Rheumatoid forefoot deformity: pathophysiology, evaluation and operative treatment options

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Abstract Despite recent advances in pharmacological management of rheumatoid arthritis, forefoot deformity, with its symptoms, remains a common problem, often requiring operative treatment. Typical deformities in these patients comprise hallux valgus and deformity of the lesser metatarsophalangeal (MTP) joints and toes. With regard to the lesser rays the standard operative procedure, advocated for the disabling forefoot pain in these patients, remains metatarsal head resection. It should be considered that with increasing success of pharmacological treatment the degree of forefoot deformity in these patients is becoming less and that resection of the lesser MTP joints is becoming more and more superfluous. This supports a trend towards metatarsal head-preserving surgery. The optimal treatment of the hallux deformity remains unclear. Fusion of the first MTP joint is, generally, recommended. This article will discuss the current surgical options in rheumatoid forefoot pathology.

Keywords Rheumatoid forefoot deformity · Preservation of metatarsal heads · Fusion of first metatarsophalangeal joint

Introduction

Although its worldwide incidence appears to be on the decline, rheumatoid arthritis continues to compromise the

weight-bearing function of the foot [1]. It is an undisputed fact that the foot, and in particular the forefoot, takes a major place in the surgical treatment of inflammatory joint diseases. Pain as a result of synovitis of the metatarsophalangeal (MTP) joints is often the initial symptom of rheumatoid arthritis and it is reported that within the first three years of rheumatoid arthritis, approximately 65 % of the patients have MTP joint involvement [2–4]. It is estimated that with chronic polyarthritis two thirds of patients will develop subluxation and dislocation of the lesser MTP joints. The incidence and severity of hallux valgus increases in the chronic stages (60–90 %). Eventually 5–22 % of these patients will be treated surgically [5, 6]. To date the extent to which the increased efficacy of the present pharmacotherapy results in a decrease of the prevalence of foot deformities in adults with chronic rheumatoid arthritis is unknown. Pharmacological therapy includes analgesics, anti-inflammatory agents, disease-modifying anti-rheumatic drugs (DMARDs) and biologicals [7].

As underlined by Karl Tillmann a thorough knowledge of the pathogenesis of these deformities and understanding of the biomechanical changes are necessary in order to plan effective surgical procedures (e.g. the selection of the best suited operative procedure among a number of methods at one's disposal) [8]. Continuous and simultaneous pharmacotherapy by the rheumatologist is imperative for both short-term and long-term results of treatment. This manuscript will discuss the current surgical options in rheumatoid forefoot pathology.

Biomechanical changes of the forefoot. Why does it hurt?

Deformities of the forefoot in patients with rheumatoid arthritis are characterised by the destruction of both the osseous and the soft tissue structures. It is generally accepted that synovitis is the initiating agent of destructive processes of the joint components. In the forefoot the MTP joints are most

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often involved. The synovitis, with ingrowth of pannus and cytokines, causes destruction of the joint cartilage and can lead to erosions of the metatarsal (MT) heads and the proximal phalanges of the toes. The severity of radiological changes is generally assessed by the Larsen classification, which correlates with the degree of articular destruction [9]. However, once the synovitis has been adequately treated with the help of pharmacotherapy or the acute symptoms have otherwise subsided it is not the amount of cartilage loss or subchondral bone resorption that determines the clinical symptoms, but the amount of resulting forefoot deformity. Thus eventually, as promulgated by Stainsby from a basic pathomechanical point of view, there is no difference between the situation of severe claw toe deformity in rheumatoid and non-rheumatoid patients [10].

Synovitis causes distension of the capsules and ligaments resulting in loss of integrity of the joint. Meanwhile erosions at the insertions of the ligaments may cause further slackening. The balance between intrinsic and extrinsic muscles is lost and eventually this may lead to subluxation, followed by dislocation of the MTP joints. At the first MTP joint this commonly results in hallux valgus. The proximal phalanges of the lesser toes are pulled dorsally and towards the fibular side. The fifth MTP joint commonly has a greater tendency towards a varus position. The continuous dorsal pulling on and extended position of the MTP joints, together with the pull of the flexor tendons of the toes, results in a clawing of the toes and eventually in fixed deformity of the MTP joints and the interphalangeal (IP) joints. Dorsal displacement of the long flexors and plantar intrinsics further enhance this process.

As a result of the dorsally extended position of the MTP joint the plantar plate is stretched dorsally and distally around the MT head (Fig. 1). The slips of the plantar aponeurosis which are attached to the plantar plate move dorsally. The MT head eventually can ‘herniate’ through the joint capsule and become tethered in a plantar position. The plantar fat pad and soft tissues intimately related to the aponeurosis are displaced distally to the MT head [11]. This results in loss of this specialised shock absorber on the plantar aspect of the MT heads. A thin inadequate layer of skin and subcutaneous tissue beneath the MT heads. The MT heads are now relatively more prominent and due to the increased biomechanical stress on the attenuated soft tissue, plantar callosities and/or large bursae can develop. This leads to metatarsalgia with impaired walking ability. For clinical purposes it is important to realise that a limited range of motion of the lesser MTP joints, in itself, might already cause metatarsalgia [12]. Clinical symptoms are most probably intimately related with the loss of cushion support provided by the plantar fat pad, and the more fixed and the more displaced the MTP joints are, the greater the incidence and severity of the metatarsalgia will be.

Additional biomechanical factors subsequently play a role. The same forces applied by the tendons that lock the MTP joints in extension and the toes in flexion also result in a plantarward force on the MT heads (Fig. 2). This results in increased pressure on the soft tissues underneath the MT heads. Analogous to the increase of plantar pressure at the location of a plantar callosity as measured in diabetics, callosities in themselves probably also cause increased pressure in patients with rheumatoid arthritis. Seldom will this lead to ulceration of the plantar skin as most patients with rheumatoid arthritis do not suffer from serious sensory neuropathy.

A major additional factor that has so far not been discussed is the hallux valgus deformity that develops in the majority of patients with chronic rheumatoid arthritis. The process is similar to that taking place in the lesser joints. The proximal phalanx of the hallux is pulled laterally initiating hallux valgus. Once hallux valgus has developed a simple biomechanical model can explain that the deformity will probably progress. Force applied to the hallux through the flexor and extensor tendons, acting laterally, will pull the hallux in a further valgus position and the hallux also turns into pronation. The reaction force created by flexion and extension force pushes the first MT head in a medial direction resulting in an increased intermetatarsal angle and typical splayfoot. As a consequence the plantar load on the hallux diminishes with increase of the valgus angle. Furthermore, in a correctly aligned first ray dorsiflexion of the great toe causes an increase of the medial longitudinal arch of the foot with increase of pressure under the first MT head because of the windlass action of the plantar aponeurosis [13]. This mechanism plays an important role when weight is taken on the MT heads and is lost in the case of severe hallux valgus.

The loss of weight-bearing capacity of the first ray in patients with hallux valgus, occurring in the vast majority of chronic rheumatoids, is explained this way. It is essential to realise that this can result in synovitis of the adjacent second MTP joint resulting in subluxation and claw toe deformity and eventually even dislocation without any activity of rheumatoid arthritis. The overload of the second ray can cause stress fracture of the second MT bone and can,

Fig. 1 Extension contracture in the MTP joint with distal dislocation of the plantar fat pad and displacement with adhesion of the plantar plate

Fig. 2 Increase with weight-bearing of the plantar pressure on the MT head due to the pull of the extensor and flexor tendons in the case of claw toe deformity

also, together with hypermobility of the first metatarsal-cuneiform joint, result in arthritis and arthrosis of the second metatarsal-cuneiform joint. Thus, changes to the forefoot are associated with collapse of the midfoot and medial longitudinal arc. Vice versa, acquired planovalgus deformity is associated with the hallux valgus complex as outlined above. A severe valgus deformity of the foot is said to occur in ten to 30 % and lowering of the medial longitudinal arc in 50 % of patients with rheumatoid arthritis [14]. Clinically it is often unclear where the problems have started.

Clinical and radiological examination

In the first place it is important to distinguish between pain due to the presence of active synovitis and pain as a result of post-arthritic changes. The most classic clinical picture, described as the *pied douloureux des rhumatisants*, will present all changes as described above: lowering of the medial arch, broadening of the forefoot, hallux valgus and clawing with dorsal (sub-)luxation of the toes. Patients might experience pain from various pressure points, often caused by the interaction of deformity and footwear: (1) at the site of the medial bunion, (2) between the hallux and the second toe, eventually the second toe might move over the hallux, (3) between fixed deformed lesser toes, (4) at the plantar aspect of the MT heads due to the changes described previously, (5) on the dorsal aspect of deformed toes and (6) at the lateral aspect of the fifth MT head, due to broadening of the forefoot, a bunion and bursa can develop. Subcutaneous rheumatoid nodules could also be the cause of pain (Fig. 3). These nodules are associated with a positive serum rheumatoid factor, often occurring at sites with some form of biomechanical overload, and are found in 20 % of patients. The changes as described must be differentiated from symptoms caused by active rheumatoid arthritis, other causes of synovitis such as Freiberg's disease, septic arthritis, Morton's neuroma, polyneuropathy and complex regional pain syndrome, etc.

In order to examine the forefoot systematically the range of motion of the MTP joints, the presence of subluxation or

Fig. 3 Claw toe deformity of the lesser rays and a rheumatoid nodule on the medioplantar aspect of the first MT head

dislocation of the MTP joints, the presence of hallux valgus, the quality of the plantar fat pad, the presence of dislocation of the fat pad and the possibility to manoeuvre the fat pad back into place while plantarflexing the MTP joints as much as possible and applying some retrocapital pressure must be registered. In addition, the presence of hammer and/or claw toes and other possible causes of pressure points are examined. Weight-bearing anteroposterior (AP) and non-weight-bearing oblique radiographs of the forefoot are taken to establish the presence of erosive disorders which can be classified according to the Larsen classification, and the radiological hallux valgus parameters can be evaluated [9]. In Fig. 4 a classification system is presented which can be used to grade the severity of the forefoot deformity [15].

Making decisions

Changes to the forefoot, midfoot, hindfoot and leg are often related to one another and multiple joint problems can be involved at the same time. In order to make clinical decisions the problems concerning the foot and ankle must be evaluated as a whole and recommendations to the patients are individualised, depending on general health aspects, involvement of other joints, age, patient expectations, social aspects, and so forth. The choice of operative treatment depends on the amount of pain and disability and limitation of activity. The estimation of benefit of the operative procedure must be weighed against the results and possibilities of conservative treatment and against the risk of (post-)operative complications and the burden of post-operative recovery.

Operative treatment

Several operative techniques in arthroplasty of the rheumatoid forefoot have been described. There are many names synonymous with forefoot operations (e.g. Kates, Hoffman

Grade 0. No clinical changes in the MTP joints, no or mild radiographic changes (Larsen 0-1).

Grade 1. Decreased mobility of one or more of the joints, particularly of plantarflexion, with the ability to reduce the plantar soft tissues under the metatarsal heads, and with adequate quality of the plantar soft tissues and/or radiographic erosive changes (Larsen 2-5) or evident intra-articular changes.

Grade 2. Loss of plantar flexion in one or more of the MTP joints (up to 0_0), and loss of the ability to reduce the plantar soft tissues under the metatarsal heads, and/or with inadequate quality of the plantar soft tissues

- A.** with a hallux valgus of more than 20^0
- B.** without a hallux valgus of more than 20^0 .

Grade 3. Extension contracture in one or more MTP joint, with or without radiographic subluxation or dislocation

- A.** with a hallux valgus of more than 20^0 .
- B.** without a hallux valgus of more than 20^0 .

Fig. 4 The Nijmegen classification of forefoot disorders in patients with rheumatoid arthritis

and Clayton) [7]. They vary from type of incisions and procedure on the first MTP joint to the degree of resection of the lesser rays and the method of stabilisation. Each method has advantages and disadvantages. In general, scientific evidence regarding this subject is remarkably limited [7].

As in the operative treatment of hallux valgus it is best to be master of different techniques for the correction of different degrees and types of deformity. For instance, if only one or two of the lesser MTP joints with moderate deformity are involved, an operation preserving the MT heads may result in a better functional result than a resection arthroplasty, while resection arthroplasty is indicated in cases of severe deformity with loss of bone. Arthrodesis of the first MTP joint after a Keller resection arthroplasty might require a different technique than that for a primary arthrodesis. Individual patient-related factors including age, expectations, general health, medication, the other joints, previous surgery and skin quality should be taken into account. For one patient it can be most suitable to operate on both feet at the same operative procedure, while for another patient this might not be an option.

The aims of surgery are to relieve pain, correct deformity, to preserve or restore function and walking stability, increase footwear options and, while doing so, the cosmetic appearance may often be improved. The surgical options can be divided into operations for the hallux deformity and those for the lesser MTP joints.

The lesser rays

Resection of the MT heads

It is remarkable that the surgical procedure described by Hoffman in 1911 (for the correction of severe claw toe deformity!), by means of resection of all MT heads, continues to be the most advocated [16]. Fowler and Clayton have modified this procedure and have more or less initiated the present-day total approach to the rheumatoid forefoot deformity underlining the importance of adequate resection of bone, usually all MT heads, with realignment of the remaining weight-bearing ends of the metatarsals [17–20]. Generally, all the lesser MT heads are resected (Fig. 5) [5, 21–42].

Excision of individual symptomatic heads leads to transfer metatarsalgia and thus to worse results than excision of all four and to more operations [19, 36, 43]. Others have concomitantly excised the base of the proximal phalanges [17, 18, 20–22, 31–33, 44–47]. Mann and Schakel found no difference in outcome comparing, retrospectively, a small series of patients in whom resection of the MT heads was combined with removal of the base of the proximal phalanges with a later group in whom only the MT head were resected [48]. However, the cosmetic appearance was more pleasing in the latter group.

Complete resection of the proximal phalanges is reported to result in a high rate of recurrent deformity, weakened strength in the push-off phase of walking, less satisfaction and less relief of pain [32].

Several incisional approaches have been used, including a transverse or elliptical plantar incision and a dorsal transverse incision, but currently the use of multiple dorsal incisions is the most common [17, 18, 20, 21, 24, 30, 38, 45]. A plantar approach allows the removal of plantar calluses and bursae and offers easy access to the MT heads. Closing the skin after elliptical excision relocates adequate skin and the plantar fat pad beneath the MT shafts. Opponents of the plantar approach argue that there is no need to risk complications of the plantar incision, such as scar formation and delayed wound healing, since the plantar callosities resolve spontaneously once pressure is reduced and the patient can walk immediately after surgery [5, 48].

The goal is to realign the lesser MTP joints, most importantly in the sagittal plane in order to relocate the plantar plate and the plantar fat pad beneath the MT shafts. Ensuring that the toes are not pulled back into a claw toe position through lengthening, transfer or severing of the tendons and the use of K-wire fixation post-operatively contributes to maintaining this repositioning. The optimal amount of bone that should be resected remains debatable but depends on the magnitude of overlap of the proximal phalanx on the MT head and whether the extensor tendons are severed. Conservative resection, being the minimal amount of bone needed to decompress the joint, and threaded K-wires are associated with improved contact area, increased weight distribution through the lesser toes and improved clinical rating scores [34]. The MT bone should be cut in such a fashion that the plantar aspect of the distal stump is oriented parallel to the weight-bearing surface of the foot, to minimise the risk of a prominent surface. The length of the lesser metatarsals is related to the length of the second MT, with the third being slightly (two to three millimetres) shorter than the second MT and the fourth and the fifth metatarsals being progressively shorter in order to leave a smooth arc of resection (Fig. 5). Fixed toe deformities are corrected through IP joint resection, fusion or closed osteoclasia. Realignment of the small toes, decompression of length when needed and rebalancing of soft tissue, for instance through cutting or transposition of the flexor tendon(s) in the case of persistent clawing, probably contribute to an overall better result; however, little clinical evidence and no adequate quantitative information can be found in the literature.

Regardless of the precise technique used, the results of different methods of resection arthroplasty show a success rate of 70–90 % [21, 24, 27, 31, 39, 45]. The procedure is generally valuable for the patients with reported satisfaction rates up to 90 % of the cases. It must be noted that these results

Fig. 5 **a** Preoperative AP view. **b** Lateral view illustrating severe extension contracture of the lesser MTP joints. **c** AP view 1 year after fusion of the first MTP joint and resection of lesser MT heads, tenotomy of the extensor tendons and PIP resections. **d** Lateral view illustrating good realignment. **e** Plantar aspect of the forefoot 1 year post-op with good clinical result

are commonly not quantified. They particularly account for the short-term results and are due to the considerable amount of pain relief. After longer follow-up a variable rate (up to more than 50 %) of recurrent deformity with progressive deformity of the lesser toes, leading to metatarsalgia, recurrent plantar keratosis under the MT remnants and lateral deviation is reported [24, 27, 32, 34, 37–39, 42]. Pressure measurements show that the toes are very often defunctioned following MT head resection and the gait pattern in many of the patients shows heel strike and forefoot contact to be almost simultaneous [23, 28, 36]. The foot might be used more as a pedestal, rather than a lever and the rolling action can be absent. The reoperation rate is between ten and 15 %, the most common procedure being excision of a single plantar prominence. It is obvious that the results of resection arthroplasty of the lesser rays are influenced by the method that has been used for correction of the concomitant first ray pathology. Thus further discussion follows in a subsequent section.

Preservation of the MT heads

Synovectomy has been advocated in a small study, but considering the positive effect of present-day disease-modifying medication this no longer seems to be indicated as a stand-alone procedure [49]. This same improvement may influence renewed interest in techniques in which the MT heads are preserved (Fig. 6) [50, 51]. A technique which can be applied

if only one or two of the lesser MTP joints are severely involved, in which all the MT heads are preserved, may result in a better functional result than a resection arthroplasty.

In techniques preserving the MT heads decompression in order to relocate the soft tissues is accomplished through tendon releases, resection of bone of the proximal phalanges, through shortening arthrodesis of the proximal interphalangeal (PIP) joints or by shortening the MT bones [35, 46, 51–64] (Fig. 7). By shortening the metatarsals the function of the plantar aponeurosis and the forefoot fat pad are not restored as advocated below [54]. Actually, some of the same disadvantages that exist for resection arthroplasty also apply for these osteotomy techniques, for instance the fact that all rays must be shortened includes those that are less or unaffected. To end up with a nicely aligned arc of the often osteoporotic and partially destroyed metatarsals is technically demanding. Toe stiffness after distal MT osteotomies frequently occurs and recurrent dislocation of the toe is reported in 15 % and transfer metatarsalgia in 11 % of patients.

The MT heads are important weight-bearing structures and at operation for resection often relatively healthy appearing MT heads are sacrificed unnecessarily [65]. By preserving the length of the MT bones and relocating the plantar plate and forefoot fat pad to their normal functional position, without dividing attachments to the deep transverse MT ligament and plantar aponeurosis, the weight-bearing function of the plantar aponeurosis and the deep transverse

Fig. 6 **a** AP view before surgery with dislocation of the MTP joints, but otherwise intact MT heads apart from the first MT. **b** Post-operative AP view, after fusion of the first MTP joint, lengthening of extensor tendons, dorsal release of lesser MTP joints, PIP resection, further

complete release of the MTP joints also with a raspatory, anatomical reduction of the lesser MTP joints and 1.0-mm K-wire fixation. **c** AP view 1 year post-op showing good alignment

MT ligaments is maintained. Thus, the longitudinal windlass mechanism and toe function remain effective [11, 54, 55]. Using the method described by Briggs and Stainsby in a relatively small study, also including patients with other causes of claw toe deformity, good subjective and objective results with no obvious deterioration over time were found, after up to 11 years follow-up [54]. Dodd et al., in a study outside the originating centre, showed short-term outcome in 16 patients, with significant improvement in Manchester-Oxford Foot and Ankle score and satisfaction rate, following the Stainsby procedure [66]. van der Heide and Louwerens retrospectively reported good results of a repositioning technique in 54 feet, after a short-term follow-up (mean 40 months, range 12–72 months) [67].

A retrospective study by Bhavikatti et al. describes a head-preserving surgical method, using Weil's shortening osteotomy and Scarf osteotomy [68]. They evaluated results in 66 procedures (49 patients). These procedures were

performed in intermediate to severe stages of rheumatoid arthritis. Weil osteotomy was performed hypothetically reducing soft tissue tension by shortening of the metatarsal. After a mean follow-up of 51 months the mean American Orthopaedic Foot and Ankle Society (AOFAS) score improved from 39.8 preoperatively to 88.7 at final follow-up. Of the patients, 74 % reported their outcome as excellent and 13.5 % as good. Persistent pain was noted in 11 feet.

The first ray

The first question that must be addressed concerns the issue of whether the hallux should be left alone when the disease is isolated to the lesser rays. An argument for routine excision of the first MTP joint is the risk that this joint will be affected by rheumatoid arthritis after time in any event [20, 69]. Nowadays pharmacotherapeutic treatment is very successful and the possibility that the first MTP joint remains uninvolved is much higher. Furthermore, the revision rate for no initial disease/no surgery to the first MTP joint has been reported to be no more than 14 % [34]. Findings in other studies support this number and it is advisable not to operate on an unaffected first ray [5, 39, 42]. However, it is sensible to tell patients that further painful deformity may develop, necessitating surgery [70]. So, a low threshold for inclusion of a symptomatic first ray may be recommended.

The second question concerns the mild to moderate hallux valgus deformity without arthritic changes of the first MTP joint. This time correction of the deformity is an integral part of the forefoot arthroplasty and the decision not to excise or fuse the joint in relation with the future possibility of arthritis and recurrence of hallux valgus is less easy. No sound information exists about the long-term results of osteotomy

Fig. 7 Use of McGlamry raspatory to release the plantar adhesions to the MT head

techniques and soft tissue procedures in patients with rheumatoid hallux valgus. Again, after advising the patients that the joint may become arthritic in the future and about the risk of recurrent deformity, in individual cases with a non-arthritic first MTP joint, it seems justified to correct a hallux valgus deformity using standard techniques in order to restore or maintain a normal function of the first MTP joint and the weight-bearing function of the first ray. Among these techniques a Lapidus fusion of the first metatarsal-cuneiform joint in combination with a soft tissue procedure of the first MTP joint in cases with unstable tarsometatarsal joint destruction should be considered [71]. For patients with a clearly diseased first MTP joint a choice must be made between fusion, resection or replacement through an implant of the first MTP joint.

Resection arthroplasty of the first MTP joint

In the past, certainly in Europe, the most commonly performed forefoot procedure was resection arthroplasty of all MTP joints [16–18, 20, 21, 23, 24, 26, 27, 32, 34, 36, 54]. Hamalainen and Raunio, alone, mention over 13,000 such forefoot arthroplasties [27]. The same authors and others report that after more than five years the percentage of satisfied patients (70–90 % at first) tends to decrease. The subjective long-term results remain quite good, but objective measurements show recurrence of hallux valgus, bony proliferation at the distal stumps of the metatarsals and callosities in 36–61 % of the patients [17, 18, 23, 24, 27, 32, 34, 38, 39, 45]. Recurrence of hallux deformity, found in more than 50 % of the cases in several large studies, is the major reason for reoperation and obviously plays a role in the development of problems in the lesser rays.

Two main types of resection arthroplasty are used. The first is excision of the entire MT head together with the sesamoids when fixed or part of it [16, 30]. Most often two thirds of the MT head is resected as described by Mayo [72]. The other is resection of the base of the proximal phalanx and of the medial prominence of the MT head or modification of the method first described by Keller [73]. Combinations have also been used. Comparing the Mayo and Keller procedures a significantly higher degree of forefoot pain, more frequent lesser toe deformities with lack of ground contact and a higher recurrence of hallux deformity with functional instability were found after Keller's procedure [24]. The success of a Keller procedure depends on the maintenance of alignment and better results are probably obtained by securing the sesamoids in their proper position under the MT head after a lateral release, performing a secure capsulorrhaphy and only resecting a limited portion of the base of the phalanx, thus not impairing the flexor function [74]. Using this method, however, more than one third of the joints become clinically stiff.

Fusion of the first MTP joint

Fusion of the first MTP joint in the correct position ensures a stable situation without risk of future deformity and is nowadays the generally advocated procedure in patients with rheumatoid arthritis. Studies, of limited methodological quality, advocating arthrodesis of the first MTP joint in combination with resection arthroplasty of the lesser rays have involved small numbers of patients and short follow-up periods [48, 75, 76]. Coughlin in a retrospective long-term follow-up study reports a 100 % fusion rate in 58 feet [5]. Subjective results were excellent and good in 30 of the 32 patients. The objective results were also favourable, only four feet being associated with limitation of daily activities and no special shoes were required. Reoperation was performed on 30 % of the feet, which is rather high. These included hardware removal, a procedure on the IP joint of the hallux, or additional procedures on the lesser toes or lesser MTP joints.

It has been argued that with a fused first MTP joint, because of reduced movement possible in the first ray, the foot has a reduced contact time with the ground, thereby protecting the lesser MTP joints from dorsiflexion forces [76]. It is also postulated that after fusion the loading on the pulp of the big toe is increased, while the load transmitted through other parts is reduced (Fig. 8) [28].

The drawback of fusion is that it is technically more demanding. A non-union rate of 0–30 % has been reported [5, 26, 34, 48, 74]. Using modern techniques a union rate of

Fig. 8 **a** Preoperative pressure measurement illustrating highest pressure centrally under the forefoot prior to surgery. **b** Same foot after fusion of the first MTP joint, illustrating transfer of pressure to the first ray

more than 90 % must be achievable. A non-union is clinically not always painful [74]. A malunion in too much dorsiflexion or plantarflexed position is, however, poorly tolerated and may lead to revision surgery. The long-term risk of clinically relevant IP joint symptoms after arthrodesis seems to be acceptable.

Comparative studies

Studies have been performed comparing the results of fusion of the first MTP joint with those of resection arthroplasty, both in combination with resection of the lesser MTP joints including two randomised prospective trials [7, 26–28, 34, 39, 74, 77–79, 80–83]. Roughly, these studies show no significant difference in terms of clinical outcome, both methods providing significant pain relief. The short-term subjective results are slightly in favour of resection arthroplasty of the first MTP joint. However, these results, with lack of power, should be interpreted with care. The pedodynographic data collected in several of these studies are more in favour of arthrodesis, showing better load-bearing of the first ray and relative unloading of the central metatarsals [74].

The use of implants for the first MTP joint

To preserve mobility at the first MTP joint, a silicone prosthesis can be implanted. Mainly retrospective reports show encouraging results using a double-stemmed implant [33, 84]. However, high rates of osteophyte formation, osteolysis with bone cyst formation and implant failure may result from silicone particle-induced synovitis. Furthermore, the joint most often has reduced mobility, only.

One study retrospectively compared hinged silicone implant arthroplasty with resection arthroplasty of the first MTP joint [19]. Results showed trends in favour of resection arthroplasty.

Particulate synovitis may be prevented by adding titanium grommets between the bone and silicone [85]. The use of metallic hemi-implants may also solve this problem [86]. These complications and the risk of concomitant pain, recurrent deformity and metatarsalgia, together with the fact that most of us have no experience with this type of surgery, favour the use of other methods.

Conclusion

Despite recent advances in pharmacological management of rheumatoid arthritis, forefoot deformity, with its symptoms, remains a common problem, often requiring operative treatment. As a result of this improved treatment the degree of forefoot deformity is becoming less severe. In this perspective, we think the indication for resection of the lesser MTP

joints is becoming less evident. However, this may support a trend towards MT head-preserving surgery.

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References

1. Lipsky P (2005) Rheumatoid arthritis. In: Kasper D (ed) Harrison's principles of internal medicine. McGraw-Hill, New York, p 1968
2. Matricali GA, Boonen A, Verduyck J, Taelman V, Verschueren P, Sileghem A et al (2006) The presence of forefoot problems and the role of surgery in patients with rheumatoid arthritis. *Ann Rheum Dis* 65(9):1254–1255
3. Michelson J, Easley M, Wigley FM, Hellmann D (1994) Foot and ankle problems in rheumatoid arthritis. *Foot Ankle Int* 15(11):608–613
4. van der Leeden M, Steultjens MP, Ursum J, Dahmen R, Roorda LD, Schaardenburg DV et al. (2008) Prevalence and course of forefoot impairments and walking disability in the first eight years of rheumatoid arthritis. *Arthritis Rheum* 59(11):1596–1602
5. Coughlin MJ (2000) Rheumatoid forefoot reconstruction. A long-term follow-up study. *J Bone Joint Surg Am* 82(3):322–341
6. Borman P, Ayhan F, Tuncay F, Sahin M (2012) Foot problems in a group of patients with rheumatoid arthritis: an unmet need for foot care. *Open Rheumatol J* 6:290–295
7. Loveday DT, Jackson GE, Geary NP (2012) The rheumatoid foot and ankle: current evidence. *Foot Ankle Surg* 18(2):94–102
8. Tillman K (1979) The rheumatoid foot. Thieme, Stuttgart
9. Larsen A (1974) A radiological method for grading the severity of rheumatoid arthritis. Dissertation, University of Helsinki
10. Stainsby GD (2004) Reply to editor: the surgical treatment of the severely clawed lesser toe. *Foot Ankle Surg* 10:51–52
11. Stainsby GD (1997) Pathological anatomy and dynamic effect of the displaced plantar plate and the importance of the integrity of the plantar plate-deep transverse metatarsal ligament tie-bar. *Ann R Coll Surg Engl* 79(1):58–68
12. Waldecker U (2004) Limited range of motion of the lesser MTP joints—a cause of metatarsalgia. *Foot Ankle Surg* 10:149–154
13. Hicks JH (1954) The mechanics of the foot. II. The plantar aponeurosis and the arch. *J Anat* 88(1):25–30
14. Vidigal E, Jacoby RK, Dixon AS, Ratliff AH, Kirkup J (1975) The foot in chronic rheumatoid arthritis. *Ann Rheum Dis* 34(4):292–297
15. Doorn PF, Keijsers NL, van Limbeek J, Anderson PG, Laan RF, Bosch PV et al (2011) A clinical classification system for rheumatoid forefoot deformity. *Foot Ankle Surg* 17(3):158–165
16. Hoffmann P (1912) An operation for severe grades of contracted or clawed toes. *Am J Orthop Surg* 9:441–449
17. Clayton ML (1960) Surgery of the forefoot in rheumatoid arthritis. *Clin Orthop* 16:136–140
18. Clayton ML (1963) Surgery of the lower extremity in rheumatoid arthritis. *J Bone Joint Surg Am* 45:1517–1536
19. Clayton ML, Leiholt JD, Clark W (1997) Arthroplasty of rheumatoid metatarsophalangeal joints. An outcome study. *Clin Orthop Relat Res* 340:48–57
20. Fowler AW (1959) A method of forefoot reconstruction. *J Bone Joint Surg Br* 41-B:507–513
21. Amuso SJ, Wissinger HA, Margolis HM, Eisenbeis CH Jr, Stolzner BL (1971) Metatarsal head resection in the treatment of rheumatoid arthritis. *Clin Orthop Relat Res* 74:94–100

22. Benson GM, Johnson EW Jr (1971) Management of the foot in rheumatoid arthritis. *Orthop Clin North Am* 2(3):733–744
23. Bitzan P, Giurea A, Wanivenhaus A (1997) Plantar pressure distribution after resection of the metatarsal heads in rheumatoid arthritis. *Foot Ankle Int* 18(7):391–397
24. Fuhrmann RA, Anders JO (2001) The long-term results of resection arthroplasties of the first metatarsophalangeal joint in rheumatoid arthritis. *Int Orthop* 25(5):312–316
25. Gould N (1982) Surgery of the forepart of the foot in rheumatoid arthritis. *Foot Ankle* 3(3):173–180
26. Grondal L, Hedstrom M, Stark A (2005) Arthrodesis compared to Mayo resection of the first metatarsophalangeal joint in total rheumatoid forefoot reconstruction. *Foot Ankle Int* 26(2):135–139
27. Hamalainen M, Raunio P (1997) Long-term followup of rheumatoid forefoot surgery. *Clin Orthop Relat Res* 340:34–38
28. Hughes J, Grace D, Clark P, Klenerman L (1991) Metatarsal head excision for rheumatoid arthritis. 4-year follow-up of 68 feet with and without hallux fusion. *Acta Orthop Scand* 62(1):63–66
29. Kadambande S, Debnath U, Khurana A, Hemmady M, Hariharan K (2007) Rheumatoid forefoot reconstruction: 1st metatarsophalangeal fusion and excision arthroplasty of lesser metatarsal heads. *Acta Orthop Belg* 73(1):88–95
30. Kates A, Kessel L, Kay A (1967) Arthroplasty of the forefoot. *J Bone Joint Surg Br* 49(3):552–557
31. Marmor L (1975) Resection of the forefoot in rheumatoid arthritis. *Clin Orthop Relat Res* 108:223–227
32. McGarvey SR, Johnson KA (1988) Keller arthroplasty in combination with resection arthroplasty of the lesser metatarsophalangeal joints in rheumatoid arthritis. *Foot Ankle* 9(2):75–80
33. Moeckel BH, Sculco TP, Alexiades MM, Dossick PH, Inglis AE, Ranawat CS (1992) The double-stemmed silicone-rubber implant for rheumatoid arthritis of the first metatarsophalangeal joint. Long-term results. *J Bone Joint Surg Am* 74(4):564–570
34. Mulcahy D, Daniels TR, Lau JT, Boyle E, Bogoch E (2003) Rheumatoid forefoot deformity: a comparison study of 2 functional methods of reconstruction. *J Rheumatol* 30(7):1440–1450
35. Saltzman CL, Johnson KA, Donnelly RE (1993) Surgical treatment for mild deformities of the rheumatoid forefoot by partial phalangectomy and syndactylization. *Foot Ankle* 14(6):325–329
36. Stockley I, Betts RP, Getty CJ, Rowley DI, Duckworth T (1989) A prospective study of forefoot arthroplasty. *Clin Orthop Relat Res* 248:213–218
37. Thomas S, Kinninmonth AW, Kumar CS (2006) Long-term results of the modified Hoffman procedure in the rheumatoid forefoot. Surgical technique. *J Bone Joint Surg Am* 88(Suppl 1 Pt 1):149–157
38. Tillmann K (1997) Surgery of the rheumatoid forefoot with special reference to the plantar approach. *Clin Orthop Relat Res* 340:39–47
39. Vahvanen V, Piirainen H, Kettunen P (1980) Resection arthroplasty of the metatarsophalangeal joints in rheumatoid arthritis. A follow-up study of 100 patients. *Scand J Rheumatol* 9(4):257–265
40. van der Heijden KW, Rasker JJ, Jacobs JW, Dey K (1992) Kates forefoot arthroplasty in rheumatoid arthritis. A 5-year followup study. *J Rheumatol* 19(10):1545–1550
41. van Loon PJ, Aries RP, Karthaus RP, Steenaert BJ (1992) Metatarsal head resection in the deformed, symptomatic rheumatic foot. A comparison of two methods. *Acta Orthop Belg* 58(1):11–15
42. Watson MS (1974) A long-term follow-up of forefoot arthroplasty. *J Bone Joint Surg Br* 56B(3):527–533
43. Brattström H, Brattström M (1970) Resection of the metatarsophalangeal joints in rheumatoid arthritis. *Acta Orthop Scand* 41(2):213–224
44. Barton NJ (1973) Arthroplasty of the forefoot in rheumatoid arthritis. *J Bone Joint Surg Br* 55(1):126–133
45. Craxford AD, Stevens J, Park C (1982) Management of the deformed rheumatoid forefoot. A comparison of conservative and surgical methods. *Clin Orthop Relat Res* 166:121–126
46. Lipscomb PR, Benson GM, Sones DA (1972) Resection of proximal phalanges and metatarsal condyles for deformities of the forefoot due to rheumatoid arthritis. *Clin Orthop Relat Res* 82:24–31
47. Mann RA, Oates JC (1980) Arthrodesis of the first metatarsophalangeal joint. *Foot Ankle* 1(3):159–166
48. Mann RA, Schakel ME (1995) Surgical correction of rheumatoid forefoot deformities. *Foot Ankle Int* 16(1):1–6
49. Aho H, Halonen P (1991) Synovectomy of the MTP joints in rheumatoid arthritis. *Acta Orthop Scand* 62(Suppl 243):1
50. Krause FG, Fehlbauer O, Huebschle LM, Weber M (2011) Preservation of lesser metatarsophalangeal joints in rheumatoid forefoot reconstruction. *Foot Ankle Int* 32(2):131–140
51. Niki H, Hirano T, Okada H, Beppu M (2010) Combination joint-preserving surgery for forefoot deformity in patients with rheumatoid arthritis. *J Bone Joint Surg Br* 92(3):380–386
52. Barouk LS, Barouk P (2007) Joint-preserving surgery in rheumatoid forefoot: preliminary study with more-than-two-year follow-up. *Foot Ankle Clin* 12(3):435–454, vi
53. Bolland BJ, Sauvé PS, Taylor GR (2008) Rheumatoid forefoot reconstruction: first metatarsophalangeal joint fusion combined with Weil's metatarsal osteotomies of the lesser rays. *J Foot Ankle Surg* 47(2):80–88
54. Briggs P, Stainsby GD (2001) Metatarsal head preservation in forefoot arthroplasty and the correction of severe claw toe deformity. *Foot Ankle Surg* 7:93–101
55. Briggs P (2003) Reconstruction of the rheumatoid forefoot. *Tech Orthop* 18:303–310
56. Davies MS, Saxby TS (1999) Metatarsal neck osteotomy with rigid internal fixation for the treatment of lesser toe metatarsophalangeal joint pathology. *Foot Ankle Int* 20(10):630–635
57. De Stoop N (2002) Surgery of the rheumatoid forefoot. *Curr Orthop* 16:187–192
58. Hanyu T, Yamazaki H, Murasawa A, Tohyama C (1997) Arthroplasty for rheumatoid forefoot deformities by a shortening oblique osteotomy. *Clin Orthop Relat Res* 338:131–138
59. Nagashima M, Kato K, Miyamoto Y, Takenouchi K (2007) A modified Hohmann method for hallux valgus and telescoping osteotomy for lesser toe deformities in patients with rheumatoid arthritis. *Clin Rheumatol* 26(5):748–752
60. Newman RJ, Fitton JM (1983) Conservation of metatarsal heads in surgery of rheumatoid arthritis of the forefoot. *Acta Orthop Scand* 54(3):417–421
61. Queally JM, Zgraj OS, Walsh JC, Butt AJ, D'Souza LG (2009) Use of the modified Stainsby procedure in correcting severe claw toe deformity in the rheumatoid foot: a retrospective review. *Foot (Edinb)* 19(2):110–113
62. Trieb K (2005) Management of the foot in rheumatoid arthritis. *J Bone Joint Surg Br* 87(9):1171–1177
63. Vandeputte G, Dereymaeker G, Steenwerckx A, Peeraer L (2000) The Weil osteotomy of the lesser metatarsals: a clinical and pedobarographic follow-up study. *Foot Ankle Int* 21(5):370–374
64. Takakubo Y, Takagi M, Tamaki Y, Sasaki A, Nakano H, Orui H et al (2010) Mid-term results of joint-preserving procedures by a modified Mann method for big toe deformities in rheumatoid patients undergoing forefoot surgeries. *Mod Rheumatol* 20(2):147–153
65. Klenerman L (1995) The foot and ankle in rheumatoid arthritis. *Br J Rheumatol* 34(5):443–448
66. Dodd L, Atinga M, Foote J, Palmer S (2011) Outcomes after the Stainsby procedure in the lesser toes: an alternative procedure for the correction of rigid claw toe deformity. *J Foot Ankle Surg* 50(5):522–524
67. van der Heide HJ, Louwerens JW (2010) Reconstructing the rheumatoid forefoot. *Foot Ankle Surg* 16(3):117–121
68. Bhavikatti M, Sewell MD, Al-Hadithy N, Awan S, Bawarish MA (2012) Joint preserving surgery for rheumatoid forefoot deformities

- improves pain and corrects deformity at midterm follow-up. *Foot (Edinb)* 22(2):81–84
69. Vainio K (1991) The rheumatoid foot. A clinical study with pathological and roentgenological comments. 1956. *Clin Orthop Relat Res* 265:4–8
 70. Hulse N, Thomas AM (2006) Metatarsal head resection in the rheumatoid foot: 5-year follow-up with and without resection of the first metatarsal head. *J Foot Ankle Surg* 45(2):107–112
 71. Shi K, Hayashida K, Tomita T, Tanabe M, Ochi T (2000) Surgical treatment of hallux valgus deformity in rheumatoid arthritis: clinical and radiographic evaluation of modified Lapidus technique. *J Foot Ankle Surg* 39(6):376–382
 72. Mayo CH (1908) The surgical treatment of bunions. *Ann Surg* 48:300–302
 73. Keller WL (1904) The surgical treatment of bunions and hallux valgus. *N Y Med J* 80:741
 74. Vandeputte G, Steenwerckx A, Mulier T, Peeraer L, Dereymaeker G (1999) Forefoot reconstruction in rheumatoid arthritis patients: Keller-Lelièvre-Hoffmann versus arthrodesis MTP1-Hoffmann. *Foot Ankle Int* 20(7):438–443
 75. Henry AP, Waugh W, Wood H (1975) The use of footprints in assessing the results of operations for hallux valgus. A comparison of Keller's operation and arthrodesis. *J Bone Joint Surg Br* 57:478–481
 76. Mann RA, Thompson FM (1984) Arthrodesis of the first metatarsophalangeal joint for hallux valgus in rheumatoid arthritis. *J Bone Joint Surg Am* 66(5):687–692
 77. Haro AA III, Moore LF, Schorn K, DiDomenico LA (2010) The surgical reconstruction of the rheumatoid forefoot. *Clin Podiatr Med Surg* 27(2):243–259
 78. Roukis TS, Meusnier T, Augoyard M (2012) Arthrodesis of the first metatarsal-phalangeal joint with flexible, ridged titanium intramedullary nails alone or supplemented with static staples and immediate weight bearing: a consecutive series of 148 procedures. *Foot Ankle Spec* 5(1):12–16
 79. Roukis TS, Meusnier T, Augoyard M (2012) Nonunion rate of first metatarsal-phalangeal joint arthrodesis for end-stage hallux rigidus with crossed titanium flexible intramedullary nails and dorsal static staple with immediate weight-bearing. *J Foot Ankle Surg* 51(3):308–311
 80. Beauchamp CG, Kirby T, Rudge SR, Worthington BS, Nelson J (1984) Fusion of the first metatarsophalangeal joint in forefoot arthroplasty. *Clin Orthop Relat Res* 190:249–253
 81. Grondal L, Broström E, Wretenberg P, Stark A (2006) Arthrodesis versus Mayo resection: the management of the first metatarsophalangeal joint in reconstruction of the rheumatoid forefoot. *J Bone Joint Surg Br* 88(7):914–919
 82. Rosenbaum D, Timte B, Schmiegell A, Miehle RK, Hilker A (2011) First ray resection arthroplasty versus arthrodesis in the treatment of the rheumatoid foot. *Foot Ankle Int* 32(6):589–594
 83. Torikai E, Kageyama Y, Suzuki M, Ichikawa T, Nagano A (2008) Comparison between resection arthroplasty alone and resection arthroplasty with arthrodesis of the first MTP joint for rheumatoid forefoot deformities. *Mod Rheumatol* 18(5):486–491
 84. Hanyu T, Yamazaki H, Ishikawa H, Arai K, Tohyama CT, Nakazono K et al (2001) Flexible hinge toe implant arthroplasty for rheumatoid arthritis of the first metatarsophalangeal joint: long-term results. *J Orthop Sci* 6(2):141–147
 85. Sebold EJ, Cracchiolo A III (1996) Use of titanium grommets in silicone implant arthroplasty of the hallux metatarsophalangeal joint. *Foot Ankle Int* 17(3):145–151
 86. Townley CO, Taranow WS (1994) A metallic hemiarthroplasty resurfacing prosthesis for the hallux metatarsophalangeal joint. *Foot Ankle Int* 15(11):575–580