamisk fottrycksmätning, livskvalitet, samt kliniska och röntgenologiska mätningar.

Delarbete I, tillhandahåller omfattande data om prevalensen av framfotskirurgi i Sverige. Prevalensen av framfots- samt hallux valguskirurgi visar stora regionala skillnader. Patienterna är överrepresenterade i storstadsregioner jämfört med landsort. Inneliggande patienter var mer vanliga på privata kliniker än på offentligt drivna sjukhus, trots gemensamma ersättningssystem. Delarbete II, visar att intraobserver reliability var högre än interobserver för intermetatarsal I-II avståndet (IMD), kosmetiken och sesambenposition. Angulära mätningar var mer tillförlitliga än linjära. Utvärderingen av utseende var mindre trovärdig än de röntgenologiska, dock var det mer tillförlitligt än de två väletablerade metoderna för utvärdering av

sesambenposition.

Delarbete III, visade inga signifikanta skillnader mellan grupperna avseende de kliniska resultaten, dock hade patienter som opererades med Lindgren osteotomi bättre röntgenologiska resultat. Radiologisk korrektion förlorades något i båda grupper mellan 3-6 år. Ingen av osteotomierna rekommenderas för patienter med en hallux valgus vinkel > 30 grader och/eller en intermetatarsalvinkel > 15 grader. Delarbete IV, visade att hallux valgus patienter har mer ont än normalbefolkningen. Kirurgi kan förbättra livskvaliteten. Graden av felställning påverkar inte livskvaliteten, dock har möjligheten att välja skodon fritt samt graden av tillfredsställelse efter kirurgi en positiv effekt på livskvaliteten. SF-36 anses vara ett relevant verktyg för utvärdering av hallux valguskirurgi. Delarbete V, visade att båda operationsmetoderna resulterade i en signifikant klinisk och röntgenologisk förbättring och smärtlindring. Dock fann vi ingen biomekanisk effekt på tryckförändringarna. Sammanfattningsvis fann vi inget samband mellan graden av radiologisk korrektion och patientnöjdhet i dessa studier.

Keywords: Hallux valgus; Osteotomi; Prevalens; Tryckmönster; Livskvalitet; Randomiserade studie; Kirurgi

ACKNOWLEDGEMENTS

I want to express my gratitude to those who with their work and enthusiasm guided and support me through this work. I want to thank:

Li Felländer-Tsai, Professor at the Department of Orthopaedic Surgery, Karolinska University Hospital, Huddinge, my tutor, for your guidance and support and most for all assistance and helps. “You helped me down hill in Davos and up hill with this thesis”.

Urban Lindgren, Professor at the Department of Orthopaedic Surgery, Karolinska University Hospital, Huddinge, my co-tutor, for many stimulating discussions and constructive criticism, giving needed advice and a little bullying whenever either was needed.

John Sevastik, Professor Emeritus at the Department of Orthopaedic Surgery, Karolinska University Hospital, Huddinge, for introducing me into the field of scientific research.

Irene Jensen, Professor at the Section for Personal Injury Prevention, Karolinska Institute, co-author, for inestimable help “always available”.

Bodil Andrén, co-author, for continuous support and help and Javier Martinez de Aragón, co-author, for invaluable help with the statistics.

Dan Johnson , Zandra Wildemyr, Ann-Sophie Bengtsson, Johanna Adami and Paul Blomqvist, co-authors, for fruitful collaboration.

Toni Arndt, co-author for stimulating discussions on dynamic foot pressure.

Peter Aspelin, Professor at the Department of Diagnostic Radiology, Karolinska University Hospital, Huddinge, for sharing your knowledge and kind support.

Wilhelm Engström, Professor, for invaluable help and efficient linguistic revision.

Elisabeth Berg at the Department of Learning, Informatics, Management and Ethics (LIME) Karolinska Institutet, Helena Bertilsson at the Section for Personal Injury Prevention, Karolinska Institutet and Per Näsman at KTH for invaluable help with statistics.

Xavier Cuscó “Netter” for the very nice medical illustrations (finally I got them at time) and Manuel Llusá for the anatomical picture.

Parisa Kiaei and Max Winerdal for hospital visits and completing the charts.

Lennart Adamsson and former chiefs (Ulf Lindsjö, Göran Sjäodén, Arne Lundberg, Lennart Sjöström, Leif Ryd) at the Department of Orthopaedic Surgery, for encouraging support.

Per Prisell, Jouko Kivioja and Hannu Määttänen for friendly discussions and sharing the dark sides of clinical research.

To all my colleagues and the staff at the Department of Orthopaedic Surgery, former and present, for friendship.

All nurses and other personal at the outpatient clinic, ambulatory surgery (MOP and DKC) and central operation.

Kurt Gerok-Andersson and Börje Åkerlund at the diabetic foot team, for stimulating discussions.

Cathrin Berggren, my secretary, for your invaluable help, taking care of all patients, encouragement and always “taking away” some administrative tasks.

Pia Häll, Chief Secretary, for always being kind and helpful.

Ann-Charlott Nordström, Inga-Lill Sandström and Susann Olsson for administrative help.

Stene Andersson, orthopaedic technician at Aktiv Ortopedteknik for always available to help, given those shoes used during the measurement of plantar pressure distribution.

Anne-Li and Berit Jönsson for all help, generosity and friendship since I came to Sweden.

To all patients participating in the studies, for their contribution.

To Karolinska Institutet for providing me the opportunity to be a PhD-student.

Ramon Cugat and Montse Garcia for providing me since last January the facility to write the last part of this thesis.

Staffan Larsson, photographer, Seija Falk and Lisa Dahlström at the Department of Diagnostic Radiology for the “anonymous woman picture”.

Maria and fantastic Hanna for being there.

My mother and brothers Justo, Ramón, Luis, Ana Belén for always being there when needed during all my life.

This study was supported by grants from the Karolinska Institutet.

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