



Rheumatoid forefoot reconstruction

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Management of the patient with rheumatoid forefoot deformity requires a multidisciplinary integrated approach for a successful outcome. Despite recent advances in the pharmacological management of rheumatoid arthritis and its impact upon disease progression, forefoot deformity and pain remain common manifestations requiring input from orthopaedic surgeons. The typical deformities encountered include hallux valgus, with subluxation or frank dislocation at the lesser metatarsophalangeal (MTP) joints. Surgical intervention is directed at correcting and decompressing these deformities, with the ultimate goal of a stable, painless, functional plantigrade foot. Although a variety of surgical options exist, fusion of the 1st MTP joint with lesser MTP joint excision arthroplasty remains the gold standard, upon which newer procedures should be judged. This article reviews the pathophysiology of forefoot deformity in rheumatoid arthritis with special emphasis on recent advances in surgical management.

Keywords : rheumatoid arthritis ; forefoot ; deformity ; reconstruction.

INTRODUCTION

Rheumatoid arthritis (RA) is a chronic, systemic, inflammatory disorder characterised by symmetric polyarthritis. Approximately 20% of patients initially present with foot and ankle symptoms (54). The overall prevalence of symptoms in the foot and ankle approaches 90%, with the forefoot affected

most frequently, particularly earlier in the course of the disease process (27). The commonly encountered deformities in the forefoot include hallux valgus and dorsal subluxation or dislocation of the lesser metatarsophalangeal (MTP) joints, with or without fixed claw toe deformity (fig 1).

Pathophysiology of MTP joint deformity

RA is characterised by chronic synovial inflammation, which results in capsular distension, joint destabilisation (due to attenuation of collateral ligaments and plantar plate), articular cartilage destruction and erosive bone loss.

The relatively small 1st MTP joint contact area and shallow articular profile of the proximal phalanx provide little inherent stability, most of which is provided by the capsuloligamentous and tendinous structures which surround and traverse

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Fig. 1. — Typical forefoot deformity associated with RA : hallux valgus with lesser hammer toe deformities. Note plantar callosities as a result of MTP joint dislocation and plantar displacement of metatarsal heads.

the joint. Disruption of these soft tissue structures results in progressive joint instability and usually valgus drift of the great toe, or very rarely, a dorsal or varus deformity. As a result, the proportion of forces transferred through the hallux are reduced, leading to greater load through the lesser rays. The combination of capsular and ligamentous attenuation and increased loading of the lesser rays results in dorsal subluxation of the proximal phalanges, distal displacement of the plantar fat pad and a resultant plantar displacement of the metatarsal heads. Progressive dorsiflexion at the lesser MTP joints during gait perpetuates the deformity. The primary plantar flexors of the MTP joints, the interossei and the lumbricals, act through their insertion onto the proximal phalanx, plantar to the axis of rotation. With dorsal subluxation of the proximal phalanx, the axis moves dorsally, relegating the interossei to weak, effectively functionless extensors (38,49). The lumbricals by virtue of their course beneath the deep transverse metatarsal ligament do not subluxate, but lose their mechanical advantage and are essentially defunctioned due to the change in the direction of action that occurs with dorsal subluxation of the proximal phalanx (38).

Flexor-extensor tendon imbalance worsens the deformity. The extensor digitorum brevis and longus function best with the toes in a neutral or slightly flexed position, however with chronic dorsiflexion at the MTP joints, they become inefficient in relation to the flexors (49). Without treatment the initial flexible claw toe deformity quickly becomes fixed, with patients developing corns and calluses

over the dorsal proximal interphalangeal joint and underneath the now prominent metatarsal heads.

Finally, the plantar plate is displaced distally, with failure often occurring at its weaker proximal attachment (38). The thicker cartilaginous attachment to the proximal phalanx subluxes dorsally, along with the plantar fat pad, effectively uncovering the metatarsal head. Plantar callosities occur underneath the metatarsal heads as a result of increased pressure during gait.

NON-SURGICAL MANAGEMENT

Conservative measures and medical therapy play an important part in the management of the rheumatoid forefoot. Administration of non-steroidal anti-inflammatory drugs (NSAIDs), corticosteroids, disease modifying anti-rheumatic drugs (DMARDs) and newer biological agents under the guidance of a rheumatologist represents the standard of care. NSAIDs do not prevent disease progression, in contrast to DMARDs which should be instituted at the earliest opportunity. Typical DMARDs include methotrexate, sulfasalazine, cyclosporine, penicillamine, leflunomide and azathioprine. If employed, corticosteroid use should be discontinued when DMARDs have gained control of the disease. Increasing evidence supports the use of cytokine modulators targeting tumour necrosis factor alpha (42).

Orthotic management includes shoe wear modification, with wide and/or high toe boxes, accommodative insoles and rocker soles. They form the mainstay of treatment for the elderly infirm patient, those with significant co-morbidities or those who are poor surgical candidates (56).

In the ankle and hindfoot, fluoroscopic guided injections have been shown to be superior to 'blind' injections for diagnostic purposes and the temporary symptomatic relief of synovitis or arthritis (7). Pre and post gadolinium enhanced MRI scans performed following corticosteroid injection in patients with juvenile chronic arthritis confirm long-lasting suppression of inflammation and negligible toxic effects on host tissues (45). The role of such injections in the forefoot remains less well defined.

SURGICAL MANAGEMENT

Perioperative management

The systemic involvement, characteristic of RA, should alert the clinician to potential pre-operative problems. A thorough examination of the entire limb is necessary to rule out proximal deformity, which generally should be corrected first. This allows one to accurately correct true forefoot deformity with reference to a normally aligned ankle, hindfoot and lower limb, reducing the possibility of recurrence or the uncovering of forefoot malalignment if the proximal limb is corrected at a later date.

Instability of the atlanto-axial junction maybe assessed with radiographs and with flexion-extension views. Rheumatoid vasculitis can predispose to accelerated atherosclerosis and an overall increased cardiovascular risk during the peri-operative period. Patients often have thin, friable skin, which demands careful soft-tissue handling to prevent infection and wound-healing complications.

Temporary discontinuation of drug therapy remains a controversial topic and is the focus of ongoing trials. Methotrexate has been shown to be safe, and one large study even demonstrated a lower infection rate in those continuing therapy, compared to those who never received it and those who temporarily stopped therapy two weeks before and after surgery (21). Little has been published to guide our management of the other common DMARDs. Divided opinions exist regarding the use of anti-tumour necrosis factor alpha inhibitors, with some studies demonstrating safety, whilst others reported an increased infection risk (8,16,46). Inherent difficulties comparing these studies, based on differing populations and varied surgical intervention means that no clear conclusion can be drawn as to whether these drugs should be discontinued or not.

The role of synovectomy

Little attention has been directed to the role of synovectomy in the management of early disease. Often, patients present to an orthopaedic surgeon towards the end of the inflammatory cascade, with-

out synovitis but with significant deformity. Aho reported significant pain relief in a small series of patients treated with early synovectomy of the lesser MTP joints, although the long-term radiographic results were not disclosed (1). Whilst it has been suggested that the natural history of the condition may be altered, a true joint preserving effect is yet to be clearly demonstrated (2,11,40).

Early advances in the management of forefoot deformity

Table I summarises the important early contributions to our understanding and management of the rheumatoid forefoot (12,18,25,28,29,30).

Dwyer first noticed that simple pan-metatarsal head excision, whilst initially relieving the patient of their symptoms, appeared only to provide a short lived effect and recurrence was common. He advocated arthrodesis of the 1st MTP joint and of the lesser toe proximal interphalangeal joints, together with metatarsal head excisions (17).

Watson observed, in a long-term follow-up of 46 patients undergoing forefoot arthroplasty, poor results associated with resection arthroplasty of the 1st MTP joint, even when stabilised with a Kirshner wire. Conversely all patients, who either presented with a 1st MTP joint arthrodesis, had it performed as part of the forefoot arthroplasty, or developed a spontaneous ankylosis after surgery, had good results (56).

Modern Concepts

A great deal of debate continues regarding the optimal treatment of rheumatoid forefoot deformity. Many regard arthrodesis as the benchmark for the treatment of 1st MTP joint arthritis (13,32,33). However, there are proponents of hallux 1st MTP joint correction (3) and replacement (15,23,47) within the literature. Recent attention has been directed to preservation of the lesser metatarsal heads with procedures such as Weil's osteotomy (4) or the Stainsby procedure (10).

A variety of options exist for correction of lesser toe deformity, including closed osteoclasis, arthroplasty and fusion. It has been suggested that the

Table I. — Historical overview of approaches to forefoot reconstruction

AUTHOR	YEAR	CONTRIBUTION
Hoffman (25)	1912	Described pan-metatarsal head excision through a single plantar apex-distal incision just proximal to the interdigital web spaces, without extensor tenotomies. Argued that relaxation of the soft tissues by generous metatarsal resection obviated the need for soft tissue correction. The disadvantage of the distal plantar approach was injury to the neurovascular bundles.
Fowler (18)	1959	Described a combined dorsal and plantar approach. The dorsal incision included short longitudinal extensions along the 1 st and 5 th metatarsals. He advocated excision of the proximal halves of the phalanges, together with metatarsal head excisions. The plantar incision was used to excise the callus and perform a dermoplasty to relocate the fat pad beneath the metatarsal remnants.
Clayton (12)	1960	Suggested using a single straighter dorsal incision, with bony resection as described by Fowler, but with extensor tendon transections if required.
Kates <i>et al.</i> (28)	1967	Promoted a single curved plantar incision, excising an ellipse for further deformity correction. A pan-metatarsal head excision was performed, with the 1 st MTP joint stabilised with a Kirshner wire and a plaster boot applied with the lesser toes plantar flexed.
Lipscomb (29)	1968	Popularised three dorsal longitudinal incisions, with metatarsal head excisions. Originally suggested by Larmon (22) in 1951.

variety of procedures commonly used reflects the population being treated, whilst others consider it a reflection of each individual surgeon's experience.

Comparison of the available literature is difficult in view of the paucity of prospective randomised studies, small patient numbers and variability in follow-up and reported outcome measures.

Management of the 1ST MTP joint : Arthrodesis

It is generally well accepted that few indications exist for resection of the 1st MTP joint as part of forefoot arthroplasty. Poor long-term results are attributed to defunctioning of the first ray, with recurrent hallux valgus and transfer metatarsalgia, plantar keratoses, lack of plantar flexion, and weakened push-off (19,34,36,41,52,53). Henry and Waugh demonstrated this dysfunction using Harris-mat studies (24). They evaluated pre and post-operative weight-bearing, in two groups of patients treated for hallux valgus with either excision arthroplasty or arthrodesis. Increased 1st MTP joint weight-bearing was reported in 80% of the arthrodesis group compared to 40% of the excision group. More recent pedobarographic studies by Coughlin (13), Beauchamp *et al* (6), Mann and Thompson (32) and Mulcahy *et al* (37), support these early findings.

Arthrodesis is the most widely used procedure in the treatment of 1st MTP joint in rheumatoid arthri-

tis. Coughlin reported his long-term follow-up of forefoot arthroplasty in 58 feet, using 1st MTP joint arthrodesis and lesser metatarsal head resection. According to the AOFAS scoring system, an excellent or good result was obtained in 90% of patients. He recommended stable realignment of the first ray, to allow permanent correction of the hallux deformity. This improved the weight-bearing capacity of the medial column protecting the lateral rays from recurrent deformity by reducing lesser metatarsal stress and maintaining correct alignment of the plantar fat pad (13).

Fixation

Numerous biomechanical studies have been performed to elucidate the optimal fixation method to secure a successful arthrodesis. Reported techniques include intramedullary Steinman pins, crossed Kirshner wires, staples, crossed or parallel screws, dorsal locked or standard plating, with or without supplementary lag screw fixation (50). Patients with RA typically exhibit poor bone quality and in the very frail, elderly patient, who presents for surgery, arthrodesis may not be technically feasible. Hughes *et al* suggested that failure to achieve union of the 1st MTP joint produced greater dissatisfaction than reported with resection arthroplasty (26). However, they disclosed a 33% failure

rate of fusion in their study, a nonunion rate that is far higher than reported elsewhere in the literature, where fusion rates of greater than 90% are consistently documented (14,50), with 100% success reported by Coughlin in his landmark study (13). He attributed this to using a dorsal plate and cross-compression screw, which has been shown to be the most stable construct (43). He also used specially designed ball and socket reamers, to promote congruent, domed fusion surfaces. The position of arthrodesis remains critical to a successful outcome, and should not be underestimated. The recommended ideal position of arthrodesis is 10 to 15° valgus, 20° to 30° of dorsiflexion relative to metatarsal shaft, and neutral rotation. Technically, ball and socket joint preparation allows accurate joint positioning and flexibility with adjustment, as opposed to planar resection using a saw blade (13). Excessive dorsiflexion can impair the ability of the toe to engage the ground resulting in transfer metatarsalgia and leads to the dorsum of the toe rubbing on footwear. Excessive plantar flexion predisposes to accelerated degenerative change at the interphalangeal joint, which may necessitate subsequent fusion. Arthritis of the interphalangeal joint is common following a well aligned 1st MTP joint arthrodesis, and has been reported to occur in up to 90% of cases in long-term studies, although most patients remain asymptomatic (13,33).

The 1st MTP joint : Alternative techniques

There are limited numbers of studies reporting various alternative surgical techniques used in the management of 1st ray involvement, including metatarsal osteotomy (3), Heuter-Mayo resection arthroplasty (22) and joint-replacement procedures (15,23,47). Grondal *et al* have published the only prospective randomised study comparing differing reconstructive modalities. The Heuter-Mayo resection arthroplasty (resection of the metatarsal head of the 1st MTP joint) was compared with hallux arthrodesis in 33 rheumatoid forefeet. Twenty-nine patients were followed up after a mean of 72 months (57-80 months). There was no statistically significant difference in deformity recurrence, patient satisfaction, shoe wear or parameters of gait

analysis. No difference was found with respect to lateral forefoot pressure measurements. The authors contended that the Heuter-Mayo resection avoids the shortcomings of the Keller procedure, as the proximal phalanx and plantar plate are preserved, providing inherent stability to the joint and maintaining flexion ability (22). Whilst considered Level 1 evidence, small patient numbers and limited power suggest that the conclusions should be interpreted with caution. These results have not been reproduced elsewhere in the literature. Fuhrmann and Anders reported a deterioration of results in the long term associated with the Heuter-Mayo resection arthroplasty (19) in keeping with the poor results generally associated with resection arthroplasties of the 1st MTP joint (36,41,52,53).

Replacement arthroplasty of the 1st MTP joint using silicone implants was developed in the late sixties, as a treatment for hallux rigidus and hallux valgus. In theory, this form of arthroplasty maintains flexibility as compared to arthrodesis, and provides more stability than resection. Despite improvements in material properties over the years, including the addition of titanium grommets to add strength, reported complication rates were relatively high (20,44), notably implant failure (as a result of wear and repeated abrasion with microparticle release initiating synovitis and bony cystic osteolysis), cock-up deformity, stiffness and transfer metatarsalgia. Implant fracture with associated cystic osteolysis makes revision surgery challenging, with most cases requiring interpositional bone block arthrodesis.

There are isolated reports of good results, despite the preponderance of poor results in the literature and these merit discussion. Cracchiolo *et al* reported the results of 86 silicone double stemmed implants followed for an average 6.8 years, with over half in patients with RA. Lesser metatarsal head excision was performed in conjunction in the RA group. Overall, 84% of patients were completely satisfied with treatment. Only two implant failures were noted out of 49 procedures in the rheumatoid group (15).

Hanyu *et al* reported the results of silicone hinge interpositional arthroplasty with concomitant shortening osteotomies of the lesser metatarsals. Of

60 feet followed for an average of 12 years, 74% of patients were satisfied with treatment. Using revision as an end-point, the implant survival rate was 93%, and with radiologically proven fracture as an end-point, the survival rate was 87% (23).

Moeckle *et al* reported on 67 silicone double-stemmed implants followed for an average of 6 years. Eighty-seven percent of patients had excellent or good results. Only 4% of patients experienced complications related to the implant, which required revision surgery. Ten percent of patients had silent radiographic fractures, or fragmentation of the implant (35). This study and that by Hanyu *et al* (23), highlight an interesting conundrum. They have shown that fracture or fragmentation per se does not necessarily dictate a poor result or necessitate revision surgery. It has been suggested that the implant functions as a spacer in this situation and a fibrous reaction occurs which stabilises the joint, imparting pain relief (48).

Rahman and Fagg however have reported synovitis occurring in up to 72% of cases in their series and on the basis of their findings suggested that the procedure should be abandoned (44). Consistent results using replacement arthroplasty of the 1st MTP joint have not been documented in the literature, and whilst a successful outcome may be more likely in the older rheumatoid patient, the complications reported and the complexity of salvage surgery, suggest caution should be exercised when using this treatment modality to correct rheumatoid 1st MTP joint deformity.

Lesser MTP joint excision or preservation

Resection of the lesser MTP joints has been considered the standard of care in rheumatoid forefoot reconstruction, largely based upon Coughlin's long-term follow-up study (13). The amount of resection should be tailored to the individual patient, although a thorough decompression should be performed to allow wound closure and relocation of the plantar fat pad.

Fowler first recognised that patients in whom the metatarsal heads were irregularly trimmed often returned with pain (18). Reconstitution of the metatarsal parabola into a smooth arc assumes

equal importance, as it provides an even distribution of weight-bearing forefoot stress, and prevents recurrence of pain and deformity. Stainsby took this concept one step further by suggesting preservation of the metatarsal head with joint arthroplasty (excision of proximal half of proximal phalanx and interpositional tenodesis of the toe extensor to the flexor tendon) (10). His technique, whilst not strictly considered to be joint-preserving, allows relocation of the plantar plate and fat pad beneath the corresponding metatarsal head and maintains the normal weight-bearing parabola. Whilst commonly performed by many surgeons in the UK, few long-term outcome studies have been published. Stainsby himself reported an 88% excellent or good result, in a study of 20 feet followed for an average of 20 months (10).

Dorsal, plantar or combined approaches to the lesser MTP joints using either transverse or longitudinal incisions have been described. The combined approach originally described by Fowler (18) is no longer deemed necessary. The Kates, Kessel and Kay complete plantar approach allows both excellent direct visualisation of the metatarsal heads, and the ability to perform a dermoplasty to relocate the plantar fat pad (28). Disadvantages include an increased risk of keratotic scar formation and wound-healing complications, given the location and orientation of the scar. Transverse incisions demand an adequate decompression to allow tension-free wound closure. Barton reported a 46% rate of wound healing complications with the plantar wound when performed as part of Fowler's original reconstruction (5). The ability to off-load the forefoot, and allow early weight-bearing using heel-wedge shoes, has reduced the incidence of complications, although a lower rate of wound problems has been reported with longitudinal dorsal incisions (36). Some argue that exposure with this technique can occasionally be inadequate, although exposure can be improved by providing generous incisions to avoid over-retraction of the soft tissues.

True joint-preserving surgery requires an intact metatarsal head and can be achieved with shortening osteotomies as described by Weil (4). Bolland *et al* described their results of 1st MTP joint arthrodesis and multiple lesser metatarsal Weil's

osteotomies, in 26 feet followed for an average of 26.2 months. Subjectively, 23 feet were reported as having an excellent or good result. A 12% rate of recurrent metatarsalgia was noted, requiring revision shortening or resection, with symptomatic resolution in all cases (9). The option of preserving the lesser MTP joint is clearly appealing, both in terms of maintaining function and widening the revision options, when faced with recurrent deformity.

Lesser toe deformity

Following correction of the lesser MTP joint deformity, lesser toe deformity can be addressed. Flexible deformities, can be corrected with soft-tissue rebalancing (extensor tendon lengthening and/or plantar plate release) with or without closed osteoclasts. A Girdlestone flexor to extensor transfer can be used. Rigid deformities require joint arthroplasty or arthrodesis. Myerson suggested reserving arthrodesis for revision surgery and recommended performing joint resection with interpositional extensor to flexor tenodesis (36). Regardless of the chosen technique Kirshner wire stabilisation should be employed for 3-6 weeks, driving the wires into the metatarsal shafts, when the metatarsal heads have been resected.

Pan MTP joint preserving surgery

Taking the concept of joint preserving surgery further, Barouk and Barouk (3) recently reported their preliminary mid-term results of pan MTP joint preserving forefoot surgery in a continuous series of 60 feet. Fifty five feet (92%) underwent a shortening and corrective scarf osteotomy, whereas only 5 patients (8%) had an arthrodesis. Ninety five percent of hallux valgus corrections were maintained, with only one failure requiring arthrodesis. The lesser metatarsals were treated similarly with joint preserving surgery when the quality of metatarsal head allowed. The severity of dislocation did not influence the ability to preserve the metatarsal head. Eighty-six percent of the lateral rays were treated with Weil's double cut osteotomies, whereas only 14% underwent resection. A more detailed analysis of these patients with validated outcome measures

is awaited. Important features of successful surgery described by Barouk and Barouk include shortening of all metatarsals respecting the MS (metatarsal shortening) point as described by Maestro *et al* (31). This represents the most proximal aspect of the proximal phalanx of the most deformed ray. The 1st ray is corrected and shortened to the MS point and the metatarsal parabola follows, with the second metatarsal shortened to the same length, followed by 3 mm, 6 mm, and 12 mm recessions of the 3rd, 4th and 5th rays respectively. Initial poor results in Barouk's study were noted with over aggressive translation of the scarf osteotomy (resulting in hallux varus), and when metatarsal shortening was not aggressive enough. As a result they report an average of 11 mm and 13 mm shortening of the 1st and lateral rays respectively.

Although the early results appear promising, few others have tried to replicate their technique and thus little support exists in the literature and more work is required. Nagashima *et al* reported on the modified Hohman osteotomy for hallux valgus correction and lesser MTP joint shortening osteotomies in RA patients, with 78% achieving complete pain resolution (39). Conversely, Thordarson *et al* noted poor results albeit in a small study which included patients undergoing 1st metatarsal osteotomy or no osteotomy and lesser MTP joint resection (51).

AUTHORS' PREFERRED METHOD

We perform a 1st MTP joint fusion for all patients with rheumatoid forefoot disease. The procedure reliably and permanently eliminates forefoot deformity, and is well supported in the literature as the gold standard of treatment. We typically use a dorsal plate and plantar transarticular screw for fixation, given the often poor bone quality. For the lesser MTP joints we individualise treatment based on the severity of the disease. Our philosophy is to try and preserve the metatarsal head if possible, and therefore we perform Weil's osteotomies for patients with early disease. As the disease progresses, we opt to perform the Stainsby procedure, on the premise that preservation of the metatarsal head may improve function. Additionally, an excisional

arthroplasty, can be performed should the index procedure fail to relieve forefoot metatarsalgia.

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