

World Journal of *Orthopedics*

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INDEXING/ABSTRACTING

World Journal of Orthopedics is now indexed in Emerging Sources Citation Index (Web of Science), PubMed, PubMed Central and Scopus.

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I-III Editorial Board

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NAME OF JOURNAL
World Journal of Orthopedics

ISSN
ISSN 2218-5836 (online)

LAUNCH DATE
November 18, 2010

FREQUENCY
Monthly

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7901 Stoneridge Drive,
Suite 501, Pleasanton, CA 94588, USA
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Fax: +1-925-2238243
E-mail: bpgoffice@wjgnet.com
Help Desk: <http://www.fjpublishing.com/helpdesk>
<http://www.wjgnet.com>

PUBLICATION DATE
May 18, 2017

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Hallux rigidus: How do I approach it?

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Author contributions: All authors equally contributed to this paper with conception and design of the study, literature review and analysis, drafting and critical revision and editing, and final approval of the final version.

Conflict-of-interest statement: No potential conflicts of interest. No financial support.

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Manuscript source: Invited manuscript

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Received: January 19, 2017

Peer-review started: January 19, 2017

First decision: March 8, 2017

Revised: March 20, 2017

Accepted: April 6, 2017

Article in press: April 10, 2017

Published online: May 18, 2017

Abstract

Hallux rigidus is a degenerative disease of the first metatarsalphalangeal (MTP) joint and affects 2.5% of people over age 50. Dorsal osteophytes and narrowed joint space leads to debilitating pain and limited range of motion. Altered gait mechanics often ensued as 119% of the body force transmit through the 1st MTP joint during gait cycle. Precise etiology remains under debate with trauma being often cited in the literature. Hallux valgus interphalangeus, female gender, inflammatory and metabolic conditions have all been identified as associative factors. Clinical symptoms, physical exam and radiographic evidence are important in assessing and grading the disease. Non-operative managements including nonsteroidal antiinflammatory drugs, intra-articular injections, shoe modification, activity modification and physical therapy, should always be attempted for all hallux rigidus patients. The goal of surgery is to relieve pain, maintain stability of the first MTP joint, and improve function and quality of life. Operative treatments can be divided into joint-sparing *vs* joint-sacrificing. Cheilectomy and moberg osteotomy are examples of joint-sparing techniques that have demonstrated great success in early stages of hallux rigidus. Arthrodesis is a joint-sacrificing procedure that has been the gold standard for advanced hallux rigidus. Other newer procedures such as implant arthroplasty, interpositional arthroplasty and arthroscopy, have demonstrated promising early patient outcomes. However, future studies are still needed to validate its long-term efficacy and safety. The choice of procedure should be based on the condition of the joint, patient's goal and expectations, and surgeon's experience with the technique.

Key words: Hallux rigidus; Cheilectomy; Arthrodiastasis; Moberg osteotomy; Arthrodesis; Interpositional arthroplasty; Arthroplasty

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Core tip: Hallux rigidus is the leading form of arthritis

of the foot. Patients experience increasing pain and decreasing motion of the first metatarsalphalangeal joint as the disease progresses, leading to significant morbidity and lower quality of life. Multiple treatment options, from cheilectomy to arthrodesis, have been utilized in treating hallux rigidus. Advances in interpositional arthroplasty and implants have introduced new opportunities in giving a more functional outcome. This review will discuss how to approach hallux rigidus in a clinical setting and examine recent evidence in the available treatment options.

Lam A, Chan JJ, Surace MF, Vulcano E. Hallux rigidus: How do I approach it? *World J Orthop* 2017; 8(5): 364-371 Available from: URL: <http://www.wjgnet.com/2218-5836/full/v8/i5/364.htm> DOI: <http://dx.doi.org/10.5312/wjo.v8.i5.364>

INTRODUCTION

Hallux rigidus is a degenerative disease of the first metatarsophalangeal (MTP) joint. It is the most common form of arthritis in the foot, affecting 1 in 40 people over the age of 50 with a 2:1 predilection for females^[1,2]. The first MTP joint plays an important functional role during the gait cycle as it carries approximately 119% of an individual's body weight with each step^[3]. Osteophyte formation and degeneration of the cartilage occurs dorsally in early stages of the disease and progresses to involve the entire first MTP joint. Consequently, individuals with hallux rigidus experience joint pain and decreased range of motion (ROM) in the sagittal plane. This leads to altered gait mechanics and significant reduction in activity and quality of life for patients^[4,5].

CLASSIFICATION

Multiple different classification systems have been described for hallux rigidus to evaluate and grade the severity of the first MTP joint damage. Beeson *et al*^[6] conducted a thorough review of 18 hallux rigidus classification systems reported in literature and found no consistency in the construction of the systems as they lacked reliability and scientific validity. Many of the included parameters were based on subjective clinical experience. The authors concluded that the system proposed by Coughlin and Shurnas^[7] most closely approximates a gold standard, as it is based on a combination of objective radiological and clinical findings (Table 1)^[6,7].

HALLUX RIGIDUS VS HALLUX LIMITUS

An important distinction needs to be made between hallux rigidus vs hallux limitus. Hallux rigidus is defined as pain due to an arthritic joint, whereas hallux limitus is defined as functional pain due to soft tissue tightness (*i.e.*, gastrocnemius contracture) or a long and elevated

first metatarsal. Patients with hallux limitus will typically have an increased hallux dorsiflexion when the foot is examined in plantarflexion, as this relaxes the gastrocnemius and removes the restricting factor. It must be noted, however, that hallux limitus may progress to hallux rigidus, thus there may be occasions of overlapping features of either condition.

If the contributing factor in hallux limitus is gastrocnemius tightness, then a gastrocnemius recession alone may be performed. If a long or elevated first metatarsal is responsible for the condition, then a shortening or plantarflexion osteotomy of the metatarsal head may be warranted, with or without a gastrocnemius recession.

RISK FACTORS

The etiology of hallux rigidus is not well understood. It has been reported that trauma is one of the main causes for unilateral hallux rigidus^[8]. Coughlin and Shurnas observed that hallux rigidus is associated with hallux valgus interphalangeus, and bilateral involvement is associated with a family history and female gender^[9]. Development of degenerative changes can also be secondary to repetitive stress or inflammatory or metabolic conditions such as gout, rheumatoid arthritis and seronegative arthropathies^[4,10]. Damage of the articular surface of the MTP joint due to osteochondritis dissecans has been proposed as well^[10]. Biomechanical and structural factors, such as long first metatarsal, metatarsus elevatus, and metatarsus adductus can also lead to increased risk of hallux rigidus^[10,11].

EXAMINATION

Clinical examination

Patients with hallux rigidus may present with altered gait patterns or pain on the lateral aspect of the foot. This is secondary to the attempt to reduce loading on the first MTP joint. Patients may also report limitations on wearing certain types of shoes due to dorsal osteophytes on the first metatarsal head and proximal phalanx. Concurrently, patients may experience numbness along the medial border of the great toe as the osteophytes can compress on the dorsomedial cutaneous nerve^[8].

Physical examination

The foot must be evaluated in the seated and standing positions. The standing position will provide information regarding the dynamic alignment and function of the hallux. The seated position will relax the soft tissues and help assess ROM.

The first MTP joint is often tender dorsally, with often palpable osteophytes. Since the dorsal osteophytes may compress on the dorsomedial cutaneous nerve, sensation deficits and vascular function of the foot should be recorded.

Evaluating the ROM of the first MTP joint is critical as it may be an indicator of the severity of arthritis. The

Table 1 Coughlin and Shurnas Clinical Radiographic System for Grading Hallux Rigidus

Grade	Dorsiflexion	Radiographic findings	Clinical findings
0	40° to 60° and/or 10% to 20% loss compared with normal side	Normal	No pain; only stiffness and loss of motion on examination
1	30° to 40° and/or 20% to 50% loss compared with normal side	Dorsal osteophyte is main finding, minimal joint-space narrowing, minimal periarticular sclerosis, minimal flattening of metatarsal head	Mild or occasional pain and stiffness, pain at extremes of dorsiflexion and/or plantar flexion on examination
2	10° to 30° and/or 50% to 75% loss compared with normal side	Dorsal, lateral, and possibly medial osteophytes giving flattened appearance to metatarsal head, no more than ¼ if dorsal joint space involved on lateral radiograph, mild-to-moderate joint-space narrowing and sclerosis, sesamoids not usually involved	Moderate-to-severe pain and stiffness that may be constant; pain occurs just before maximum dorsiflexion and maximum plantar flexion on examination
3	≤ 10° and/or 75% to 100% loss compared with normal side. There is notable loss of metatarsophalangeal plantar flexion as well (often ≤ 10° of plantar flexion)	Same as in grade 2 but with substantial narrowing, possibly periarticular cystic changes, more than ¼ of dorsal joint space involved on lateral radiograph, sesamoids enlarged and/or cystic and/or irregular	Nearly constant pain and substantial stiffness at extremes of range of motion but not at mid-range
4	Same as in grade 3	Same as in grade 3	Same criteria as grade 3 but there is definite pain at mid-range of passive motion

most common finding is a decreased passive and active ROM, most notably in dorsiflexion. In milder forms of hallux rigidus, pain during passive ROM usually occurs at or near the end points of flexion. However, pain in midrange motion indicates more diffuse level of arthritic change in the joint.

ROM has typically been measured clinically using a goniometer. However, clinical goniometric measurement has been proven to be unreliable and difficult to reproduce in a standardized manner as it is affected by various factors including instrumentation and different patient types^[12]. A new reliable and reproducible method for measuring the hallux MTP ROM using dynamic X-rays has been reported by Vulcano *et al.*^[13]. There was a significant difference between clinical ROM and radiographic ROM, with clinical dorsiflexion being equal to or less than the radiographic dorsiflexion. The difference was more pronounced in patients with a clinical dorsiflexion less than 30 degrees. In addition, radiographic measurements of hallux dorsiflexion had excellent intra- and interobserver reliability^[13].

The hallux interphalangeal (IP) joint should also be carefully examined. Should the joint also be arthritic, the surgeon should avoid fusing both IP and MTP joints to prevent abnormal gait patterns.

Radiographic examination

Weight-bearing anteroposterior (AP), lateral and oblique views of the affected foot should be obtained. The degree of joint space narrowing is best observed on the oblique view. In later stages of hallux rigidus, osteophytic formation can be observed in the periarticular area of the metatarsal head and proximal phalanx. It is important to note that the dorsal osteophytes can obstruct the AP view of the joint. This can lead to false impression of more severe osteoarthritis. Deland and Williams noted that osteophytes can also mislead the actual amount of joint space narrowing as it can help maintain the joint space^[8]. The dorsal aspect of the joint is generally affected first. Other radiographic findings include joint

sclerosis and subchondral cysts. Magnetic resonance imaging (MRI) and computed tomography (CT) images should not be necessary to diagnose the condition or to plan surgery.

TREATMENT

Nonsurgical management

Non-operative treatment for hallux rigidus should be attempted prior to surgical treatments. These treatments include medical therapy, intra-articular injections, shoe modification, activity modification, and physical therapy.

Medical therapy mainly involves oral nonsteroidal anti-inflammatory drugs aimed to reduce swelling and joint pain. However it has been observed that oral medications alone are insufficient to provide pain relief^[8].

Intra-articular injections have been shown to provide good relief in some patients with hallux rigidus. Solan *et al.*^[14] conducted a study evaluating manipulation under anesthesia (MUA) and intra-articular steroid injection in patients with hallux rigidus. They found that patients with Grade 1 hallux rigidus (Karasick and Wapner classification) experienced pain relief of six months while one-third required surgery; grade 2 patients experienced pain relief of three months with two-thirds requiring surgery; grade 3 patients experience minimal benefit as all required surgery. The authors concluded that MUA and intra-articular injections should be recommended to patients with early grades of hallux rigidus^[14]. Prolotherapy, or proliferation therapy, (*i.e.*, injection of platelet rich plasma or bone marrow aspirate) has also been shown to decreased pain and stiffness while improving various quality of life parameters^[15]. However, the current scientific evidence is too scarce to draw definitive conclusions regarding its effectiveness in treating hallux rigidus.

Shoe modification and orthotics reduce pain by modifying the biomechanics of the first MTP joint. Motion extension and navicular pads have been used to immobilize and alter the loading patterns of the joint. Rocker-bottom soles can help reduce painful dorsiflexion

by allowing the patient to transition from heel strike to toe-off in the gait cycle without requiring the foot or shoe to bend. Shoes with high toe box can help prevent direct contact between the dorsal osteophytes and the shoe thereby taking pressure off the joint.

Physical therapy involves joint mobilization, manipulation and improving the ROM. Gaiting training, ice packs and rest reduce pain and inflammation. The use of extracorporeal shockwave therapy, iontophoresis and ultrasonography therapy have also been proposed^[16]. However, evidence supporting the use of these adjunct therapies are still scarce.

Surgical management

When conservative management fails, there are a variety of surgical treatment options available. These techniques can be divided into joint sparing or joint sacrificing techniques. The choice of procedure is based on the condition of the joint, patient's goals and expectations of the surgical outcome, and patient's motivation. The goal of surgery is to relieve pain, improve function, maintain stability of the first MTP joint and improve quality of life.

CHEILECTOMY

Cheilectomy is a joint-sparing technique that involve resection of < 30% of the dorsal metatarsal head. In addition, intraarticular loose bodies and osteophytes localized in the metatarsal head and proximal phalanx are removed, and the medial, lateral and plantar capsules of the metatarsal heads are released. Greater than 30% of the dorsal metatarsal head removal is not advised as the joint can become unstable and the proximal phalanx can sublux. The procedure improves dorsiflexion of the first MTP as well as gait function as it increases the peak ankle push-off power in the sagittal plane^[17].

Cheilectomy is the treatment of choice for early stages of hallux rigidus. It is a relatively simple procedure that preserves 1st MTP joint motion, allowing for faster return to daily activities. The reported complication rate for cheilectomy is low (0% to 3%)^[18]. Cheilectomy does not compromise future surgical treatments should revision become necessary. However, cheilectomy does not prevent the progression of the disease and is rarely a permanent solution to the problem. Dorsal exostosis has been observed in up to 30% of patients, with continued progression of chondrolysis and joint deterioration^[4].

Coughlin and Shumas^[19] reported the longest follow-up study to date for cheilectomy with a mean follow-up of 9.6 years. The study concluded that cheilectomy should be performed for Coughlin and Shurnas Grade I, Grade 2, and Grade 3 with less than 50% metatarsal head cartilage loss. Similarly, Bussewitz *et al.*^[18] reported an overall success rate of 98.5% in 197 cases with a mean follow-up of 3.2 years. Nicolosi *et al.*^[20] evaluated the long-term efficacy of aggressive cheilectomy by analyzing patient satisfaction using American Orthopaedic Foot and Ankle Society (AOFAS) scale in 58 patients

with mean follow-up period of 7 years. The average improvement in pain relief was 87.71%, and 94.83% of all patients stated that they would undergo the same procedure again. The authors concluded that aggressive cheilectomy should be performed over arthrodesis in patients with Grade I to Grade III hallux rigidus using the Coughlin and Shurnas classification system.

Cetinkaya *et al.*^[21] assessed the results of cheilectomy in the treatment of Grade III hallux rigidus using the Coughlin and Shurnas classification system for 21 patients (22 toes). There was no revision surgery done, and the visual analog scale (VAS) score improved from 89 preoperative to 29 postoperative. Cetinkaya *et al.*^[21] concluded that cheilectomy is the preferable method as the first line treatment option for Grade III hallux rigidus.

CHEILECTOMY WITH MOBERG OSTEOTOMY

Moberg osteotomy is a dorsal closing-wedge osteotomy of the proximal phalanx. This procedure simulates an increased dorsiflexion that facilitates the third rocker of gait. Further, the Moberg osteotomy shifts the center of pressure on the first metatarsal head in a plantar direction. As a result, less forces act on the arthritic joint surface^[22].

Moberg osteotomy is typically performed in conjunction with a cheilectomy for early stages of hallux rigidus. As noted previously, cheilectomy doesn't prevent further degeneration of the joint and therefore progressive loss of dorsiflexion can occur. Moberg osteotomy can offer decompression of the joint while preserving the movement at the first MTP joint. It has been argued that one potential drawback of the osteotomy is that it could affect dorsal plate positioning in case of arthrodesis revision surgery^[23].

In a study of 60 patients (60 toes) with an 8-year follow up, Waizy *et al.*^[24] compared the results of cheilectomy alone (27 patients) vs combined cheilectomy and Moberg osteotomy (33 patients). No revisions or further operations were done in both groups. Four patients had persistent hyperesthesia of the medial side of the great toe and 3 patients had delayed wound healing. Patients who had cheilectomy with Moberg osteotomy reported higher satisfaction than cheilectomy alone (32.6% vs 21.7%). The authors concluded that a Moberg osteotomy should be supplemented if dorsiflexion of greater than 70° could not be achieved intraoperatively with cheilectomy alone.

Moberg osteotomy alone has also demonstrated good clinical results in moderate hallux rigidus. Perez-Aznar *et al.*^[25] evaluated the results of a Moberg osteotomy alone in 40 patients (42 toes) with Coughlin and Shurnas Grade II and III hallux rigidus. Both AOFAS (51.7 to 88.8) and VAS scores (76.6 to 1.9) improved significantly from pre-op to post-op. Additionally, dorsiflexion improved from 20.3° to 55.7°.

O'Malley *et al.*^[23] investigated the use of cheilectomy and Moberg osteotomy for the treatment of advanced hallux rigidus. In a cohort of 81 grade III hallux rigidus with

a mean follow-up of 4.3 years, significant improvements in dorsiflexion and AOFAS scores were reported. Patient satisfaction was high (85.2%), with 4.9% ultimately requiring arthrodesis. The authors encouraged and recommended cheilectomy with Moberg osteotomy in patients with high grade hallux rigidus with at least 20° of preoperative dorsiflexion.

ARTHRODESIS

Arthrodesis of the 1st MTP joint has been widely accepted as the standard of care for severe, end-stage hallux rigidus due to its perceived safety and efficacy^[8,11,26-31]. The procedure is typically performed as open surgery, although few recent reports have demonstrated a percutaneous approach^[28,32]. The arthrodesis surfaces can be prepared either in a dome-cup pair configuration or flat and tapered. Dome-cup pair configuration allows for high degrees of adjustability in a three-dimensional plane, making final optimal alignment of the great toe easier.

There are multiple internal fixation techniques to achieve fusion (plates, screws, wires and staples). Ultimately, the choice depends on the surgeon's skills and experiences with a particular fixation technique. Politi *et al.*^[33] evaluated and compared the strength of fixation of five commonly utilized techniques for arthrodesis and found that the most stable technique was the combination of an oblique lag screw and a dorsal plate. The weakest technique was dorsal plate alone with Kirschner wire fixation. Dening *et al.*^[34] demonstrated that plate fixation alone has significantly fewer non-unions than a single screw fixation. Hyer *et al.*^[35] compared the cost and results of two crossed screws and dorsal plating techniques. The two crossed screws represented a simple and less costly technique, with no statistically significant differences in time to fusion, revision surgery or hardware removal rate between the two techniques.

When performing a hallux fusion it is crucial to maintain the load bearing capacity of the first ray in order to prevent lateral transfer of forces towards the lesser metatarsals. The angle of fusion should be within 15° to 40° of extension and 15° and 30° of valgus^[36].

Recent studies have reported fusion rates between 77% to 100% with dorsal plating and screw fixation^[37]. Arthrodesis has been shown to improve propulsion power, weight-bearing function of the foot, and stability during gait^[27]. However, complications such as nonunion have been reported to be as high as 20%^[29]. Further, patients may complain of joint stiffness, metatarsalgia and limited footwear options, particularly women desiring to wear high heels.

ARTHROPLASTY

Unlike arthrodesis in which the joint motion is sacrificed to improve pain, partial or total arthroplasty is a surgical option intended to relieve pain while preserving the mobility of the first MTP joint. Both total joint arthroplasty and

hemiarthroplasty of the proximal phalanx or metatarsal have been developed. Despite the potential benefit of maintaining joint motion while relieving pain, multiple complications have been documented for arthroplasty, including implant failure, soft tissue instability, aseptic loosening of components, pathological wear, limited soft tissue coverage and infection^[38,39].

Mixed results have been reported on the long-term outcomes of various types of implants^[38-41]. Good short-term and long-term functional outcome and high patient satisfaction level were reported with the use of ToeFit-Plus (Plus Orthopedics AG, Switzerland) implants and silicone implant prosthesis^[40,41]. Conversely, a loss of ROM and changes in component alignment over time was demonstrated with the use of an anatomically designed 3-component MTP-I prosthesis (Metis, Newdeal SA, Integra Life Science ILS, New Jersey, United States)^[38]. Similarly, high rates of radiolucency, change in angulation, sinkage and malalignment were observed with the use of the second-generation ceramic press fit prosthesis (Press-fit Plus MTP, Moje Keramik-Implantate GmbH and Co KG, Petersberg, Germany)^[39]. Because of the poor clinical and radiological results, the authors in the study did not recommend the prosthesis.

Similar to total joint arthroplasty, hemiarthroplasty also helps maintain the motion of the first MTP joint. However, hemiarthroplasty requires less bone resection and ensures maintenance of toe length. As a result, conversion to arthrodesis would be easier if a revision becomes necessary. Like total arthroplasty, studies on hemiarthroplasty have shown mixed results. Gheorghiu *et al.*^[42] observed a marked decrease in patient satisfaction along with significant decrease in ROM in patients with hemiarthroplasty compared to arthrodesis with a mean follow-up of 3.92 years. On the other hand, Voskuijl and Onstenk^[43] found patients with hemiarthroplasty in their study reported greater satisfaction. In addition, symptom intensity and magnitude of disability were found comparable in both hemiarthroplasty and arthrodesis.

While the success and benefit of implants have been documented in the literature, the reports of higher complication rates, unpredictable results and poor survival have led orthopedic surgeons to become cautious with the use of implant arthroplasty. Part of the challenge with arthroplasty is the difficulty in mimicking the native joint and the various anatomical and mechanical stresses it endures. Failure of the arthroplasty is very difficult to manage as significant bone loss was introduced by the procedure in the first place. Additionally, the cost compared to arthrodesis is significantly higher^[38]. Therefore, larger cohorts and longer follow-up studies are necessary to draw more definitive conclusions on arthroplasty in hallux rigidus.

INTERPOSITIONAL ARTHROPLASTY

Interpositional arthroplasty is a joint sparing procedure that maintains joint motion in patients with severe hallux rigidus. Keller resection arthroplasty was one of the

pioneer procedures for the treatment of hallux rigidus that involves the resection of up to 50% of the base of the proximal phalanx. The goal of the procedure was to decompress the joint while increasing dorsiflexion. However, the procedure may destabilize the first MTP joint leading to transfer metatarsalgia, excessive shortening of the toe, cock-up deformity, clawing of the IP joint, and high rates of revision^[8,44-47]. In addition, pedobarographic evaluations of foot following Keller resection arthroplasty have demonstrated a decrease in the maximum pressure, force and contact area under the operated great toe^[45].

Schneider *et al.*^[45] reported a 90% stable first MTP joint in 78 patients (87 toes) who underwent Keller resection arthroplasty with 23 years of follow-up. The revision rate was reported at 5%. However, it is important to note that even though only one patient required revision with a cock-up deformity, 23% (19 toes) of patients presented with a cock-up deformity. It has been proposed to reserve the Keller resection arthroplasty in patients with advanced hallux rigidus, over the age of 70, and with less physical demand^[8,46].

In light of the potential complications, multiple modifications of the Keller resection arthroplasty have been developed. These include a much more limited resection of the proximal phalanx, addition of a cheilectomy, and a placement of a spacer (joint capsule, extensor hallucis brevis, tendon autograft, tendon allograft, synthetic matrix, etc.). The aim of the modifications is to preserve the bone stock, maintain or increase joint motion, stability and length^[48].

Aynardi *et al.*^[49] retrospectively reviewed 133 patients who underwent interpositional arthroplasty with either autograft or synthetic soft tissue. Ninety percent of patients reported good to excellent outcomes at a mean follow-up of 62.2 mo. Overall failure rate was 3.8%, and a 1.5% infection rate. Six patients reported cock-up deformity of the 1st MTP joint and 23 patients reported metatarsalgia of the 2nd or 3rd MTP joint.

Schenk *et al.*^[50] compared the outcomes of Keller resection arthroplasty and interpositional arthroplasty and found no significant difference between the clinical and radiological outcomes of the two procedures. However, these were short term-results with a mean follow-up of 1.26 years. Mackey *et al.*^[47] compared interpositional arthroplasty with arthrodesis and reported that interpositional arthroplasty had equivalent clinical outcomes to arthrodesis. However, it presented the additional benefit of motion preservation and resulted in a more physiologic pattern of plantar pressure during gait.

Berlet *et al.*^[48] described the use of a regenerative tissue matrix (RTM) (Wright Medical Technology, Inc., Memphis, TN, United States) as an allograft interpositional spacer for the treatment of advanced hallux rigidus. RTM is a biologically engineered allograft consisting of collagen and extracellular protein matrices. In their preliminary report, 9 patients underwent the procedure and no failures were reported at 10.1 mo follow-up. At 5-year follow-up, none of the patients had subsequent fusion or

additional procedures performed on the first MTP joint and all were satisfied with the procedure^[51].

Baumhauer *et al.*^[5] described the use of a synthetic cartilage implant as an allograft interpositional spacer. This synthetic cartilage implant (Cartiva, Inc., Alpharetta, GA, United States) is 8 or 10 mm in diameter and requires minimal bone and joint resection for implantation. The authors compared synthetic cartilage implant and arthrodesis in patients with advanced stage hallux rigidus and concluded that both procedures had equivalent decrease in pain and improvement function at 2-year, with an overall failure rate of 10%.

ARTHODIASTASIS

Arthodiastasis involves extra-articular distraction of a joint. This is based on the principle that offloading the articular surfaces of a joint can provide an environment that stimulates bone healing and fibrocartilage generation^[4]. Pain can potentially be reduced, and arthrodesis or arthroplasty is still possible if distraction fails. Distraction of other joints in the body has been well reported, including the hip and ankle^[52-54]. Abraham *et al.*^[55] reported a statistically significant reduction of pain in 9 hallux rigidus patients (10 distractions) using joint distraction with a mean follow up of 2.2 years. All patients were stage II or III hallux rigidus on the Regnaud classification system, and none of the patients had subsequent procedures on the first MTP joint. The downside of the procedure, however, is the need to carry an external fixator for about 3 mo.

ARTHROSCOPY

The use of arthroscopy in the treatment of hallux rigidus is an emerging technique that has recently been described^[56,57]. It is mainly used for grade I and II hallux rigidus where joint motion still remains. For patients that have failed conservative treatments, arthroscopic debridement and dorsal cheilectomy can be performed as an alternative to an open cheilectomy. Advantages include smaller incisions, reduced operative morbidity and more rapid rehabilitation. In addition, access to the entire joint is easier, which allows for identification of concomitant pathologies in the joint. If visualization of the joint is limited, the dorsomedial portal can be extended and convert the procedure to an open cheilectomy^[56]. Arthroscopy of the 1st MTP joint is technically challenging and requires additional surgical training. Complications that have been described include iatrogenic articular cartilage injury, superficial or deep infection, wound dehiscence and sinus tract formation^[56].

CONCLUSION

An array of techniques has been developed to address the arthritic changes in hallux rigidus. Surgical treatments can be considered only after failure with non-operative management. Surgical options can be divided into joint sparing and joint sacrificing. Determining the extent of

the degenerative changes in the first MTP joint is critical in selecting which surgical technique to perform. Cheilectomy has demonstrated excellent outcomes for early stages of hallux rigidus, while arthrodesis is the gold standard for end-stage hallux rigidus. Other procedures, such as interpositional arthroplasty, seem to provide promising patient outcomes, but long-term follow-up studies are needed to validate the available results.

REFERENCES

- Gould N, Schneider W, Ashikaga T. Epidemiological survey of foot problems in the continental United States: 1978-1979. *Foot Ankle* 1980; **1**: 8-10 [PMID: 6115797 DOI: 10.1177/107110078000100104]
- Razik A, Sott AH. Cheilectomy for Hallux Rigidus. *Foot Ankle Clin* 2016; **21**: 451-457 [PMID: 27524700 DOI: 10.1016/j.fcl.2016.04.006]
- Jacob HA. Forces acting in the forefoot during normal gait--an estimate. *Clin Biomech* (Bristol, Avon) 2001; **16**: 783-792 [PMID: 11714556 DOI: 10.1016/S0268-0033(01)00070-5]
- Perler AD, Nwosu V, Christie D, Higgins K. End-stage osteoarthritis of the great toe/hallux rigidus: a review of the alternatives to arthrodesis: implant versus osteotomies and arthroplasty techniques. *Clin Podiatr Med Surg* 2013; **30**: 351-395 [PMID: 23827492 DOI: 10.1016/j.cpm.2013.04.011]
- Baumhauer JF, Singh D, Glazebrook M, Blundell C, De Vries G, Le IL, Nielsen D, Pedersen ME, Sakellariou A, Solan M, Wansbrough G, Younger AS, Daniels T. Prospective, Randomized, Multi-centered Clinical Trial Assessing Safety and Efficacy of a Synthetic Cartilage Implant Versus First Metatarsophalangeal Arthrodesis in Advanced Hallux Rigidus. *Foot Ankle Int* 2016; **37**: 457-469 [PMID: 26922669 DOI: 10.1177/1071100716635560]
- Beeson P, Phillips C, Corr S, Ribbons W. Classification systems for hallux rigidus: a review of the literature. *Foot Ankle Int* 2008; **29**: 407-414 [PMID: 18442456 DOI: 10.3113/FAI.2008.0407]
- Coughlin MJ, Shurnas PS. Hallux rigidus. Grading and long-term results of operative treatment. *J Bone Joint Surg Am* 2003; **85-A**: 2072-2088 [PMID: 14630834]
- Deland JT, Williams BR. Surgical management of hallux rigidus. *J Am Acad Orthop Surg* 2012; **20**: 347-358 [PMID: 22661564 DOI: 10.5435/JAAOS-20-06-347]
- Coughlin MJ, Shurnas PS. Hallux rigidus: demographics, etiology, and radiographic assessment. *Foot Ankle Int* 2003; **24**: 731-743 [PMID: 14587987 DOI: 10.1177/107110070302401002]
- Migues A, Slullitel G. Joint-preserving procedure for moderate hallux rigidus. *Foot Ankle Clin* 2012; **17**: 459-471 [PMID: 22938644 DOI: 10.1016/j.fcl.2012.06.006]
- Hamid KS, Parekh SG. Clinical Presentation and Management of Hallux Rigidus. *Foot Ankle Clin* 2015; **20**: 391-399 [PMID: 26320554 DOI: 10.1016/j.fcl.2015.04.002]
- Gajdosik RL, Bohannon RW. Clinical measurement of range of motion. Review of goniometry emphasizing reliability and validity. *Phys Ther* 1987; **67**: 1867-1872 [PMID: 3685114 DOI: 10.1093/ptj/67.12.1867]
- Vulcano E, Tracey JA, Myerson MS. Accurate Measurement of First Metatarsophalangeal Range of Motion in Patients With Hallux Rigidus. *Foot Ankle Int* 2016; **37**: 537-541 [PMID: 26660863 DOI: 10.1177/1071100715621508]
- Solan MC, Calder JD, Bendall SP. Manipulation and injection for hallux rigidus. Is it worthwhile? *J Bone Joint Surg Br* 2001; **83**: 706-708 [PMID: 11476310 DOI: 10.1302/0301-620X.83B5.11425]
- Hauser RA, Hauser MA, Cukla JK. A retrospective observational study on Hackett-Hemwall Dextrose Prolotherapy for unresolved foot and toe pain at an outpatient charity clinic in rural Illinois. *J Prolotherapy* 2011; **3**: 543-551
- Kunnasegaran R, Thevendran G. Hallux Rigidus: Nonoperative Treatment and Orthotics. *Foot Ankle Clin* 2015; **20**: 401-412 [PMID: 26320555 DOI: 10.1016/j.fcl.2015.04.003]
- Smith SM, Coleman SC, Bacon SA, Polo FE, Brodsky JW. Improved ankle push-off power following cheilectomy for hallux rigidus: a prospective gait analysis study. *Foot Ankle Int* 2012; **33**: 457-461 [PMID: 22735316 DOI: 10.3113/FAI.2012.0457]
- Bussewitz BW, Dymment MM, Hyer CF. Intermediate-term results following first metatarsal cheilectomy. *Foot Ankle Spec* 2013; **6**: 191-195 [PMID: 23606380 DOI: 10.1177/1938640013484793]
- Coughlin MJ, Shurnas PS. Hallux rigidus. *J Bone Joint Surg Am* 2004; **86-A** Suppl 1: 119-130 [PMID: 15466753 DOI: 10.2106/00004623-200409001-00003]
- Nicolosi N, Hehemann C, Connors J, Boike A. Long-Term Follow-Up of the Cheilectomy for Degenerative Joint Disease of the First Metatarsophalangeal Joint. *J Foot Ankle Surg* 2015; **54**: 1010-1020 [PMID: 25981441 DOI: 10.1053/j.jfas.2014.12.035]
- Cetinkaya E, Yalcinkaya M, Sokucu S, Polat A, Ozkaya U, Parmaksizoglu AS. Cheilectomy as a First-Line Surgical Treatment Option Yields Good Functional Results in Grade III Hallux Rigidus. *J Am Podiatr Med Assoc* 2016; **106**: 22-26 [PMID: 26895357 DOI: 10.7547/14-098]
- Kim PH, Chen X, Hillstrom H, Ellis SJ, Baxter JR, Deland JT. Moberg Osteotomy Shifts Contact Pressure Plantarily in the First Metatarsophalangeal Joint in a Biomechanical Model. *Foot Ankle Int* 2016; **37**: 96-101 [PMID: 26385611 DOI: 10.1177/1071100715603513]
- O'Malley MJ, Basran HS, Gu Y, Sayres S, Deland JT. Treatment of advanced stages of hallux rigidus with cheilectomy and phalangeal osteotomy. *J Bone Joint Surg Am* 2013; **95**: 606-610 [PMID: 23553295 DOI: 10.2106/JBJS.K.00904]
- Waizy H, Czardybon MA, Stukenborg-Colsman C, Wingenfeld C, Wellmann M, Windhagen H, Frank D. Mid- and long-term results of the joint preserving therapy of hallux rigidus. *Arch Orthop Trauma Surg* 2010; **130**: 165-170 [PMID: 19306008 DOI: 10.1007/s00402-009-0857-1]
- Perez-Aznar A, Lizaar-Utrilla A, Lopez-Prats FA, Gil-Guillen V. Dorsal wedge phalangeal osteotomy for grade II-III hallux rigidus in active adult patients. *Foot Ankle Int* 2015; **36**: 188-196 [PMID: 25288332 DOI: 10.1177/1071100714552481]
- Tomlinson M. Pain after cheilectomy of the first metatarsophalangeal joint: diagnosis and management. *Foot Ankle Clin* 2014; **19**: 349-360 [PMID: 25129348 DOI: 10.1016/j.fcl.2014.06.002]
- Brodsky JW, Baum BS, Pollo FE, Mehta H. Prospective gait analysis in patients with first metatarsophalangeal joint arthrodesis for hallux rigidus. *Foot Ankle Int* 2007; **28**: 162-165 [PMID: 17296132 DOI: 10.3113/FAI.2007.0162]
- Fanous RN, Ridgers S, Sott AH. Minimally invasive arthrodesis of the first metatarsophalangeal joint for hallux rigidus. *Foot Ankle Surg* 2014; **20**: 170-173 [PMID: 25103703 DOI: 10.1016/j.fas.2014.03.004]
- Faraj AA, Naraen A, Twigg P. A comparative study of wire fixation and screw fixation in arthrodesis for the correction of hallux rigidus using an in vitro biomechanical model. *Foot Ankle Int* 2007; **28**: 89-91 [PMID: 17257545 DOI: 10.3113/FAI.2007.0016]
- Fuhrmann RA. First metatarsophalangeal arthrodesis for hallux rigidus. *Foot Ankle Clin* 2011; **16**: 1-12 [PMID: 21338925 DOI: 10.1016/j.fcl.2010.12.003]
- Roukis TS, Meusnier T, Augoyard M. 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* 2012; **51**: 308-311 [PMID: 22225597 DOI: 10.1053/j.jfas.2011.11.007]
- Sott AH. Minimally Invasive Arthrodesis of 1st Metatarsophalangeal Joint for Hallux Rigidus. *Foot Ankle Clin* 2016; **21**: 567-576 [PMID: 27524706 DOI: 10.1016/j.fcl.2016.04.009]
- Politi J, John H, Njus G, Bennett GL, Kay DB. First metatarsal-phalangeal joint arthrodesis: a biomechanical assessment of stability. *Foot Ankle Int* 2003; **24**: 332-337 [PMID: 12735376 DOI: 10.1177/107110070302400405]
- Dening J, van Erve RH. Arthrodesis of the first metatarsophalangeal joint: a retrospective analysis of plate versus screw fixation. *J Foot Ankle Surg* 2012; **51**: 172-175 [PMID: 22178200 DOI: 10.1053/j.jfas.2011.10.044]
- Hyer CF, Glover JP, Berlet GC, Lee TH. Cost comparison of crossed

- screws versus dorsal plate construct for first metatarsophalangeal joint arthrodesis. *J Foot Ankle Surg* 2008; **47**: 13-18 [PMID: 18156059 DOI: 10.1053/j.jfas.2007.08.016]
- 36 **Aas M**, Johnsen TM, Finsen V. Arthrodesis of the first metatarsophalangeal joint for hallux rigidus--optimal position of fusion. *Foot (Edinb)* 2008; **18**: 131-135 [PMID: 20307426 DOI: 10.1016/j.foot.2008.03.002]
- 37 **Chraim M**, Bock P, Alrabai HM, Trnka HJ. Long-term outcome of first metatarsophalangeal joint fusion in the treatment of severe hallux rigidus. *Int Orthop* 2016; **40**: 2401-2408 [PMID: 27542800 DOI: 10.1007/s00264-016-3277-1]
- 38 **Horisberger M**, Haeni D, Henninger HB, Valderrabano V, Barg A. Total Arthroplasty of the Metatarsophalangeal Joint of the Hallux. *Foot Ankle Int* 2016; **37**: 755-765 [PMID: 26979844 DOI: 10.1177/1071100716637901]
- 39 **Nagy MT**, Walker CR, Sirikonda SP. Second-Generation Ceramic First Metatarsophalangeal Joint Replacement for Hallux Rigidus. *Foot Ankle Int* 2014; **35**: 690-698 [PMID: 24986899 DOI: 10.1177/1071100714536539]
- 40 **Erkocak OF**, Senaran H, Altan E, Aydin BK, Acar MA. Short-term functional outcomes of first metatarsophalangeal total joint replacement for hallux rigidus. *Foot Ankle Int* 2013; **34**: 1569-1579 [PMID: 23877170 DOI: 10.1177/1071100713496770]
- 41 **Morgan S**, Ng A, Clough T. The long-term outcome of silastic implant arthroplasty of the first metatarsophalangeal joint: a retrospective analysis of one hundred and eight feet. *Int Orthop* 2012; **36**: 1865-1869 [PMID: 22729664 DOI: 10.1007/s00264-012-1576-8]
- 42 **Gheorghiu D**, Coles C, Ballester J. Hemiarthroplasty for Hallux Rigidus: Mid-Term Results. *J Foot Ankle Surg* 2015; **54**: 591-593 [PMID: 25746772 DOI: 10.1053/j.jfas.2014.11.001]
- 43 **Voskuijl T**, Onstenk R. Operative Treatment for Osteoarthritis of the First Metatarsophalangeal Joint: Arthrodesis Versus Hemiarthroplasty. *J Foot Ankle Surg* 2015; **54**: 1085-1088 [PMID: 26277243 DOI: 10.1053/j.jfas.2015.06.019]
- 44 **Clews CN**, Kingsford AC, Samaras DJ. Autogenous capsular interpositional arthroplasty surgery for painful hallux rigidus: assessing changes in range of motion and postoperative foot health. *J Foot Ankle Surg* 2015; **54**: 29-36 [PMID: 25441283 DOI: 10.1053/j.jfas.2014.09.004]
- 45 **Schneider W**, Kadnar G, Kranzl A, Knahr K. Long-term results following Keller resection arthroplasty for hallux rigidus. *Foot Ankle Int* 2011; **32**: 933-939 [PMID: 22224321 DOI: 10.3113/FAI.2011.0933]
- 46 **Sanhudo JA**, Gomes JE, Rodrigo MK. Surgical treatment of advanced hallux rigidus by interpositional arthroplasty. *Foot Ankle Int* 2011; **32**: 400-406 [PMID: 21733443 DOI: 10.3113/FAI.2011.0400]
- 47 **Mackey RB**, Thomson AB, Kwon O, Mueller MJ, Johnson JE. The modified oblique keller capsular interpositional arthroplasty for hallux rigidus. *J Bone Joint Surg Am* 2010; **92**: 1938-1946 [PMID: 20720136 DOI: 10.2106/JBJS.I.00412]
- 48 **Berlet GC**, Hyer CF, Lee TH, Philbin TM, Hartman JF, Wright ML. Interpositional arthroplasty of the first MTP joint using a regenerative tissue matrix for the treatment of advanced hallux rigidus. *Foot Ankle Int* 2008; **29**: 10-21 [PMID: 18275731 DOI: 10.3113/FAI.2008.0010]
- 49 **Aynardi MC**, Atwater L, Dein EJ, Zahoor T, Schon LC, Miller SD. Outcomes After Interpositional Arthroplasty of the First Metatarsophalangeal Joint. *Foot Ankle Int* 2017; **38**: 514-518 [PMID: 28068843 DOI: 10.1177/1071100716687366]
- 50 **Schenk S**, Meizer R, Kramer R, Aigner N, Landsiedl F, Steinboeck G. Resection arthroplasty with and without capsular interposition for treatment of severe hallux rigidus. *Int Orthop* 2009; **33**: 145-150 [PMID: 17929015 DOI: 10.1007/s00264-007-0457-z]
- 51 **Hyer CF**, Granata JD, Berlet GC, Lee TH. Interpositional arthroplasty of the first metatarsophalangeal joint using a regenerative tissue matrix for the treatment of advanced hallux rigidus: 5-year case series follow-up. *Foot Ankle Spec* 2012; **5**: 249-252 [PMID: 22547531 DOI: 10.1177/1938640012443285]
- 52 **Aldegheri R**, Trivella G, Saleh M. Articulated distraction of the hip. Conservative surgery for arthritis in young patients. *Clin Orthop Relat Res* 1994; **(301)**: 94-101 [PMID: 8156703 DOI: 10.1097/00003086-199404000-00016]
- 53 **van Valburg AA**, van Roermund PM, Marijnissen AC, van Melkebeek J, Lammens J, Verbout AJ, Lafeber FP, Bijlsma JW. Joint distraction in treatment of osteoarthritis: a two-year follow-up of the ankle. *Osteoarthritis Cartilage* 1999; **7**: 474-479 [PMID: 10489320 DOI: 10.1053/joca.1998.0242]
- 54 **Marijnissen AC**, Van Roermund PM, Van Melkebeek J, Schenk W, Verbout AJ, Bijlsma JW, Lafeber FP. Clinical benefit of joint distraction in the treatment of severe osteoarthritis of the ankle: proof of concept in an open prospective study and in a randomized controlled study. *Arthritis Rheum* 2002; **46**: 2893-2902 [PMID: 12428229 DOI: 10.1002/art.10612]
- 55 **Abraham JS**, Hassani H, Lamm BM. Hinged external fixation distraction for treatment of first metatarsophalangeal joint arthritis. *J Foot Ankle Surg* 2012; **51**: 604-612 [PMID: 22749986 DOI: 10.1053/j.jfas.2012.04.022]
- 56 **Hunt KJ**. Hallux metatarsophalangeal (MTP) joint arthroscopy for hallux rigidus. *Foot Ankle Int* 2015; **36**: 113-119 [PMID: 25550495 DOI: 10.1177/1071100714559728]
- 57 **Siclari A**, Piras M. Hallux metatarsophalangeal arthroscopy: indications and techniques. *Foot Ankle Clin* 2015; **20**: 109-122 [PMID: 25726487 DOI: 10.1016/j.fcl.2014.10.012]

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