From

Department Of Molecular Medicine And Surgery

Karolinska Institutet, Stockholm, Sweden

THE RHEUMATOID FOREFOOT - SURGICAL TREATMENT AND EPIDEMIOLOGICAL ASPECTS

Lollo Gröndal, MD

Karolinska Institutet

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Cover illustration: Surgery of the rheumatoid forefoot may have great impact on pain and walking ability. The time for walking 20 m with shoes on from preop to follow-up was significantly ($p<0,001$) reduced in both groups examined in this study. In spite of having a chronic, progressive joint disease and being several years older, the patients walked significantly quicker 6 years after surgery than before. This may be an illustration of the general importance of good foot surgery for these patients.

To Sanna and Lotti, my wonderful daughters
To Mum and Dad in heaven
To my sisters and all near and dear ones

Och när vi dansa yurgen står det klart
att allt som heter yurg är underbart
när Daisi Doody vrider sig i yurg
och jollrar slangen ifrån Dorisburg:

du gammar ner dig och blir jail och dori,
Men gör som jag, jag sitter aldrig lori.

Här slumrar ingen chadwick, putar Daisi,
jag rörs i gejdern, jag är vlamm och gondel,
min deid är gander och min fejd är rondel
och vept i taris, gland i deld och yondel.

Ur Aniara
Harry Martinson

Det finns mitt i skogen en oväntad glänta,
som bara kan hittas av den som gått vilse

T. Tranströmmer

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ABSTRACT

Background: The forefoot is frequently involved in rheumatoid arthritis (RA) resulting in a painful, handicapping deformity. The prevalence stated has long been based on a study from 1956. The most common surgical treatment has been a resection of the metatarsal joints (MTP), initially effective but often connected to recurrence of pain and deformity. Fusion instead of resection in MTP 1 seemed to produce better results. This operation is though technically more demanding. The aim of this thesis was to analyse and optimise the operative technique for fusion in MTP 1, to compare it to Mayo resection in MTP 1 in a prospective, randomised manner and to investigate the frequency and impact of foot problems in patients with RA today.

Results:

- A guide-plate may aid the positioning of the arthrodesis in recommended angles. The rounded cup and cone technique for preparation of the joint surfaces and two crossed cortical screws for fixation resulted in a high healing rate.
- In comparing resection of MT heads 2 to 5 combined with either Mayo resection or fusion in MTP 1, after mean 3 years follow-up, we found excellent patient satisfaction rate, significant reduction of pain and handicap according to the Foot Function Index with no statistically significant differences between the groups. There were no recurrent prominences or tenderness under the forefoot in any group, no recurrent severe hallux valgus in the resection group and no increased risk for painful IP joint problems after fusion. The operating time was significant longer for fusion.
- After mean 6 years follow-up, patient satisfaction rate was still excellent and the reduction in the parameters mentioned above was still significant with no differences between the methods. Gait velocity, step length, plantar moment, mean pressure or position of centre of force under the forefoot, measured in half of the patients, did not differ significantly either. Cadence (steps/min) was higher and stance phase (ground contact time) shorter in the fusion group.
- In a study of 1000 RA patients, 80 % reported current foot problems, of which 86 % located in the forefoot. In 45 % the forefoot had been involved in the debut of the disease. Difficulty in walking due to the feet was declared in 71 %. For 41 % the foot was the most important part and for 32 % the only part in the lower extremity causing reduced walking capacity.

Conclusions: The positioning of a fusion in MTP 1 may be facilitated by the use of a guide-plate. Careful preparation and fixation lead to a high healing rate.

In a prospective, randomised study, both fusion and Mayo resection in MTP 1 as part of a total rheumatoid forefoot reconstruction resulted in significant and lasting reduction of pain, handicap and deformity with no statistically significant differences between the groups. Load distribution under the forefoot and time-and distance gait data, measured after 6 years, did not differ either, except in cadence and stance phase, possibly as a sign of the loss of motion in MTP 1 after fusion.

The foot is still, during active medical treatment today, next to the hand, the most frequently symptomatic joint complex in RA. In ¾ of the cases the foot caused walking disability and was twice as often as the knee or hip the only joint impairing the gait.

Key words: Rheumatoid forefoot surgery - Arthrodesis of MTP 1 - Arthrodesis versus resection - Rheumatoid forefoot prevalence - load distribution and time-and distance parameters

SAMMANFATTNING PÅ SVENSKA

Bakgrund: Framfoten, med tårnas grundleder, anses bli angripna hos i stort sett alla patienter med Reumatoid Artrit (RA, ledgångsreumatism). Denna uppgift grundar sig i huvudsak på en stor studie från 1956. Förändringarna resulterar i en smärtsam felställning av framfoten. Den under många år vanligaste metoden att operera detta har varit en sk metatarsalhuvudresektion, dvs borttagande av strålbenshuvudena i tårnas grundleder, initialt effektivt men med risk för återfall i smärta och deformitet. En steloperation (artrodes), istället för borttagande (resektion) av stortåns grundled, föreföll minska återfallsfrekvensen. En artrodes är dock tekniskt mer krävande. Syftet med denna avhandling har varit att analysera och optimera operationstekniken vid denna steloperation, att sedan jämföra denna operation med resektion enlig Mayo, det bästa av de tidigare sätten att operera stortåns grundled samt att undersöka utbredningen och betydelsen av fotengagemang vid RA idag.

Resultat:

- En rundad skål - och kul form för preparation av ledytorna, en nykonstruerad riktskena för inställningen av stortån mot foten och fixation med två, korsade skruvar resulterade i en hög läkningsfrekvens och tillfredställande vinklar.
- Vid jämförelse mellan resektion enligt Mayo och artrodes i stortåns grundled som del av en hel framfots-rekonstruktion pga RA, fann vi efter medel 3 års uppföljning utmärkt patient tillfredsställelse och signifikant minskad smärta och handikapp mätt med Foot Function Index utan någon statistisk skillnad mellan grupperna, ej heller avseende återfall i deformitet eller ömhet under foten.
- Efter medel 6 års uppföljning förelåg fortfarande signifikant minskad smärta, handikapp och deformitet utan statistisk skillnad mellan grupperna. Gånghastighet, steglängd, kraftutveckling, tryck och position av kraftcentrum under framfoten mättes också hos hälften av patienterna utan att någon statistisk skillnad kunde påvisas. I kadens (steg/min) och stödjefas (kontakttid mot golvet för en fot) fanns en viss skillnad.
- I en studie av 1000 RA patienter uppgav 80 % aktuella besvär av sina fötter, varav i 86 % lokaliserat till framfoten. För 45 % hade framfoten varit ett debutsymptom. Hos 71 % gav foten gångbesvär och mer än dubbelt så ofta som knät eller höften utgjorde foten den led i nedre extremiteten som mest hindrade gångförmågan.

Slutledning:

En genomtänkt operationsteknik vid artrodes av stortåns grundled kan förbättra de tekniska resultaten.

Väl utförd framfotskirurgi pga reumatisk framfotsdeformitet kan ha stor och varaktig effekt på smärta, handikapp och deformitet. Inga tydliga skillnader mellan den tidigare operationstekniken med resektion enligt Mayo, och den nyare, mer komplicerade operationen med artrodes i stortåns grundled vid denna typ av kirurgi har framkommit. En skillnad i kadens (steg/min) och stödjefas (kontakttid mot golvet för en fot) fanns, troligen ett uttryck för den förlorade rörligheten i stortås grundled efter artrodes, och kan tänkas vara både en för - och en nackdel.

Foten är fortfarande, under modernt medicinskt behandlad sjukdom år 2005, näst handen, det vanligast symptomgivande ledsystemet hos patienter med RA.

Engagemang i foten är också den vanligaste orsaken till subjektivt nedsatt gångförmåga hos dessa patienter.

LIST OF PUBLICATIONS

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A guide plate for accurate positioning of first metatarsophalangeal joint during fusion. Operat Orthop Traumatol 2004; 16: 167-78.

II. Grondal L, Stark A.
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Arthrodesis versus Mayo resection. The management of the first metatarsophalangeal joint in reconstruction of the rheumatoid forefoot. J Bone J Surg [Br] 2006; 88-B: 914-19.

V. Grondal L, Tengstrand B, Nordmark B, Wretenberg P, Stark A.
The foot – still the most important reason for walking incapacity in rheumatoid arthritis. Distribution of symptomatic joints in 1000 RA patients during 2005. Submitted.

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CONTENTS

LIST OF ABBREVIATIONS

ACR	American College of Rheumatology
Anti-CP	Antibodies against Citrullinated Proteins
AI	Angle of Inclination
CRP	C-Reactive Protein
DAS	Disease Activity Score
DFA	Dorsi-Flexion Angle
DMARD	Disease-Modifying Anti-Rheumatic Drugs
ESR	Erythrocyte Sedimentation Rate
FFI	Foot Function Index
GRF	Ground Reaction Force
HAQ	Health Assessment Questionnaire
HV	Hallux Valgus
HVA	Hallux Valgus Angle
IP	Interphalangeal joint
MT	Metatarsal
MTP	Metatarsophalangeal joint
ns	not significant
NSAID	Non-Steroidal Anti-Inflammatory Drugs
PIP	Proximal Interphalangeal joint
RA	Rheumatoid Arthritis
RF	Rheumatoid factor
TMT	Tarsometatarsal
TNF	Tumor Necrosis Factor
VAS	Visual Analogue Scale

1 INTRODUCTION

1.1 RHEUMATOID ARTHRITIS

1.1.1 The diagnosis

Rheumatoid arthritis (RA) is a chronic, inflammatory and fairly common disease, occurring in about 0,5-1 % of the population.[1] It affects the synovium and leads to joint damage and bone destruction and thereby causes considerable disability. It is also connected to increased mortality.[18,125] The words are derived from Greek, "rheumos" for fluid and "arthrein" for joint, that is, swelling with increased amount of fluid in the joint. The origin of the disease is still unknown but is believed to be both hereditary and environmental.[1] The main risk factors include genetic susceptibility, sex and age, smoking, infectious agents as well as hormonal, dietary, socioeconomic and ethnic factors with the highest prevalence in North America and North Europe.[1] The risk for developing the disease is reported to be 3-5 times higher in first degree relatives to RA patients and genetically the HLA-DR gene is involved.[130] Two thirds of the patients are female and the incidence is at its highest at about 60 years of age. Presence of antibodies against citrullinated proteins (anti-CP) have high specificity for RA[138] and may trigger RA-specific immune reactions, indicating a correlation with smoking as smoking promotes the formation of these proteins.[81] Smokers of both sexes are also reported to have an increased risk for developing sero-positive RA.[155] As there is no single diagnostic or pathognomonic symptom, sign or test, the diagnosis is set on the basis of several criteria. Usually the American College of Rheumatology classification criteria for RA is used, where 4 out 7 criteria have to be fulfilled for the diagnose RA.[2] Of the laboratory tests, anti-CP and Rheumatoid factor (RF) are of diagnostic value even if the sensitivity is no more than 60-70 %.[130] Erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) show general inflammatory activity. All these four tests, together with early involvement of many joints, destructive changes on radiographs and early disability measured with health assessment questionnaire (HAQ), a self-reporting index measuring functional capacity,[36,44] have been identified as prognostic factors for the severity of the disease but the prognosis for each individual is not possible to predict.[183] The goal in the treatment of RA is to suppress current symptoms but also to reduce long-term morbidity. Measurements of function, besides of inflammatory activity, are therefore of great importance.[183] There is no single outcome that measures both the severity of RA and its effects on the patient. Disease

Activity Score (DAS),[127] including patients global assessment score, number of swollen and tender joints and ESR rate, together with HAQ for disability and changes on radiographs are methods used to follow disease activity and to evaluate effects of intervention. Pain measured with visual analogue scale (VAS)[17,128] and number of disease-modifying anti-rheumatic drugs (DMARDs) may also be used as outcome measures.[183]

1.1.2 The pathogenesis – mechanisms of disease

RA attacks the synovium and causes a hyperplasia of the synovial membrane with increased vascularity and infiltration of inflammatory cells, mainly macrophages, T cells and B cells.[160] The antigen-activated CD4+ T cells stimulate monocytes, macrophages and synovial fibroblasts to produce inflammatory cytokines like TNF-α, interleukin-1 and 6 and also to promote angiogenesis. TNF-α and interleukin-1, in their turn, stimulate fibroblasts, osteoclasts and chondrocytes to release tissue-destroying matrix metalloproteinases. They also recruit neutrophils into the joint that release other proteases attacking the cartilage. The osteoclasts are stimulated both by CD4+ T cells and by TNF-α. Together this results in the destruction of cartilage and bone.[18] A part from the hydrolytic enzymes present in the synovial fluid, erosions are caused by the so called pannus tissue, a granulation tissue in the synovia formed at the junction between synovia- cartilage- and bone, containing proliferating fibroblasts, small blood vessels and inflammatory cells, also mostly T cells of CD4+ and CD8+ type, activating the production of the inflammatory cytokines, also here causing joint destruction. Mast cells may be activated and have been shown to be involved in the angiogenesis and proteolytic activity.[98] The destructions are soon noticeable on radiographs,[183] often first in MTP 5.[130,165] The granulation tissue produces adhesion molecules attracting the opposite joint surface resulting in a reduced mobility of the joint and in the end a fibrous ankylosis. Activated CD4+ T cells also stimulate B cells to produce immunoglobulins, e.g. the Rheumatoid factor.[18] In fact, lately, greater interest in the B cells importance for both the inflammation and the underlying immunoregulatory disturbance is taken. The positive effect of anti B cell treatment indicates an important role also for B cells in RA.[35]

1.1.3 The treatment

1.1.3.1 Medical treatment

The medical and surgical treatments have progressed considerably during the last decades. Concerning the drug treatment, a profound change has occurred during the last ten years in two aspects. First, a definite reorientation towards more early, aggressive combination therapy have come about, where the use of different DMARDs simultaneously is now advocated, in contrast to the earlier, slow step-up model of introducing different drugs.[83,183] Methotrexate, Sulphasalazine, Chlorokinphosphate, Hydroxychlorokine, Azathioprin, Leflunamide, Ciclosporine and injectable gold are examples of DMARDs. Second, the introduction of the anti tumor necrosis factor-alfa (TNF-α) treatments since the end of the ninetieths have brought about far-reaching changes of the medical treatment based on completely new biological knowledge. Still, however, there is no definite cure to the disease. In a recently published British study of almost 3000 RA patients, only 9 % were considered to be in remission after 6 months with anti-TNF-α treatment while 50 % had a moderate response. Current use of non-steroidal anti-inflammatory drugs (NSAIDs) as well as Methotrexate was associated with better response.[63] The increased efficiency of TNF treatment when combined with Methotrexate have been shown in several studies,[77,80,177] even though the mechanism by which Methotrexate modulates inflammation is not clearly understood.[159] The greatest gains of early, aggressive treatment can be achieved in the early cases before joint destruction and deformity have developed.[83] A new generation of biological drugs, with B cells targeted therapy e.g. rituximab, which recognize cell-surface CD20 on B cells is developing,[34,35] with hopefully lower risk for side effects as iatrogenic infections.[83] Also here, combination with Methotrexate seems favourable.[34] Other drugs like interleukin-6 blockers, stem cell factor receptors or c-kit blockers are under trial and further development in drug treatment of RA is to be expected.[83] Oral glucocorticoids have been used for a long time and have an important role in the arthritis therapy as an anti-inflammatory drug. Recently, studies have also shown a significant anti-erosive effect of glucocorticoids.[8,79] Combination with DMARDs and glucocorticoids in early rheumatoid arthritis have been shown to provide high remission rate with few adverse events and no increase in bone loss compared to the non-glucocorticoid treated group during a 2 year period.[158] Intra-articular glucocorticoid injections are also effective tools, with high rate (over 75%) of adequate response still after six months.[180] Reduced protein expression of synovial proinflammatory molecules, e.g. TNF, after steroid injections have been shown too.[82]

Aspiration of the synovial fluid before injecting the steroid have also been shown to increase the effectiveness significantly by decreasing the intra-articular pressure, reducing the amount of proinflammatory substances and preventing dilution of the steroid. Infectious complications are rare and recent findings contradict negative side-effects on the cartilage.[180]

1.1.3.2 Surgical treatment

The surgical options have also developed enormously during the last decades with the introduction of prosthetic surgery. In the lower limb, excellent results for the knee and hip have been achieved.[58,136] Also hand, shoulder and elbow surgery have progressed profoundly with both soft tissue operations, arthrodesis and arthroplasty.[30,45,110,114,163] The knowledge of the importance of post-operative regime with both physiotherapist and occupational therapist intervention has raised the outcome success rates. In foot surgery, new techniques have developed but it appears this field has not been quite as successful as others, maybe somewhat neglected behind the tremendous development of prosthesis surgery of the larger joints. Hand surgery becoming a speciality of its own has most likely been of benefit for the RA patients (in Sweden in early 1970s). Also, the hands being more exposed, including a cosmetic element, and of even greater dignity for activities of daily life, have rightfully caused much focus to be put into this region. However, the demands of a life, as normal as possible, in spite of a chronic disease and the knowledge of the importance of exercise for these patients,[108,154] have increased the urge today to be able to move around as unrestrictedly as the situation permits. This will hopefully push foot surgery forward.

1.2 THE FOOT IN RHEUMATOID ARTHRITIS

1.2.1 Development of forefoot deformity

In the forefoot, the disease strikes the metatarsophalangeal (MTP) joints. Due to the inflammation, the laxity of the joints increases. This makes it possible for the MTP joints to subluxate or luxate by which the metatarsal (MT) heads protrudes plantarly, whereas the lesser toes dislocate dorsally with hyperflexion in the MTP and the proximal interphalangeal joints (PIP) joint form a so called digitus malleus deformity of the lesser toes (Fig 1). This position of the lesser toes produces a downward pressure on the MT heads, the so called piston effect (Fig 2). Seldom, but yet sometimes, the dislocation turns out the other way round, with a plantarly dislocation of the lesser toes with hyperextension in the MTP and PIP joints. The exact mechanism for this is not known. Maybe a parallel to the swan neck deformity of the fingers can be drawn.[10,133] The hallux may take different positions in any direction – valgus, varus, hyperflexion or extension in the MTP 1 joint, but usually turns out in valgus, in the so called hallux valgus position (Fig 1). The fat pad beneath the MT heads dislocates distally-dorsally with the lesser toes, leaving the MT heads, already destructed and painful by the inflammation, unshielded just subcutaneously. For protection, unfortunately with the opposite effect, the skin produces callosities (Fig 3). These callosities just tend to increase the painful feeling of the dislocated MT heads, described as “walking on marbles” by many patients. The callosities may also split, form a chronic ulcer and open a pathway for infections. Furthermore, the malposition of the toes causes problems with the shoes and risk for dorsal ulcers, especially over the PIP joints but also over any other deformed joint. Together, the changes result in a typical forefoot deformity with a high and broad forefoot and painful, protruding MT heads plantarly. Standing and walking turn out more and more painful. The patients tend to walk with a special gait pattern with stiff, short and outwardly rotated feet to avoid the normal flexion in the MTP joints during the lift-off phase of the step and thereby reducing the load on the forefoot. Insoles and adjustments of the shoes may help out in the beginning but eventually surgery often gets necessary. In advanced cases, the destroyed, luxated MTP joints have to be removed through some sort of resection to relieve pain. The procedure when the whole forefoot is taken into account is called a total rheumatoid forefoot reconstruction.

Fig 1: Subluxated/luxated MTP joint, digitus malleus and hallux valgus

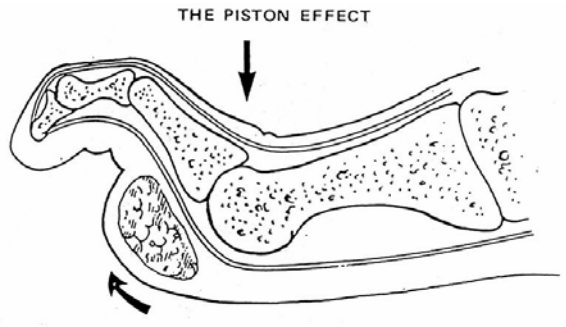

Fig 2: The piston effect

Fig 3: Plantar callosities beneath subluxated/luxated MTP joints

1.3 HISTORICAL ASPECTS OF FOREFOOT SURGERY

1.3.1 Resection of MTP joints

To our knowledge, the first time a discussion about painful deformity in MTP 1 is written down is 1887, where Mr Davies-Colley relates a procedure with a resection of the proximal half of the first phalanx of the great-toe.[27] This type of resection is later described in print by Mr Keller in 1904 who thereby gives his name to this operation.[75] Another way to go about bunions and hallux valgus deformities is suggested by Mr Mayo in 1908, in which part of the first MT head is removed instead of the base of the proximal phalanx of the first digit.[101] This method is then used by Mr Hoffmann in the first publication of a total forefoot resection operation for "Severe grades of contracted

or clawed toes" in general.[60] The patients described in these studies are though usually not strictly rheumatoid patients. The latter method is thereafter more or less predominant for a long period. In 1951, Larmon introduces a modification for the rheumatoid forefoot with 3 longitudinal incisions and a Keller type of resection of the great-toe again.[85] In the late 1950s, Fowler and Clayton suggest a dorsal transversal approach with resection of the bases of the proximal phalanges of all the toes as well as the MT heads,[19,43] combined with a plantar excision of abundant skin.[43] Kates, Kessel and Key return to a plantar incision 1967, with resection of only the MT heads, but also including a plantar dermatoplasty.[74] The discussion was principally focused round dorsal or plantar incision and resection of both sides of the joint or just one side, even though some approach suggesting amputation of all toes popped up along the line too.[41,118] Brattstrom and Brattstrom, the pioneers in Swedish rheuma surgery showed that the resections must include all MT heads.[11]

1.3.2 Arthrodesis in MTP 1

In 1894, Mr Clutton publishes a technique to fuse the MTP 1 with ivory pegs and the idea turns up again in 1940 in a publication of Thompson.[20,164] Different techniques for preparation and fixation of the arthrodesis are then published over the years,[96,97,103] but its not until the mid 1970s arthrodesis of MTP 1 in total rheumatoid forefoot reconstruction is seriously being taken in consideration.

2 SURGICAL TECHNIQUE FOR ARTHRODESIS

2.1 BACKGROUND TO STUDY I AND II

To achieve the best functional result, the position of a fusion in MTP 1 seems to be of utmost importance.[23,39, 62,89,103,111,131,132,136,164,171,178 ,189] Optimal angles are not easily obtained though. The angles in question are the Hallux Valgus angle (HVA), the angle in the frontal plane between the long axis of the first metatarsal (MT 1) and digit 1 (Fig 4). The second angle is the angle of dorsi-flexion. This can be measured as the Dorsi-Flexion Angle (DFA) or as the Angle of Inclination (AI), (Fig 5). The DFA is the angle between the long axis of the MT 1 and digit 1 in the lateral projection. The Angle of Inclination (AI) is the angle between the long axis of digit 1 and the floor, also in the lateral projection. As the height of the longitudinal arch, and thereby the inclination of MT 1 towards the first digit vary in the population, aiming at a specific Dorsi-Flexion Angle may result in different angles between the first digit and the floor in different patients. A specific AI, on the other hand, is constant and represents the functional angle by which the patient walks. Therefore, it seems logical to use the Angle of Inclination (= functional angle) as measurement, and not the Dorsi-Flexion Angle, when discussing the positioning in first metatarsophalangeal joint fusion. The third angle is the angle of rotation between the MT 1 and the great-toe, which may be estimated by inspecting the position of the nail plate in a horizontal plane. Too high or too low HVA and AI may result in different problems.

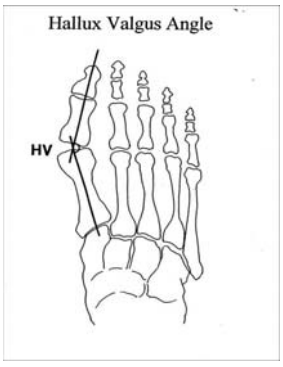

Fig 4: The Hallux valgus angle

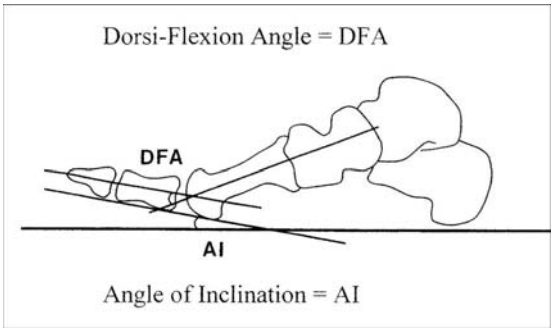

Fig 5: Different measurements of dorsi-flexion

Concerning the joint surface preparation and the fixation of the arthrodesis, there are different ways of addressing this. The reported rate of pseudarthrosis differs between 0 and 44 %, [24,62,95,121,175] presumably, at least to a certain extent, due to the choice of surgical technique. The surfaces may be cut flat[48,94,117,119,171] or formed in a cup or a cone (more pointed) manner, by hand or by a reamer[22,23,68,69,89,96,97,103,184,185] The preparation of the joint surfaces influences the possibility to choose the angles of the fusion. Flat cut surfaces may lead to large fitting areas, but restrict the possibilities to freely choose the angles in the fusion. A long and pointed cone-form gives good stability, but the position is still tied up to the surfaces preparation and bound by it.[96,97,185] A rounded cup-form retains the possibility to choose the angles after the preparation, without loosing the good contact area.[22,23] The method of fixating the fusion vary from one intramedullary screw,[103] to smooth or threaded Kirschner wires (K-wires),[62,117,149] threaded Steinmannpins,[93-95] two parallel screws,[171] one crossing screw,[141] a dorsal plate,[23] two crossed screws[189] and compression staples.[115] The chosen method should give good stability and preferably good compression without compromising the surroundings, that is, the skin and the adjacent joints.

3 TOTAL RHEUMATOID FOREFOOT RECONSTRUCTION

3.1 BACKGROUND TO STUDY III AND IV

The painful, deformed rheumatoid forefoot may be treated with resection of the lesser metatarsal heads MTP 2- 5 combined with either arthrodesis or resection of the first metatarsophalangeal joint (MTP 1).[166] Resection of all MTP joints, 1 to 5, was first introduced in 1912 by Hoffman as described in the historical survey above.[60] The resection procedure has been reported to provide good results initially with pain relief, but the rates of recurrent deformity and pain under the forefoot, that is, hallux valgus, metatarsalgia and plantar callosities have sometimes been high.[26,53,102,173] The resection may be done in two different ways but the distinction between these two types is not always clear. There are though obvious differences between them. The resection in MTP 1 may be of the Keller type,[75] that is resection of the base of the first digit or of the Mayo type,[101] partial resection of the first metatarsal head.

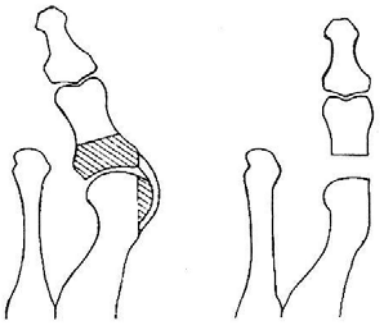

Fig 6: The Keller resection in MTP 1

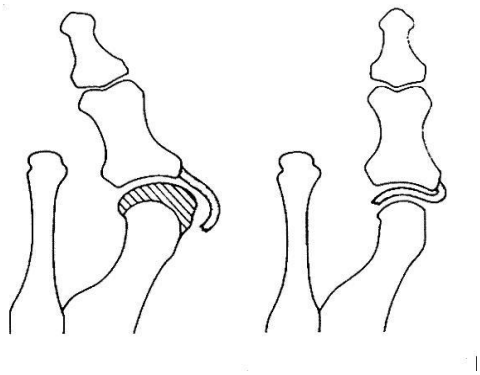

Fig 7: The Mayo resection in MTP 1

The risks for recurrent problems after MTP 1 resection as mentioned above seem to be much higher after a Keller resection compared to after a Mayo.[46] This may be due to the different biomechanical situation the different resection types result in. A Keller resection leads to a loss of the plantar structures at the base of digit 1, resulting in a reduced flexion and weight-bearing capacity of the great-toe and a transfer of peak plantar pressure towards the central metatarsals, producing a possible ground for metatarsalgia.[46,57,143] Measurements after Mayo resection on the other hand, tend to show increased load underneath MT 1 instead, [126,155] which is more like the situation

shown after fusion.[143] The differences between Keller and Mayo resection may be of importance for the outcome after "resection".

In the 1970s it was noted that postoperative stiffness in a resected first MTP joint seemed to produce better results in terms of better balance, steadier gait and less risk for redislocation of both the hallux and the smaller toes in valgus as well as for new callosities.[32,92,93,116,173,176] This led to a new approach with arthrodesis in the first MTP joint in order to provide the foot with a stable first ray[94,131] and a weight-bearing hallux,[6,24,94,112] thereby reducing the load on the resected lesser metatarsals, which could lead to fewer and less marked callosities beneath them. The operative technique for an arthrodesis is though more demanding and takes longer time to perform.[51] Malposition, malunion or interphalangeal (IP) joint problems in the long run are possible risks after this procedure.[23,53,62,189]

Results reported after arthrodesis have sometimes shown very good results with high patient's satisfaction rates and few recurrent deformities.[23,24,95] Retrospective studies comparing resection of the MTP 1, mostly of the Keller type, to fusion have been made,[53,62,112,132,173,175] sometimes favouring fusion, but not entirely[53,62,132] Together, the results have not been conclusive as to which method to use. A thorough comparison between arthrodesis and resection in MTP 1 as part of a total rheumatoid forefoot reconstruction felt indicated.

To our knowledge, no other prospective, randomised study, comparing the two methods exists. Based on the differences described between the Keller and the Mayo resection, we chose to compare fusion to the Mayo resection.

3.1.1 Load measurements and time-and distance parameters.

Biomechanics can be defined as the studies of mechanical laws on biological systems.[181] When standing still, so called quiet standing, the ground produces the ground reaction force (GRF), approximately equal and opposite the body weight. The GRF is an average of all the forces or pressure under the feet. Pressure is not borne evenly under the plantar surface of the foot, but is concentrated to the heel and the ball (the forefoot). The location of the centre of pressure (CoP) marks the line of action of the GRF and is in quiet standing positioned about 5 cm anterior to the ankle joint, under the navicular bone. There is though very little actual pressure under this region, the CoP is just a mathematical concept.[78] Force can be defined as the capacity to do work or cause physical change. It is a vector quantity with a magnitude and a direction. Pressure is force/unit area with the force applied uniformly and perpendicular onto a surface.

The centre of force is the point where all forces acting on the plantar foot are concentrated.[181]

The Fscan is a computerised system measuring force, centre of force and pressure under the foot. The Fscan mat (Fig 9) is composed of sensors. These sensors respond to compression resulting in a change of voltage. This change is registered and converted to a force. The sensor have a known area, so the pressure can be calculated from force and area (pressure=force/unit area). The parameters are presented in a visual display with plantar pressure profiles and graphs. The centre of force can be marked on the display and the pressure/minute standing is presented in figures.

Gait refers to the manner and style of walking and running. The gait cycle is the interval from initial contact with one foot with the ground to the next initial contact with the same foot - right foot down to right foot down again (Fig 8). This is called a stride and the distance between two successive placements of the same foot is called the stride length. The stride consists of two steps, one with each foot. The gait cycle is divided into 8 phases: initial contact, loading response, mid stance, terminal stance, pre swing, initial swing, mid swing and terminal swing.[124] The period when the foot is on the ground is called the stance phase. The period when the foot is in the air is called the swing phase. During the stance phase there are two shorter periods with double support, that is, both feet have contact with the ground, and one period with single support when the foot not on the ground, is in the air, in its swing phase. The stance phase lasts about 60 % of the gait cycle and the swing phase about 40 % (Fig 8). However, this varies with the speed of walking. The faster the speed, the shorter the stance phase and double support until it finally disappears in running and is replaced with a so called double float.[124]

Cadence is the number of steps taken per unit of time, usually steps/minute and is a measure of half-cycles. The speed of walking is the distance the whole body moves per unit of time and is usually measured in meters/second. The speed varies with the cadence and the stride length, each of them or normally both. Cadence, speed, step length, single and double support are so called time-and distance parameters and can be analysed in a gait analyse system. The moment of force, the joint moment, is a force applied some distance away from the joint, aiming to rotate the joint in the direction of the force. It is measured as the force multiplied with the distance from the joint where the force is applied, the moment arm, and is presented as Newton-meters, Nm. The external moment results from the GRF and the weight of the body and the internal

moment from muscles contractions and ligament tensions. The net moment is the sum of all the external and internal moments and is presented as Nm/kg.[181]

The time-and distance parameters and the plantarflexion moment of the ankle can be analysed in a 3 dimensional gait analyse system, in which the patient walks in a walkway with reflective markers placed on the skin to infer the position of the body segments (Fig 10). The markers reflect the light from a number of infrared cameras to sensors mounted on the cameras. With this information it is possible to reconstruct the position of the markers in three dimensions. Movements during walking can then be recorded and the parameters presented above measured by using a computerised biomechanical model.[72] This kind of system have been used on rheumatoid patients with symptomatic, but not operated forefeet, showing delayed and reduced forefoot loading, shorter stride length, decreased ankle plantar flexor moment and slower gait velocity compared to healthy controls.[86,120] It has also been used in gait analysis on rheumatic children[15] and on non-rheumatoid patients after arthrodesis because of hallux rigidus.[28]

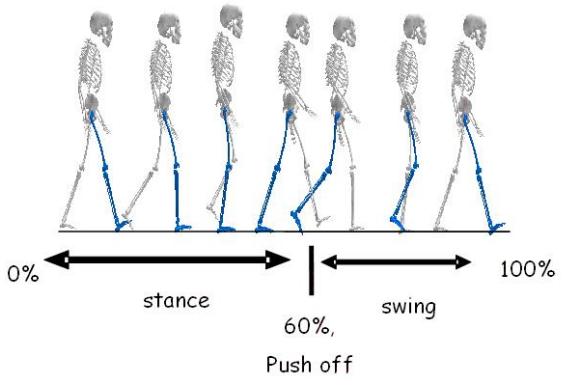

Fig 8: Normal gait cycle

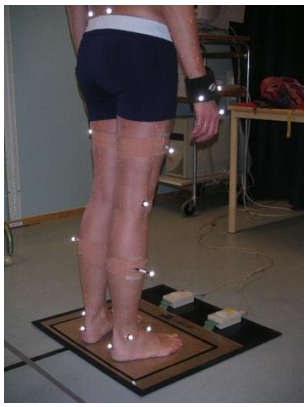

Fig 9: The Fscan mat

Fig 10: Walking in the 3D motion Vicon system with reflective markers on

4 EPIDEMIOLOGICAL ASPECTS

4.1 BACKGROUND TO STUDY V

In the literature dealing with the rheumatoid foot problem, the frequency of foot involvement is usually stated in all papers by references. Only a few authors have actually performed an investigation of their own concerning this aspect. Many references go far back in time. Most often K Vainios study of 955 adults from 1956 is referred to.[172] Later investigations exist but usually include a lot fewer patients,[40,65,76,105,107,152,182] except a newly published study of 285 patients assessing forefoot problems only.[100] All these are clinical studies while others are just based on radiographic findings.[52,165] Great changes in the medical as well as surgical treatment since the 1950s may have led to a different scenery.[83] No modern investigation of the same magnitude as the Vainio study exists.

5 OTHER POSSIBLE OPERATIVE PROCEDURES FOR THE RHEUMATOID FOREFOOT

5.1 METATARSAL HEAD PRESERVING METHODS

Other techniques suggested for the rheumatoid forefoot with subluxated/luxated MTP joints have been different kinds of shortening or elevating oblique metatarsal osteotomies in order to reduce the load on the metatarsal heads. Helal reported good results after distal oblique osteotomies of three to five metatarsals,[55] based on a method published 1916 by Meissenbach.[104] Modifications were made and the management was called telescoping osteotomy and the results reported were initially good with pain relief in over 80 %.[56] Internal fixation and plaster casting was not used though, making malplacement of the MT head, delayed or non-union possible and the procedure have been found unpredictable.[64,186] A similar type of osteotomy producing shortening by actually removing a thin slice of the metatarsal bone and with postoperative fixation with longitudinally introduced K-wires and a walking cast for 3 weeks was published by Hanyu.[54] Some recurrence of deformity of the lesser toes (34 %) and callosities (12 %) was reported and the technique is not widely spread. The Weil osteotomy, an oblique osteotomy of the metatarsal neck and shaft, parallel to the ground and internally fixated with screws or pins, presents another possibility for shortening of the

metatarsals.[5] Use of this method have shown better results,[61,170] superior to the Helal type,[167] but still connected to some risk for dorsiflexion contracture,[169] plantar penetration of hardware,[170] elevation/"floating" of the lesser toes and stiff MTP joints.[7,61] At least experimentally, reduction in load transmission is not certain.[151] All these techniques are though used for metatarsalgia of other reasons than RA as well. In recent years, a new MT head preserving operative technique have emerged, the Stainsby forefoot reconstruction.[13] Here, an extensive dorsal MTP joint release with extensor tenotomy is combined with resection of the base of the proximal phalanx of all toes, sometimes including the MTP 1. The plantar plate and fat pad is relocated under the MT heads. The extensor tendon is sutured to the flexor tendon to prevent recurrent elevation of the toes and recurrent downward pressure on the MT heads. Only one, retrospective study on this technique has been found, in which excellent pain relief was reported in 93 % of the patients. The material, however, was mixed and no specific data concerning preoperative severity of deformity and destructions were presented.[12]

5.2 DIGITUS MALLEUS

This flexion contracture of the proximal interphalangeal joint (PIP) of the lesser toes is common in patients with RA. The deformity starts in the MTP joint, with the plantar dislocation of the MT head. The proximal phalanx is then pulled dorsally in a proximal direction with the development of a flexion contraction in the PIP joint. The deformity and the callosity produced over it, result in shoe fitting problems. This may be dealt with by a resection arthroplasty or an arthrodesis. Results after both are reported good, independent of technique.[25,84,88,122] However, extensor tenotomy and dorsal capsulotomy of the MTP joint is strongly recommended to tackle the underlying cause of the problem and to diminish the piston MT head depressing effect of the deformity as presented above (Fig 2)

5.3 ISOLATED HALLUX VALGUS

Hallux valgus (HV) is an acquired deformity with an increased valgus angulation between the great toe and the first metatarsal.[134] It is common in the non-RA population, but in patients with RA, due to the laxity of the forefoot, this is almost always a part of the entire forefoot deformity. The problem is usually a shoe fitting problem due to the increased width of the forefoot.[134] In early cases of RA, an isolated HV may be symptomatic and in need of surgery, before any other deformity has

developed. In these cases, ordinary width-diminishing HV surgery as the Chevron osteotomy e.g.[3,70,168] may be indicated if there are no erosions or destruction in the MTP 1. If there are erosions, an isolated arthrodesis may be contemplated. The loss of the motion in digit 1 should be discussed with the patient though, as it may be experienced bothersome if the preoperative situation wasn't profoundly disabling. Isolated Mayo resection is not reported on. The Keller procedure is not recommended, referring to the discussion in this thesis. Replacement of the MTP 1 with silastic, metal and polyethylene implants have not enjoyed the same success as hip or knee arthroplasties. Silicon synovitis, breakage of implant, radiolucencies around the implant and soft tissue instability are among problems encountered, maybe to less extent in non-rheumatoid patients.[37,47]

6 AIMS

The general aim of this thesis was to improve the outcome after surgery of the rheumatoid forefoot and to investigate the frequency and importance of rheumatic involvement of the foot in the 2000s.
The specific aims were:

1. To analyse and optimise the operating technique for arthrodesis in MTP 1 and the technique for resection of the metatarsal heads in total rheumatoid forefoot reconstruction.

2. To compare the newer technique, arthrodesis in MTP 1, to the best of the older techniques, Mayo resection in MTP 1, as part of a total rheumatoid forefoot reconstruction in a prospective, randomised study in a shorter and longer perspective.

3. To investigate the prevalence of subjective symptomatic involvement of the foot in patients with RA today with special reference to the impact of this involvement on subjective walking ability.

7 PATIENTS AND METHODS

This thesis includes one methodology study, one retrospective study, one prospective, randomised study with two, separate follow-ups after median 3 and 6 years and one observational, cross-section epidemiology study.

7.1 GENERAL OPERATIVE TECHNIQUE USED FOR TOTAL RHEUMATOID FOREFOOT RECONSTRUCTION.

The operations were performed in spinal anaesthesia and bloodless field with one single dose of antibiotic (isoxazolylpenicillin) administrated 45-60 minutes before surgery. Two dorsal longitudinal incisions for the resection of MT 2-5 and extensor tenotomy were used. A thorough release of the dorsal structures provides a complete relocation of the lesser toes and the fat pad, making a plantar excision of skin to achieve this relocation unnecessary. The abundance of skin disappears spontaneously over time. The resections of MT heads 2-5 were meticulously performed with a small saw (Linvatec-Hall micro 100-sagital saw; Conmed/Linvatec, Largo, Florida, USA) in 45° plantar angle to produce a kind of ”rocker-bottom” surface for the weight-bearing area (Fig 11 and 13) without sharp edges and also forming a smooth arch from MT 2 to 5. For the MTP 1, a straight medial incision was used. The medial exostosis was removed with the saw. In the cases allocated to resection, a Mayo resection was performed. Approximately ¼-1/3 of the first MT head was removed with the saw and/or forceps and a small capsular flap was placed over the rest of the head. In the cases allocated to fusion, the Coughlin first metatarsophalangeal joint reamer (Stryker Howmedica, Rutherford, USA) was used for the preparation (Fig 12),[23] resulting in two, nicely fitting, cup-and cone formed surfaces, possible to position in any angles without sacrificing good bone contact. If the great-toe is longer than the second toe, bone should be removed to reduce the length of the first ray to no more than around 5 mm longer than the second. Care must be taken if the bone is osteoporotic. The joint was then positioned according to the Grondal-Stark guide-plate aiming at a HVA of 15-25° and an AI of 10-15° (Fig 15).[49] Two cortical screws, introduced with lag-screw technique and not compromising the IP joint, provided fixation. This operative technique is thoroughly described in study II.[50] After the Mayo resection, a longitudinally inserted 1.6 mm K-wire transfixed the first MTP joint for 3 weeks. All of

the lesser MTP joints were after resection also transfixed with 1.4 mm K-wires for the same period (Fig 14). Postoperatively, the Mayo resection group had a soft dressing for 6 weeks, whereas the fusion group had a small plaster along the medial side of the foot for the same period. Both groups were allowed weight-bearing mobilisation as tolerated in a stiff soled postoperative shoe.

Fig 11: Small sagittal saw

Fig 12: The Coughlin 1st metatarso-phalangeal joint reamer

Fig 13: Sawing in 45° plantar angle

Fig 14: K wires for temporary fixation

7.2 STUDY I

This study describes our guide-plate, developed to aid the positioning of an arthrodesis in MTP 1. The guide-plate is a simple device made of stainless steel, pre-bent in a Hallux valgus angle of 15° and an Angle of Inclination of 12°. The device is to be put along the plantar and medial border of the foot after the preparation of the joint (Fig 15). A medial hook holds the plate against the heel. A loop wire or the hand of the assistant placed around the middle of the foot secures the plate and may facilitate a proper position between the great-toe and the first metatarsal.

The postoperative angles in 10 patients operated on with this equipment were measured. In 9 cases the patients had had a total rheumatoid forefoot reconstruction

including an arthrodesis in MTP 1. In 1 case an isolated arthrodesis in MTP 1 had been performed. All patients had Rheumatoid arthritis. There were 7 females and 3 males, with median age of 52 years (35-66). Hallux valgus angles and Angles of Inclination obtained were measured on postoperative radiographs after median 7 months by an independent radiologist. In the frontal projection, the centre of the fusion site was connected with the centre of the distal joint surface of the proximal phalanx of the digit 1 towards the IP joint and the centre of the proximal joint surface of the MT 1 towards the first tarsometatarsal joint (TMT 1),[144] resulting in a HVA (Fig 4, in Introduction). For the DFA, the centre of the fusion site was connected with the centre of the shaft of the proximal phalanx of digit 1 and of the shaft of MT 1,[95,161] instead of the TMT 1 as the TMT 1 is wide and difficult to define in the lateral projection. The AI was measured as the angle between the line connecting the base and the distal end of the proximal phalanx of digit 1 on the plantar side and the floor, also in the lateral projection (Fig 5, in Introduction).

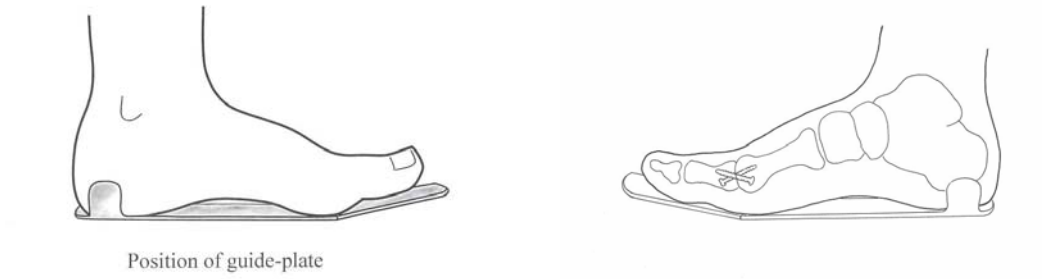

Fig 15: Position of guide-plate

7.3 STUDY II

This study analyses the whole operating technique as an entity, including the joint surface preparation and the possible techniques for fixation of the arthrodesis. Between February 1998 and June 1999, we operated 22 feet in 21 patients, 16 females and 5 males, with an average age of 53 years (33-67) with fusion of MTP 1. Seventeen patients had rheumatoid arthritis, 3 Hallux rigidus and 1 severe Hallux valgus. We used the rounded cup preparation technique [22,23] the Grondal-Stark guide-plate for positioning aid[49] and two crossed cortical screws for fixation (Fig 16).[189] Postoperative mobilisation was allowed with a small cast and weight-bearing as tolerated.

Radiographs were performed after median 7 months and analysed by an independent radiologist with the same technique concerning the angles as described in Study I.

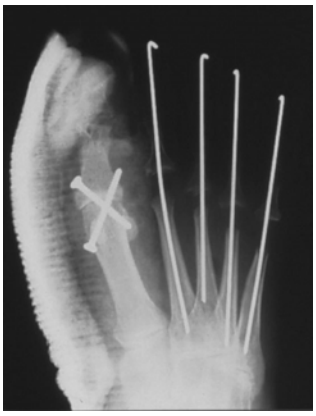

Fig 16: Post-operative radiograph after total forefoot reconstruction with fusion in MTP 1

7.4 STUDY III-IV

From April 1998 to June 1999, 31 patients (26 female and 5 male) with an average age of 54 years (33-77), with severe, painful forefoot deformity due to rheumatoid arthritis were included in a prospective, randomised study and allocated to either Mayo resection or arthrodesis in MTP 1 combined with resection of metatarsal (MT) heads 2-5. Randomisation was performed with a computerised system using to the minimization method, with stratification according to gender and age (over or under 45 years) .[129] The inclusion criteria were rheumatoid arthritis, severe pain and deformity of the forefoot with subluxation/luxation in two or more MTP joints with plantar callosities and bone destruction, healthy interphalangeal (IP) joint in digit 1 and no valgus deformity of the hindfoot.

The subjective pain and incapacity were investigated with Foot Function Index (FFI), a self-administered protocol with visual analogue scales (VAS) graded from 0 to 100 points (Fig 17), validated for rheumatoid arthritis.[16,140] The score included 7 questions concerning pain, (originally 9 but the two concerning orthoses were excluded, as in the validation study),[140] 9 for handicap and 5 for general activity.

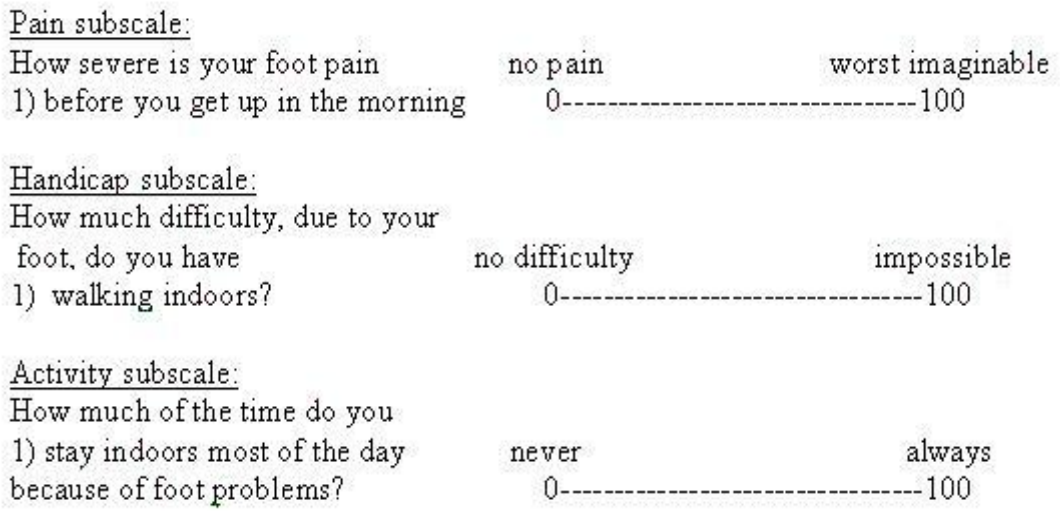

Fig 17: Sample items of Foot Function Index

The deformity of the foot was examined by an independent observer according to a specially designed protocol where prominences, tenderness, subluxation/luxation, involvement of the IP joint according to Fitzgerald[39] and degree of valgus of the great-toe, clinically measured and defined as one of three subgroups: group 1: < 20°, group 2: 20-40° and group 3: > 40° of hallux valgus angulation were noted. In a simple walking test with shoes on, time for walking 20 m was measured with an ordinary stop watch. These patients were examined preoperatively, after 6 months and mean 36 months (24-52).[51]

In Study IV we investigated the long-term results of this prospective, randomised study. Twenty-nine out of 31 patients (1 man dead of other reasons, 1 woman severely ill) were reviewed again after mean 72 months (57-80) using the same parameters. In 14 cases (7 in each group) an additional investigation concerning the load distribution under the forefoot was performed on a Fscan mat (46x31 cm, Type 3100, Tecscan, Boston, Mass., USA), a validated pressure sensitive transducer system.[91] The pressure was measured in mean g/cm^2/1 minute during standing after calibration with the patient's weight. The forefoot area was defined as the distal third of the total foot length. The distance from the medial border of the foot to the centre of force under the forefoot was measured and related to the full width of the forefoot, resulting in a certain percentage (Fig 18). The higher the percentage, the more lateral position of the centre

of force. Seven healthy controls (age 21-56, mean 36 yrs, 6 females) were measured with the same procedure for comparison.

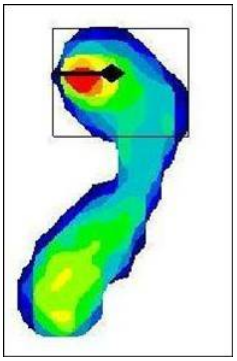

Fig 18: Measurement of position of centre of force:
Distance from medial border/whole width of forefoot

In 12/14 cases, gait data with time-and distance parameters were also measured with a 6-camera 3D motion analysis system (Vicon, Motion System, Oxford, England). Walking speed (m/sec), step length (m), cadence (steps/min), stance phase (sec) and plantar flexion moment of the ankle (Nm) were recorded with this camera system, monitoring the patient when walking barefoot on a 7,5 m long walkway at a self-chosen velocity with reflective markers (25 mm) placed on the subject's skin to infer the position of the body segments (Fig 19). The 3D motion system is documented and validated.[72,146] Due to geographical reason, all of the patients were not possible to examine with these two advanced equipments.

Fig 19: Study patient with reflective markers in gait laboratory

7.5 STUDY V

In this observational, cross-section study, 1000 patients with rheumatoid arthritis according to the American College of Rheumatology,[2] on their ordinary visit to the Rheumatology Outpatient Clinic during 2005 were enrolled in the study. The patients were asked to participate in an inquiry, consisting of a questionnaire concerning gender, age, duration of illness, current medication, debut joints, currently affected joints, joint surgery, foot problems and subjectively experienced reasons for reduced walking capacity. Three hospitals in Stockholm, Sweden, the Karolinska University Hospital, the Soder Hospital and Danderyds Hospital took part in the study.

The questionnaires, numbered but anonymous, were handed out by a nurse after the diagnosis had been verified in the disease code registers. The patients then voluntary filled in the questionnaires while sitting in the waiting room. The forms could be returned in a special box named ”Inquiry”, if and when each patient found appropriate, without any connection to the oncoming visit to the doctor. Questionnaires were distributed to 1287 patients, of whom 1000 were adequately filled in, resulting in a frequency of answers of 78 %. The rate of missing answers in the separate questions was low, varying between 2 and 15. The question of duration of illness was an exception with 59 missing answers (n= 941). Each percentage given in this paper is calculated on the actual numbers of answers.

8 STATISTICS AND ETHICS

The studies were approved by the regional Board of Ethics. (Dnr 96-404, Dnr 04-895/2).

8.1 STATISTICS FOR STUDY I AND II:

Descriptive statistics were used.

8.2 STATISTICS FOR STUDY III AND IV:

To compare the two operation methods, the chi-square test and the Fisher's exact test were used to analyse variables, measured on a nominal scale. The Mann-Whitney U test was used to analyse the VAS measurements. The Spearman rank order correlation coefficient was used to measure the association between variables. For comparisons over time Freedman's ANOVA followed by multiple comparisons between visits based on ranks, was performed for ordered categorical data, while for nominal data the McNemar Test was used. $P < 0.05$ was considerate statistically significant.

The Mann-Whitney U test was also used to analyse time-and distance parameters and pressure area. For the variable "walking time" a two way analysis of variance (ANOVA) with the within factor Time (0, 36 and 72 months) and the between factor Operation method (resection and arthrodesis) was performed. All statistical analyses were performed using the Statistica software package (StatSoft Inc, USA). $P<0,05$ was considered statistically significant.

8.3 STATISTICS FOR STUDY V:

Categorical data were summarised using frequency counts and percentages. Continuous data were presented as mean and standard deviation or as median and interquartile range (P25; P75). Associations between variables (affected joints, medicines etc) have been presented in contingency tables. Logistic regression analysis was performed to evaluate the association between "walking disability" and age, adjusted for gender and disease duration and between "currently affected joints" and treatment (biological and non biological), adjusted for disease duration. Disease duration was log-transformed before the analyses, as the distribution was positively skewed. $P<0.05$ was considered statistically significant

9 RESULTS

9.1 STUDY I

The guide-plate to aid positioning during fusion of the MTP 1 and how to use it is presented (Fig 20 and 21). After using it in 10 rheumatoid patients we found a postoperative HVA of mean 14° (2-29°) and a dorsiflexion position of 12° (6-19°), measured as Angle of Inclination from the floor. One pseudarthrosis occurred. This patient was a heavy smoker. There were no infections or reoperations, except for the uneventful removal of the proximal screw in 3 cases due to local irritation.

Fig 20: The Grondal-Stark guide-plate

Fig 21: Peroperative position

9.2 STUDY II

In this retrospective study, investigating the technical results when using our chosen way of performing an arthrodesis in MTP 1, 21 out of 22 fusions healed (Fig 22). One pseudarthrosis occurred. In this case the hardware was removed after which the joint was painfree. Mean postoperative Hallux valgus angle was 13° (2-29) and the Angle of Inclination 13° (0-31). Analysed separately, the HVA in the rheumatoid group was mean 15° compared to 5° in the non rheumatoid patients, illustrating the need to adjust the position to the individual foot configuration present. This usually differs between these two groups of patients. There was no deep infection. One superficial infection occurred in a rheumatoid patient, recently treated with local glucosteroids because of skin manifestations. The infection healed easily with antibiotic medication a short

period. In 3 cases, also in the rheumatoid group, the proximal screw had to be removed after some time (6-24 months) due to subcutaneous irritation of the screw head. This was simply performed in local anaesthesia and did not influence the overall outcome.

Fig 22: Fused MTP 1 after fixation with two crossed, cortical screws not compromising the IP joint and status after resection MTP 2-5, eight months postoperatively.

9.3 STUDY III

In this prospective, randomised study, total rheumatoid forefoot reconstruction with resection of MT heads 2-5 combined with either Mayo resection or arthrodesis in MTP 1 were compared to each other.

Preoperatively, there were no statistically significant differences between the allocated groups in median VAS score for pain, handicap and activity measured with the FFI.

Six months after surgery, median VAS for pain, handicap and activity was significantly reduced in both groups ($p<0,001$, except for handicap in resection group and activity in fusion group, in which $p=0,02$) with no statistically significant differences between the groups. This reduction remained unchanged to the follow-up after mean 36 months (24 - 52), and there were still no statistically significant differences between the methods (pain $p=0,15$, handicap $p=0,83$, activity $p=0,80$) (Table 1).

None of the groups showed recurrent prominences or tenderness under the forefoot (Table 2). Median subjective satisfaction scores, also measured by VAS, were 96 points out of 100 in the resection group and 92 points in the fusion group, not a significant difference between groups (p=0,85). Eighty-eight percent of the patients in the resection group and all of the patients in the fusion group would undergo the procedure again, not a significant difference either (p=0,49).

Fourteen out of 15 fusions healed. The angulations obtained in the fusion group were measured to a median of 17° (2-29°) of hallux valgus angle and 13° (0-31°) of angle of inclination. Preoperatively, the degree of involvement of the IP joint was equal between the groups. At mean 36 months, 1 patient in each group had a clinical disturbance of the IP joint.

Also, there was no statistical difference between the groups concerning the degree of hallux valgus preoperatively. Before surgery 8 patients in the resection group had a hallux valgus of more than 40°. At 24 months, only 1 belonged to this subgroup nr 3, indicating no recurrence of severe hallux valgus.

The only statistically significant difference found was in operating time with a mean of 90 minutes for resection compared to 106 minutes for arthrodesis (p=0,03). There was no statistically significant difference in incidence of wound infection (3 in each group, all superficial)

9.4 STUDY IV

Preoperatively, the same data as in Study III were valid with no differences between the groups in mean FFI scores for pain, handicap and activity and deformity.

In the resection group, after median 6 years median VAS for pain, handicap and activity was significantly reduced compared to preoperative data (p<0,001, p=0,013, p=0.003 respectively) and the reduction had stayed unchanged between 3 and 6 years (Table 1).

In the arthrodesis group, median VAS for pain and handicap was significantly reduced (p<0,001, p=0,003 respectively), while the reduction in median VAS for activity was not statistically significant (p=0,09). (Table 1).

Table 1: Median VAS in Foot Function Index								
	Mayo resection group				Fusion group			
	n	pain	handicap	activity	n	pain	handicap	activity
preop	16	48	56	16	15	58	48	13
3 yrs	16	4	27	4	15	11	24	4
6 yrs	14	9	19	5	15	6	17	6

Compared to each other, there were no statistically significant differences between the groups in reduction of FFI after mean 6 years in pain (p=0,8), handicap (p=1,0) and activity (p=1,0).

Patient's satisfaction with the result of the operation after 72 months, also measured on a VAS scale, was median 95/100 in the resection group and 96/100 in the fusion group, not a significant difference between the groups (p=0,6). Satisfaction especially concerning the great-toe was median 90/100 in the resection group and 89/100 in the fusion group, not a significant difference either (p=0,9). There was no difference between the groups in willingness to have the operation again (13 patients in each group).

After 6 years, still only 1 patient in each group had painful motion in the IP joint, the same result as after 3 years. Five patients in the fusion group and 2 in the resection group had a lateral but painless deformity in the IP joint. This was not a significant difference between the methods though (p=0.38).

Callosities were significantly reduced from preop to 3 years in both groups (p<0.001) and from preop to 6 years (p=0,003 for resection, p<0,001 fusion), with no significant difference between the groups (p=0,58) (Table 2). Tenderness under the forefoot did not differ either (p=0,13).

The use of insoles or special shoes did not differ after 6 years (insoles p=1,0, shoes p=0,25) (Table 2).

Table 2: Median number of callosities / patient Number of patients using of insoles and special shoes.								
	Mayo resection group				Fusion group			
	n	Callosities	Insoles	Special shoes	n	Callosities	Insoles	Special shoes
preop	16	4	8	11	15	4	10	7
3 yrs	16	0		6	15	0		3
6 yrs	14	0,5	8	6	15	0	8	3

Clinical lateral deviation of the lesser toes was found in 6/14 cases in the resection group and 10/15 in the fusion group, not a statistically significant difference though (p=0.19).

Concerning degree of hallux valgus., there was a significant reduction in the resection group from preop to 36 months which stayed unchanged to 6 years (p=0,02). Eight patients belonged to the third subgroup (HV>40°) preoperatively, while only 1 patient was still in this subgroup after both 3 and 6 years.

Time for walking 20 m with shoes on was reduced from mean 20 sec to 16 sec in the resection group and from 19 to 15 sec in the fusion group, a significant reduction (p<0,001), with no significant difference between the groups (p=0,53) (Fig 23).

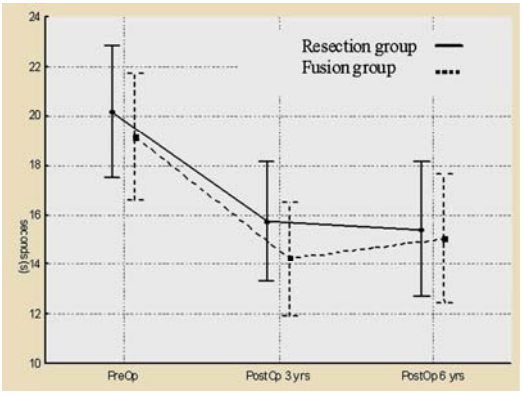

Fig 23: Time for walking 20 m with shoes (sec)

Concerning the load bearing under the forefoot and the gait analysis, we found a mean pressure during 1 minute of 372 gr/cm^2 in the resection group, 341 gr/cm^2 in the fusion group and 365 gr/cm^2 in the control group. The differences were not statistically significant between the groups (p=0,65) or between each group and the controls (resection p=0,85, fusion p=0,61). The centre of force was placed 47 % lateral (medial border of foot =0 %, lateral border =100 %) relative the whole forefoot width in the resection group, 51 % in the fusion group and 54 % in the control group. These differences were not statistically significant between the operated groups (p=0,41), but between the resection group and the controls (p=0,04). None of the operated patients made a foot print of their big toe during standing, while all of the controls did. (Table 3).

Table 3: Load distribution data measured with Fscan

At mean 6 yrs follow-up	Mayo resection n = 7 mean	Fusion n = 7 mean	Controls n = 7 mean
Pressure under forefoot standing, g/cm^2/1 min	372	341	365
Position of centre of force, % of width of forefoot 0 % = medial border of foot 100 % = lateral border of foot	47	51	54
Footprint of digit 1 on Fscan mat	0	0	7

Data for walking speed, step length, plantar flexion moment, cadence and stance phase is shown in table 4. There were no statistically significant differences in velocity (p=0,42), step length (p=0,63) or plantar flexor moment (p=0,26). Cadence (steps/min) was mean 114 in the resection group and 123 in the fusion group. Stance phase was mean 0.90 sec in the resection group compared to 0,81 in the fusion group. This was a statistically significant difference between the groups in both parameters (p=0,04 both) (Table 4).

Table 4: Time-and distance parameters measured with Vicon 3D motion system		
At mean 6 yrs follow-up	Mayo resection n= 6 mean	Fusion n= 6 mean
Walking speed, barefoot, m/sec	1,0	1,1
Step length, m	0,53	0,56
Plantar moment, Nm/kg	1,1	1,0
Cadence, steps/min	114	123
Stance phase, sec	0,90	0,81

9.5 STUDY V

In this inquiry of 1000 patients, we found 75 % females and 25 % males (n= 996), with an average age of 60 years (19-88) and a duration of illness of median 10 years (4-19, P25; P75), (n=941).

In 45 % the forefoot and in 17 % the hindfoot/ankle was engaged in the debut. The joints of the fingers were involved in 58 % and the wrist in 44 %. Comparison with the other joints is shown in Table 5.

Table 5: Joints involved in the debut of RA disease, n= 997.								
	Forefoot	Hindfoot/ankle	Knee	Hip	Finger	Wrist	Elbow	Shoulder
%	45	17	32	10	58	44	14	28
	Foot as one entity 53, = 85 % forefoot and 32 % hindfoot/ankle				Hand as one entity 72, = 81 % finger and 62 % wrist			

When more than one joint was involved in the debut, the disease started in median 2 joints (1-3, P25; P75). Forefoot-finger involvement was the most usual combination in 29 %, followed by forefoot-wrist in 20 %. Hindfoot/ankle-finger were combined in

11 % and hindfoot/ankle-wrist in 11 % as well. Involvement of both the forefoot and the hindfoot/ankle as debut combination was recorded in 9 %.

94 % declared having currently involved joints. 80 % stated current foot problems, of which 86 % were located in the forefoot and 52 % in the hindfoot. Both parts of the foot were affected in 45 %. The hands were currently affected in 83 %. Comparison with involvement of other joint is shown in Table 6.

The distribution and number of currently affected joints were also compared for patients with or without anti TNF treatment. No differences were found between the groups.

Table 6: Currently affected joints during active RA disease, n= 992.

	Foot	Knee	Hip	Hand	Elbow	Shoulder
% of all	80	55	29	83	36	57
% of pat on anti TNF	82	52	31	81	41	58
% of pat not on anti TNF	79	56	28	83	34	56

When more than one joint were currently involved, median 3 joints were affected (2-5, P25; P75). Here, foot-hand-shoulder was the most usual combination in 47 %, followed by foot-hand-knee in 45 %.

71 % (n=996) declared difficulty in walking due to their feet. There was a significant correlation between foot related walking incapacity and duration of illness ($p<0,000001$) but not with age ($p=0,55$).

In 41 % the foot affected the subjective walking capacity the most. In 32 % the foot was the only joint affecting the gait. Comparison with knee and hip is shown in Table 7.

Table 7: Joints affecting the subjective walking capacity in patients with RA, n= 994

	Foot and ankle	Knee	Hip
Most obstructing joint, %	41	16	9
Only obstructing joint, %	32	8	7

Of the patients with current foot problems, 21 % were operated on in the forefoot, and 7 % in the hindfoot/ankle. 96 % of the patients who had undergone an operation in the forefoot or in the hindfoot/ankle still declared walking disability due to their feet.
Table 8.

Table 8: Survey of patients with current foot problems							
	Forefoot affected	Hindfoot affected	Both affected	Having insoles	Using insoles	Operated forefoot	Operated hindfoot
% of foot patients	86	52	45	68	93	21	7

Operations of other joints were reported in the hands in 25 %, in the knees 12 %, in the hip 12 % as well, in the shoulder 5 % and elbow 4 %.

96 % (n= 1000) were on some active medication, of median 2 types (1-2, P25; P75). 27 % were on Glucocorticoids, 73 % on Methotrexate, 16 % on Sulphasalazine and 31 % on anti TNF treatment. 30 % used NSAIDs. Other medications (Cyclo-phosphamide, Hydroxychlorokine, Leflunamide, Azathioprin, Chlorokinphosphate, Cikclosporine, Chlorambucil) were less than 6 % each.

Debut panorama preceding involvement today: Current involvements of other joints were much higher (> 40 %) after debut involving the forefoot and the hand, compared to debut involving hip, elbow, hindfoot, shoulder or knee (10-40 % involvement of other joints later in the disease), with the lowest figure after hip debut.

10 DISCUSSION

10.1 THE NEED OF SURGERY

Great advances in the medical treatment for rheumatoid arthritis have been reached during the last decade with early, aggressive, combination treatments and the introduction of the biological drugs.[83] However, true remission is reported obtained only in a small proportion of patients,[63] and so far, there is no definite cure to the disease. Surgical treatment is still of need for painful and deformed joints, even though a decrease in in-house surgical procedures in general in RA patients have been shown recently.[179] This may be a consequence of a reduced need of surgery, as shown for patients diagnosed after 1985 and /or a trend towards earlier but less radical surgery, at least in the foot, with day-care surgery being sufficient.[9,148] Young age, sero-positivity, rheumatoid nodules and female gender are considered risk factors for disease related joint surgery.[99,148] Low haemoglobin concentration, high disease activity measured with DAS including high scores for erythrocyte sedimentation and number of affected joints, and radiographic signs as erosions have been shown to be risk factors for large joint replacement surgery. These parameters were valid for hand and foot surgery too, as well as high HAQ score and female gender. In this material, 11 % of RA patients treated with conventional drug therapy for 5 years had undergone large – or small joint surgery.[67] This is in concordance with our findings with operations reported in 12 % in the hip and knee joints. The foot though, had in our material been operated on in 21 % of the cases.

10.2 ARTHRODESIS OR RESECTION OF MTP 1?

In the severely deformed rheumatoid forefoot, when total forefoot reconstruction is needed, arthrodesis or resection are the two major surgical options for the first metatarsophalangeal joint.[166] Patients satisfaction after resection vary a lot, with 51 % to 93 % good-excellent results noted in different papers.[29,89,102,132,173,175] The major complaints have been high recurrence of hallux valgus, metatarsalgia and plantar callosities in sometimes up to 53 %, 36 % and 61 % respectively.[53,102,173] In these studies the Keller, not the Mayo type of resection was used.

During the 1980s and 1990s arthrodesis grew in popularity. A stable first ray would maintain the weight-bearing capacity of the big toe. Studies with Harris foot mat

showed that the hallux bore weight in 50 % more of the cases after fusion compared to after Keller resection which could prevent metatarsalgia.[57,112] The cosmetic result was also reported better after arthrodesis compared to after resection.[6,112]

Retrospective follow-up studies after total forefoot reconstruction with arthrodesis in MTP 1, have shown high degree of patient's satisfaction, 88 to 96 % after up to 6 years with few recurrent plantar callosities.[24,94,95,116] The operative technique for an arthrodesis is though often more demanding. Accurate position of the great toe is important but can be difficult to achieve.[23,53,189] The rate of pseudarthrosis vary up to 44 % and may call for reoperation.[24,62,121,175] Arthritic degeneration of the IP joint can develop and have been reported in 30 to 60 %.[24,94,95,173] The higher figures were shown in cases where heavy threaded Steinmann pins, longitudinally inserted penetrating the IP joint, had been used for fixation the MTP 1 fusion. Only one-third of these were reported painful though.[94,95]

A thorough analyse of the operative technique for an arthrodesis felt necessary to start with.

10.3 OPERATIVE TECHNIQUE FOR ARTHRODESIS - STUDY I AND II

This analysis resulted in the development of a guide-plate and a careful surgical technique for the preparation and the fixation of the fusion, in order to increase the rate of healing and to optimise the positioning.[49,50] The optimal angles, according to the literature, are reported to be a Hallux Valgus angle of 5-25°, with a mean of 15°. The dorsi-flexion is most often given in DFA degrees, and then 25°-35° of Dorsi-Flexion Angle is stated as desirable.[23,39,90,111,131,141,149,178] This corresponds to an Angle of Inclination of 10-15° approximately. The rotation should be none. When using our guide-plate, we found a mean postoperative Hallux valgus angle of 13° (2-29°) and an Angle of Inclination of 13° (0-31°). Analysed separately, the HVA in the rheumatoid group was mean 15° compared to 5° in the non rheumatoid patients. This may illustrate the difference in foot configuration between these two groups. A rheumatoid foot has often a lateral deviation of the whole forefoot, while a Hallux rigidus foot on the other hand is usually more straight. Sometimes therefore, the position of the great-toe has to be adjusted according to the situation present. The AI may be influenced by different thickness of the soft-tissues underneath the great-toe and MTP 1, explaining a certain variation of the measurements.

Some spreading of the degrees in the positions in spite of the use of the guide-plate indicate the difficulty indeed to position the fusion correctly under any circumstances, a part from the need to consider the individual foot configuration. It is also difficult to perform accurate measurements of the angles on radiographs.[134] The findings may vary depending on method used for the measurements.[144] Furthermore, points of reference and techniques for defining the angles in this area are seldom accounted for. Our reference points for measuring the HVA were set as recommended as the most appropriate method according to Schneider et al.[144] For the AI we used the plantar surface of the proximal phalanx of digit 1, as this forms the "end point" for the dorsi-flexion of the great-toe during lift-off, and the floor. Five random, blinded re-measurements showed a high degree of conformity with maximum 4° discrepancy, which is well within the interobserver error reported in hallux valgus surgery[134]

A prospective, randomised study to compare the use to non-use of the guide-plate would have been preferably, but the amount of patients in need of this procedure is limited. In our view, the aid of the guide-plate may protect from serious malposition and as this is of great consequence for the patient and difficult to attend to, it may be considered of value. Also, it focuses on the fact that measurement of dorsal angulation should be done according to the Angle of Inclination, not the Dorsi-flexion angle, as the AI constitutes the functional angle by which the patient walks. The rate of healing of the fusion with the technique we chose was higher (4,5 % pseudarthrosis) than many others (10-26- 44 % pseudarthrosis)[62,121,175] even if one American study have reported 0 %.[24] In total, our choice may be considered proven to be adequate.

10.3.1 Operative technique for the lesser MTP joints - general remarks

Many different incisions and different amount of bone to be resected in the lesser MTP joints have been advocated.[19,43,74] We chose to use two dorsal, longitudinal incisions to be able to perform a total dorsal soft-tissue release with extensor tenotomy. This reduces the dorsally pulling forces and thereby the piston effect of the smaller toes, pushing the metatarsals downwards towards the floor. Also, using a saw instead of a rongeur when resecting the smaller metatarsal heads and aiming at a 45° angle towards the floor, as well as a smooth arc between the head, may be of importance for less recurrence of painful prominences. A 90° cut leaves a sharp edge, presumably predisposing for new metatarsalgia. The use of temporary K wires may be of help for retaining the position of the lesser toes during soft tissue healing. Our results with significantly reduced

prominent callosities in both groups still after mean 6 years support the effectiveness of this surgical approach, emphases the importance of how to perform these resections and may well be part of the reasons for the high patients satisfaction rate.

10.4 TYPE OF RESECTION IN MTP 1 TO COMPARE TO ARTHRODESIS?

The main question in this thesis was to compare the two different ways to deal with the MTP 1 in a total rheumatoid forefoot reconstruction, resection or arthrodesis. Is arthrodesis superior to resection? Is the outcome better, more long-standing and motivating the risks for technical problems maybe leading to malposition, disturbances of adjacent joints and pseudarthrosis and possible need for reoperations? After having analysed the operative technique of the fusion, a choice between the two types of resection, Keller (resection of the base of the proximal phalanx of the hallux)[75] and Mayo (partial resection of the first MT head)[101], had to be made as to which method to use for the comparison to fusion.

Many of the disadvantages reported after resection may be a consequence of the de-functioning of the big toe which the Keller resection leads to. To perform a Keller, the plantar structures, that is the plantar plate and intrinsic muscles, giving the great toe flexion capacity, have to be detached.[42] A distinct proximal migration of the sesamoids and the absence of active flexion in up to 68 % after a Keller procedure, compared to 21 % after a Mayo procedure, supports this[46,174] and may result in a cock-up position of the great toe[21,174] and recurrence of hallux valgus (Fig 24).[46,102,173] Most important, this also reduces the weight bearing capacity of the digit 1.[31,57] The load not taken by the great-toe may then be transferred to central parts of the forefoot which have been shown in several studies,[46,57,143] resulting in so called transfer-metatarsalgia, an usual drawback reported after MT head resection.[102,112,157] Fuhrmann-01 also found a lateralisation of the centre line of weight-bearing under the forefoot after Keller.[46] Clinically, stress fractures on MT 2 and 3, as a sign of increased load, have also been reported after Keller resection.[42] Transfer-metatarsalgia can be very handicapping and resistant to treatment in all kind of patients, but certainly not desirable for patients with RA, already having destructed or even removed MT heads. So a Keller resection, whether isolated or as part of a total rheumatoid forefoot reconstruction, seems to be hazardous for all, but especially for the rheumatoid patient

Fig 24: A cock-up position after a Keller resection in MTP 1

The Mayo technique on the other hand, leaves the plantar structures to the great-toe and thereby retains the flexion capacity, even if it certainly shortens the lever-arm. In comparison between Mayo and Keller resection, 50 % less recurrent callosities and metatarsalgia after Mayo have been found.[46] Other retrospective studies have also shown high degree of patients satisfaction in 88 - 93 % after 11-12 years follow-up after using the Mayo technique in MTP 1.[71,73] Recently, these good results after this type of resection have been confirmed by Thomas et al 2005 with no recurrent, severe hallux valgus and recurrent plantar callosities in only 2/37 feet and by Reize et al 2006 with 85 % painless feet, both studies with a follow-up of more than 5 years.[135,162] All these reports support the profound difference between Keller and Mayo resection, making it important to distinguish them from each other. If a need for a reoperation should occur, fusion is also easier to perform after a Mayo than after a Keller resection. In our study we chose the Mayo type of resection to compare with fusion due to the reasons given above.

10.5 ARTHRODESIS COMPARED TO MAYO RESECTION- STUDY III AND IV

Retrospective studies comparing resection, mostly of the Keller type, to fusion sometimes indicate better results after fusion with a higher degree of recurrent hallux valgus, higher pressure under MT 2-3 and more callosities under the forefoot after resection.[112,173] In other reports, the patients were just as, or more, satisfied in the resection groups.[53,62,175] It is possible that a stiff first metatarsal joint, even though cosmetically pleasing, may impede the gait to some extent, thereby reducing the positive effects in other aspects. Sagittal plane blockade of MTP 1 is known to reduce efficient advancement of the body during walking.[188] A reduction in ankle power, shown after arthrodesis in MTP 1 for hallux rigidus, supports this view.[28]

Our prospective, randomised study is to our knowledge and according to a systematic review from 2005, up until now, the only one in its field.[38] In this study we chose to analyse patients' subjective view of the situation concerning pain, handicap and general activity with a validated instrument, the Foot Function Index[16,140] and general patient's satisfaction rate was measured with VAS after median 3 and 6 years. A significant correlation between FFI and both HAQ (a functional score often used in assessment of RA) and DAS-44 (disease activity score with 44 joints count) has been shown.[4,87] This supports the importance of foot problems in RA and the value of FFI, as HAQ and DAS are parameters commonly used for prediction of disease severity and for response of treatment.[77,83,183] For the objective analysis we chose deformity in terms of recurrent callosities, degree of hallux valgus and symptomatic degeneration of the IP joint after median 3 and 6 years. Bony healing of the arthrodesis was measured on radiographs. Load distribution on Fscan mat and time-and distance parameters measured were with a 3D Motion system were recorded in approximately half of the patients after median 6 years. Due to geographical reason, all of the patients were not possible to examine with these two advanced equipments.

After both median 3 and 6 years, we found excellent patients satisfaction rate and significant, lasting reduction in pain and handicap according to FFI with no statistically significant differences between the groups. There were no significant recurrences of prominences or tenderness under the forefoot in either group. Ninety-three percent of the fusions healed. There was no risk for recurrence of severe hallux valgus in the resection group. The Hallux valgus angle was not measured exactly radiographically, except after fusion. It has been shown that the clinical outcome of hallux valgus surgery is not well correlated to radiographic changes.[134] Instead we measured the hallux valgus angle clinically in three groups; straight < 20 degrees, average position 20-40 degrees and severe >40 degrees. We believe this is a functional way to describe hallux valgus. The range for the hallux valgus angle in asymptomatic feet has been found to be 0-32°.[153] According to these findings, only the severe position was here considered to be of clinical importance. 7/8 patients with a severe hallux valgus preoperatively were improved and stayed improved after mean 6 years. Measured with VAS, the resection group reached median 91/100 points when asked about satisfaction with the great-toe in particular. The fusion group rated 90/100 in this question. Clinically important IP joint problems, that is, painful deformity, were not increased after fusion. A tendency towards a lateral, but painless deformity of the IP joint was seen in this group though,

but this was not statistically significant. The operating time was significant longer in the fusion group but the rate of infection was not increased.

10.5.1 Load measurements and time and distance parameters in study IV

In unoperated rheumatoid patients, studies have shown absence of the normal rolling action of the foot,[14,147] delayed and reduced forefoot loading[120] and a slight lateral shift of load from the medial side of the foot to central[109] or even lateral parts.[29,145] Load measurements reported after forefoot surgery are highly varying. Comparisons are difficult to make as so many different types of equipment and techniques of measurements are used. [28,29,46,57,123,126,143,155,188] The Fscan mat is a well documented device for foot pressure measurement.[91] Different ways of dividing the foot into areas of interest have been used. To minimise measurement errors, we preferred not to divide the footprint into many, small areas. Since none of our patients made foot prints of their toes, the distal 1/3 of the foot was easy to distinguish as the "forefoot" where the mean pressure could be measured. The width of this area was measured and defined as 100 % to which the position of centre of force was related. The fact that non of the patients, compared to the healthy controls, made foot prints of their great-toe during standing may contradict a superior support of this toe after fusion, at least during standing. Furthermore, referring to the discussion of the angles, a position giving contact with the ground during standing would presumably also be inconvenient to walk with, disturbing the roll-of action of the step. The negative impact of reduced dorsal motion in MTP joints on walking parameters have recently been shown by Laroche et al.[86] In this study, preservation of the motion in MTP 1 is presented as favourable. This can be interpreted as a support for the Mayo resection, which produces a kind of painless semi-joint or pseudarthrosis. Clinically, the importance of a possible motion in the MTP1 may be illustrated by the description of the good function for patients with pseudarthrosis in some studies.[23,94]

Our goal was to compare the two groups to each other in search for detectable, objective differences in load distribution. Neither in mean pressure per 1 minute nor in position of centre of force did we find any statistically significant differences between the two groups. This seems to be in concordance with the deformity findings with no differences in recurrent callosities or tenderness. The operative technique for the lesser metatarsal joints, with sawing in 45° plantar angle to produce a kind of "rocker-bottom" surface, may be of importance for creating a smooth weight-bearing area under the

forefoot with less risk for recurrent callosities and pain, besides the avoidance of transfer of weight by not using the Keller technique. The small difference in position of force between the resection group and the controls may, if anything, contradict lateralisation of weight-bearing after Mayo resection.

The 3D 6 camera Vicon system is a well-established and reliable method for evaluating gait and has been used in analysis of rheumatic adults and children with juvenile idiopathic arthritis.[15,120,147] In a similar 3D system, the correlation between decreased dorsal motion in the MTP joints and reduced walking velocity and stride length discussed above has been shown.[86] The system has also been used on non-rheumatoid patients operated with arthrodesis in MTP 1 due to hallux rigidus.[28] This study showed decreased step length after arthrodesis compared to healthy controls. In the time-and distance parameters in our study, there were no statistically significant differences between the groups in velocity or step length**.** A higher cadence, more steps/min, and a shorter stance phase (ground contact time) were found in the fusion group, maybe as a sign of the loss of motion in MTP 1 resulting in a quicker lift-off. A fusion is supposed to provide the foot with a more stable first ray and thereby a stronger push-off. An insufficient push-off causes the foot to leave the ground prematurely which might be recorded as a reduced stance phase on that foot.[181] In our material, we did not find a shorter stance phase in the resection group that would imply an impaired push-off compared to the fusion group, on the contrary, it was longer. This, on the other hand, may be a possible sign of prolonged duration of loading and thereby a risk for pain and damage according to Otter et al.[123] The higher cadence together with the shorter stance phase in the fusion group may therefore be considered as both a disadvantage - affected push-off, and an advantage - reduced duration of loading. In all, conclusions must be carefully drawn since the sample in this gait analysis is small and the significances found were not strong (p=0,04).

The plantar flexion moment expresses the force acting on the ankle during gait. In this parameter, there was no significant difference between the groups. Compared to a control group of healthy adults (n=14) measured with the same Vicon system in the same laboratory there was a significant difference in plantar moment between both our groups and these controls (unpublished data). This is in line with earlier findings showing significantly lower plantar moment in rheumatoid patients compared to nonarthritic.[120] The reduced plantar moment shows the impaired efficacy in the protrusion of the foot as a segment in rheumatoid patients overall.

The time for walking 20 m with shoes on from preop to follow-up was significantly reduced ($p<0,001$). In spite of having a chronic, progressive joint disease and being several years older, the patients walked significantly quicker 6 years after surgery than before. This seems to be well in line with the significant correlation shown between FFI and both HAQ and DAS [4,87] and may be an illustration of the general importance of good foot surgery for these patients (Fig 23, in Results).

In conclusion, in a prospective and randomised study, comparing Mayo resection to fusion in MTP 1 as part of total rheumatoid forefoot reconstruction, we found after mean 6 years still excellent patient satisfaction rate and significant, lasting reduction of FFI with no statistically significant differences between the groups. There were no significant differences in recurrent deformity or load-distribution under the forefoot measured with Fscan. Velocity, step length and plantar moment did not differ. Cadence was higher and stance phase shorter in the fusion group, maybe as a sign of the loss of the rocker function in MTP1 and maybe both a disadvantage and an advantage. The compiled results support that Mayo resection may still be a good choice for MTP 1 approach in total rheumatoid forefoot reconstruction also in the long run.

6 years after total rheumatoid forefoot reconstruction

Fig 25: with fusion in MTP 1

Fig 26: with Mayo resection in MTP 1

10.6 EPIDEMIOLOGICAL ASPECTS - STUDY V

In RA, the forefoot have been stated affected in almost all of the patients after 10 years duration of disease ever since K Vainios investigation from 1956.[172] Later, but a lot smaller, investigations have supported the involvement of the foot in 80-90% of the patients with rheumatoid arthritis (Table 9, page 46).[76,100,105,107,172,182] We can now confirm this situation 50 years after Vainio in a material of 1000 patients, where 80 % stated current foot problems. The hands were currently involved in 83 %. In 19- 46 % of the cases the feet have been reported to be engaged in the debut of the disease.[40,65,76,107] In our material 53 % stated debut affecting any part of the foot, 45 % explicit the forefoot. This is almost as often as debut in the joints of the hand,[40] a localisation more commonly known to be a site for a first sign of RA. This is important to point out, as diffuse forefoot symptoms, like tenderness and/or pain during lift-off, should be suspected to be a possible sign of an oncoming RA. In adults, the forefoot dominates the picture over the hindfoot and ankle by far, both as debut joint[40] and later in the disease.[107,152,172,182] In our study 86 % of the patients with current foot problems stated forefoot involvement compared to 52 % hindfoot/ankle problems. This is in concordance with other reports[76,100,172,182] except for Michelson et al who found 80 % ankle symptoms compared to 68 % forefoot problems.[105] Hindfoot involvement often starts insidiously and proceeds with a slowly oncoming valgity, easily foreseen. There is also often a certain clinical difficulty to distinguish ankle symptoms from talo-navicular involvement in the hindfoot, both for the patient and the physician, with the pain being experienced medially on the foot, just distal of the medial malleolus. On account of this, we preferred to merge symptoms from these two joint systems, the ankle and the hindfoot, into one entity. Forefoot synovitis has often a more distinct, painful onset with the stress brought upon the MTP joints during the lift-off phase of walking and is possibly more easily recognized.

Thirty-one percent of our patients were on biological treatment, the same level as reported elsewhere.[9] Unexpectedly, we did not find any significant differences in currently affected joints reported between the patients on or not on biological drugs. However, we do not have data concerning the duration of the arthritis in each case before the introduction of this treatment. Extensive involvement of different joints might have been ongoing already. If this assumption is correct, the findings may indicate a limited effect of these last new medicines in an advanced disease. On the other hand, our patients stated currently affected joints in median 3 joints, compared to

13 joints reported in the mid 1990s, maybe as an effect of the new medication paradigm.[105] Also, our study does not include any quantification of the involvement or the level of pain, just the presence of subjective symptoms. Still it reflects the patients' everyday reality and experiences.

Hand and foot involvement also seem to imply a more severe disease, as involvement of other joints later in the disease was much more often found after this type of debut compared to after debut in the larger joints. Disease severity has also been shown to be related to the progression of foot deformities radiographically.[146]

In ¾ of the cases the foot caused walking disability and was twice as often the only joint in the lower extremity impairing the gait. This correlates well with the findings of Kerry et al who reported the foot as the only cause of walking difficulty in 24 % and in association with other joints causing problems in 76 %.[76] The surgical options for the knee and hip have developed enormously during the last decades with excellent results.[58,136] This might be a reason for the high percentage that experienced reduced walking capacity due to the foot compared to the knee and hip. On the other hand, only 12 % stated having had an operation of each of these two joints.

Insoles had been prescribed in 68 % of the patients with foot problems and were declared being used by 93 %, which are high figures compared to others, where 5-15 % had special shoes or insoles[76,105] Recently, Matricali et al reported a use of insoles in 42 % and custom-made shoes in 25 %, together with our findings, maybe a sign of an increasing trend.[97] As orthoses have been shown to reduce pain and alter pressure distribution in painful forefeet as well as to reduce excessive subtalar eversion during the stance phase in symptomatic valgus hindfoot deformity, both studies on RA patients, the use of orthoses may be encouraged.[59,187]

Surgery had been performed in 21 % in the forefoot and in 7 % in the hindfoot/ankle cases, also in line with the Matricali study with surgery in the forefoot in 36 % and in the hindfoot in 7 %.[100] Over 90 % of our patients reported walking disability in spite of this too. This may be a reflection of the difficulty to perform successful foot surgery. High demands, unrealistic expectations and prospects from the patients and the physicians may be other reasons. Further development of knowledge and skills in foot surgery is therefore of high interest, even though it always must be remembered that surgery only offers an effort to repair or reduce damage, never a complete renewal. This need for increased knowledge within foot surgery has indeed been our guideline throughout this research project.

Table 9: Investigations of foot involvement in rheumatoid arthritis.					
	Patients, n	Debut in the foot % of pat	Debut in forefoot especially % of pat	Debut in hindfoot especially % of pat	Current foot involvement % of pat
Vainio -56	955				89 foot involvement in general 67 hindfoot involvement 9 ankle involvement
Minaker -73	50	46 28 only foot as debut	34 16 only forefoot as debut		84 forefoot pain 38 hindfoot/ankle pain 22 midfoot pain
Jacoby -73	100	21			
Vidigal -75	104				77 forefoot clinically involved 86 forefoot x-ray changes 48 ankle clinically involved 26 ankle x-ray changes 21 subtalar clinically involved 32 subtalar x-ray changes 62 midtarsal clinically involved
Fleming -76	102	19	13	6	
Spiegel -82	50				65-55 forefoot synovitis 30 subtalar synovitis 37-63 ankle synovitis
Kerry -94	100	32			79 foot involvement in general 59 forefoot pain 61 hindfoot pain 10 midfoot pain
Michelson -94	99				94 foot symptoms in general 68 forefoot pain 80 ankle pain
Matricali 2006	285				81 forefoot pain
Grondal 2005	1000	53	45	17	80 foot symptoms in general 86 forefoot symptoms 52 hindfoot/ankle symptoms

10.7 FUTURE PERSPECTIVE

The development of the medical treatment of RA is moving fast forward. The definite cure may well be within reach. An effective modulation of the disease seems to limit

the degree of joint deformities. Hopefully the indication for joint-sacrificing surgical procedures will be reduced. As all parts of our bodies have a definite role to play, removing as little as possible and preserving as many joints as possible must be our goal. Different ways to try to diminish the pressure on the MT heads without resecting them have been introduced. MT head preserving operations have developed during the last years and may be preferable to any type of resection or arthrodesis. Of the MT osteotomy techniques though, the Helal type[55,56] is unfortunately commonly connected to non-union and persistent metatarsalgia.[113,167,186] The Weil osteotomy has better results but complications in terms of dorsi-flexion contraction of the MTP joint in question and floating and stiff toes are reported.[7,61,105,169] The materials in these studies are also mixed, sometimes including RA sometimes not. As far as can be understood though, RA patients with advanced destructions of the MTP joints are not included in any of them. Also, patients with previous Keller resection did worse with persistent metatarsalgia after the Weil procedure, illustrating the difficulty to treat transfer-metatarsalgia after a Keller operation.[61] As for the Stainsby MT head preserving technique, the soft-tissue procedure to reduce the piston effect[13] is quite in line with our approach but we chose to resect the eroded MT heads instead of the non-eroded digital bases. Only one follow-up study on this method has been found.[12] This included both RA and non RA patients and the information about the degree of destructions of the MT heads was scanty.[12] Furthermore, recurrent hallux valgus was noted in 20 %, maybe due to the use of the Keller resection in MTP 1. Altogether, the effect of joint-preserving forefoot procedures on feet with erosive destruction of the MT heads has not, as yet, been shown and further research is of need. On the other hand, earlier and less radical surgery with the goal to diminish the pressure on the MTP joints, as in this latter technique, may possibly prevent the formation of severe deformities.
Luckily, knowledge is not a steady-state business. As long as man's curiosity remains and research continues, the future will certainly bring new developments about.

Fig 27: Quid si sic…T. Brahe

11 SUMMARY

In study I and II we analysed the methodology for performing an arthrodesis of MTP1. The angles of importance for the positioning are the Hallux Valgus Angle (HVA) and the Angle of Inclination (AI). The AI is the angle between the great-toe and the floor and constitutes the functional angle by which the patient walks. This is more appropriate to use for measurement of the dorsiflexion of the arthrodesis than the Dorsi-flexion Angle (DFA), which is the angle between the great-toe and the first metatarsal. A guide-plate to aid the positioning in recommended angles was presented. Different techniques for preparation and fixation of an arthrodesis in MTP 1 were penetrated. The rounded cup and cone preparation technique produces two well-fitting bony surfaces with retained possibility to choose the angles of the arthrodesis after the preparation without loosing contact area. Two cortical screws, crossed over the fusion site, introduced in a lag-screw manner without compromising the IP joint, were used for fixation. Together, we found this concept a reliable and satisfying method for fusion of the first MTP joint with a high healing rate in a good position with few complications.

In study III and IV, total rheumatoid forefoot reconstruction with resection of MTP 2 to 5 combined with either Mayo resection or arthrodesis in MTP 1 were compared in a prospective, randomised concept. Preoperatively, the groups were statistically alike concerning pain, subjective handicap and activity according to Foot Function Index. Also, there were no differences in degree of deformity, as hallux valgus and prominent, tender callosities under the forefoot, or in IP joint involvement.

After mean 3 years, we found excellent patient's satisfaction rate with significant reduction in Foot Function Index (FFI) with no statistically significant differences between the groups. There were no recurrences of callosities in any of the groups, no increased risk for recurrent severe hallux valgus in the resection group or for painful IP joint problems in the fusion group. The operating time for fusion was though significantly longer.

After mean 6 years, the reduction in pain and handicap remained and there were still no statistically significant differences between the groups in FFI. Patient's satisfaction rate was still excellent and the number of callosities and tenderness were still significantly reduced. The risk for recurrent severe hallux valgus in the resection group

was not increased, nor was the rate of painful IP joint problems after fusion. A tendency towards increased lateral deviation of the IP joint after fusion was seen but this was not statistically significant. Time for walking 20 m with shoes on was significantly reduced in both groups with no statistical differences between them.

Gait velocity, step length, plantar moment, mean pressure or position of centre of force under the forefoot measured in half of the patients, did not differ significantly either. Cadence (steps/min) was higher and stance phase (ground contact time) shorter in the fusion group, possibly due to the loss of motion in MTP 1.

In study V, during the year 2005, 1000 patients with rheumatoid arthritis answered a questionnaire concerning gender, age, duration of illness, current medication, debut joints, currently affected joints, joint surgery, foot problems and subjectively experienced reasons for reduced walking capacity. In 45 % the forefoot had been involved in the debut of the disease, compared to the fingers in 58 %. Eighty percent stated current foot problems of which 86 % were located in the forefoot. Hand problems were reported in 83 %. Thirty-one percent were on biological treatment. Analysed separately, this group did not present a different panorama of current joint problems. However, no data concerning duration of illness or severity of disease before the introduction of the biological treatment was collected and no quantification of the symptoms was made. Difficulty in walking due to the feet was declared in 71 %. There was a significant correlation between foot related walking incapacity and duration of illness, but not with age. For 41 % the foot was the most important part and for 32 % the only part in the lower extremity causing reduced walking capacity.

12 CONCLUSIONS

- Optimal positioning of a fusion in MTP 1 is considered important and is difficult to obtain. The procedure may be facilitated by the use of a guide-plate to aid the positioning to prevent serious malposition. Careful preparation with a rounded cup and cone reamer and fixation with two cortical screws, not compromising the IP joint, may lead to a high healing rate of the fusion.

- In a prospective, randomised study, after both mean 3 and 6 years follow-up, total rheumatoid forefoot reconstruction resulted in significant and lasting reduction of pain, subjective disability and deformity. Patient's satisfaction rate was excellent. Time for walking 20 m with shoes on was significantly reduced. Arthrodesis of MTP 1 as part of the procedure, compared to resection according to Mayo, did not present any significant superiority in the parameters mentioned above. Load measurements under the forefoot and time-and distance parameters after mean 6 years were statistically equal between the groups, except in cadence (step/min) and stance phase (time for ground contact with one foot), possibly a sign of the loss of motion in MTP 1 after fusion, and possibly both an advantage and a disadvantage.

  Extensor tenotomy, dorsal capsular release and the surgical technique for the resection of the lesser MT heads are factors believed of importance for a good result.

- The foot is still, during active medical treatment in the year of 2005, in 80 % of 1000 patients experienced as troublesome. The forefoot is almost as frequently as the hand involved in the debut of RA. In ¾ of the cases the foot caused subjective walking disability and was twice as often as the knee or the hip stated as the only joint impairing the gait. Involvement of the foot still seems to be of great importance to patients with rheumatoid arthritis today.

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The Danderyds Hospital, where I learnt orthopaedic surgery

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The Red Cross Hospital, where I wrote the thesis

The Karolinska University Hospital, where my tutors act

So long for now, new adventures are waiting!

Chercher pour trouver et trouver pour chercher encore.

J. Eyheralde

Nysilat vin av den gröna myrans märke
En liten eldstad av röd lera
Det kommer att snöa mot natten
Vill du dela en bägare med mig

Okänd kinesisk poet