Introduction

The term “hallux rigidus” refers to the osteoarthritis of the metatarsophalangeal (MTP) joint of the first toe. This disease was first reported in 1887 by Davies-Colley. He suggested the name “hallux flexus”. Shortly thereafter Cotterill was the first to introduce the term “hallux rigidus”. Since then multiple names have been suggested, such as metatarsus primus elevatus, dorsal bunion, hallux dolorosus, or hallux malleus, to describe the same diagnosis. 1

It is more common in females, hallux rigidus is thought to affect 1 in 45 individuals over the age of 60 years. 2

The exact cause for hallux rigidus is controversial. Coughlin et al demonstrated that 80% of all patients suffering from bilateral hallux rigidus have a family history. Furthermore, in a long term study they could detect that most patients develop a bilateral hallux rigidus over time. 2

Some authors blame poor shoe wear, a tight achilles tendon or believe in a spontaneous onset. Another popular concept is that an elevated first ray, the so called metatarsus primus elevatus, leads to hallux rigidus. 1

Hallux rigidus is characterised by arthralgia, which is usually worsened by walking. With time the joint enlarges and the symptoms become more pronounced with pain at the dorsal bony prominence of the first MTP joint and decreased range of motion, especially dorsiflexion. In this process the destruction of the cartilage commonly starts at the dorsal portion of the metatarsal head and the bony prominence might impinge against the proximal phalanx. Physical examination usually shows a painful, tender and swollen first MTP joint with limited motion and pain usually when dorsiflexed. 2
Multiple different grading systems for hallux rigidus have been introduced differentiating between two and five different grades. A classification system should aid the decision on treatment and allow a meaningful comparison of different treatment strategies. Furthermore, in order to compare the results of different studies and procedures a consistent classification is crucial. 1

Beeson et al performed a systematic review of the literature to critically evaluate the different classification systems for hallux rigidus. The authors criticize, that none of the classification systems has been tested in regard to reliability and validity. 3

Taking this short, they consider the classification system by Coughlin et al to be the closest to a “gold standard”. These authors base their classification on subjective and objective clinical and radiographic findings. 2

Non operative treatment of hallux rigidus should be applied in accordance to the degree of symptoms. Anti-inflammatory medications and strapping of the toe might be sufficient. Furthermore, shoe modification or the use of rigid shoe inserts and modification of activities might be beneficial. 4

Currently, the standard surgical treatment in advanced cases is still metatarso-phalangeal arthrodesis. Comparative studies show that the articular fusion present a higher patient satisfaction rate when compared to arthroplasty. 5

However, the loss of mobility is not well tolerated by young adult active patients and complications of this procedure include: non-consolidation in 10% of cases, mal-position of the proximal phalanx, limitation of sports activities and increased stress in the lateral rays. 6
Therefore, it becomes necessary to investigate procedures for maintaining joint mobility. Arthroplasty of the first metatarsophalangeal joint allows improvement of painful symptoms and restitution of joint mobility. This surgical procedure can be classified into partial and total arthroplasty.7

There are several other treatments available that can either prolong the life of the remaining joint or artificially mimic the original biomechanics by replacing a portion of or the entire joint with the added advantage of preserving joint mobility. There are several new and emerging joint preservative techniques that may delay or prevent the need for a joint-destructive procedure, such as arthrodesis or arthroplasty.

This thesis uses an alternative technique to arthrodesis for late stages hallux rigidus, the modified oblique Keller capsular interposition arthroplasty (MOKCIA). With this operation, the dorsal capsule of the hallux MTP joint is interposed into the joint, offering pain relief without sacrificing range of motion.
Aim of the work

The aim of this study is to evaluate the short term results of Modified oblique Keller capsular interposition arthroplasty in treatment of hallux rigidus.
Pathophysiology of hallux rigidus:

The pathophysiology of hallux rigidus is similar to that of degenerative arthritis in any joint. Overuse, injury, or abnormal joint mechanics lead to abnormal stresses on the articular cartilage. In an in vitro study, Ahn et al used a magnetic tracking system to monitor the three-dimensional movement of the proximal phalanx while the toe position was changed from a neutral position to full extension. Contact distribution shifted dorsally with increasing degrees of extension. These data are consistent with the observation that chondral erosions associated with hallux rigidus and degenerative arthritis initially affect the dorsal articular surface of the first metatarsal bone. Articular degenerative changes are associated with dehydration of the cartilage, which, in turn, is more susceptible to injury resulting from shear and compressive forces. The subchondral bone shares these stresses, which subsequently lead to increased subchondral bone density, formation of periarticular osteophytes, and, in severe cases, cystic changes. The osteophytes limit first MTP joint motion and further compromise the normal mechanics of this joint. This effect can accelerate the degenerative process. In severe cases, the articular cartilage is completely denuded.

Etiology of hallux rigidus:

The true etiology of hallux rigidus is not known. Most commonly, hallux rigidus is thought to be caused by wear and tear on the first MTP joint. Multiple theories have been proposed for the underlying etiology. Some authors have associated hallux rigidus with athletic activities involving running; in this case, the disorder possibly results from repetitive hyperextension of the first MTP joint with chronic gradual attenuation of the plantar plate and subsequent instability. Hallux rigidus has also been seen as a long-term outcome of acute injuries to the great-toe MTP joint,
such as turf toe. Several authors have suggested traumatic injury to the articular cartilage either acute trauma (as in turf toe) or chronic, repetitive, minor injury as the underlying mechanism. 2

Clanton et al found hallux valgus and early hallux rigidus to be long-term sequelae. After more than 5 years of follow-up, Clanton and Seifert found that among 20 athletes with previous turf-toe injury, half suffered from persistent symptoms. The long-term effects of turf-toe require further study. In 1933, Kingreen reported that osteochondritis dissecans led to development of hallux rigidus. Goodfellow proposed that the development of an osteochondrosis in childhood creates a defect and secondary slow-remodeling collapse, leading to abnormal motion in the forefoot. 9

McMaster reported on 7 adolescent patients who had an articular defect of approximately 5 mm located directly beneath the dorsal lip of the proximal phalanx; this defect was associated with symptoms of hallux rigidus.10

Lambrinudi proposed the so-called metatarsus primus elevatus, in 1938. Theoretically, an abnormally elevated first MT causes excessive flexion of the great toe during gait and subsequent development of flexion contracture at the first MTP joint. These abnormal mechanics cause hallux rigidus. Others, such as Jack, in 1940, postulated that with the elevated first MT, increased overload of the second metatarsal bone occurs, with compensatory contracture of the flexor hallucis brevis (FHB). This contracture pulls the proximal phalanx inferiorly, driving its dorsal rim into the metatarsal head and leading to localized degenerative changes in the articular cartilage. 11

Hypermobility of the first ray leading to flexor spasm and impingement of the proximal phalanx on the metatarsal head is another
proposed theory. Yet other researchers, such as Jansed, in 1920, have implicated flatfoot.\textsuperscript{12}

All of these theories are without true scientific data. In 1986, Mann first theorized that a flat first metatarsal head restricts, to a relative extent, the medial and lateral motion of the first MTP joint, creating increased stress in the sagittal plane. This restriction of motion, he said, accelerates the degenerative process. Others have proposed that flattening of the head is a secondary result. \textsuperscript{13}

Some authors propose that the disease may develop somewhat differently in adolescents than in adults. The observation that the first MTP joint returns to normal under anesthesia in adolescents suggests that anatomic anomalies and spasm may be contributing factors. Bingold and Collins suggested that the disease proceeds in stages from adolescence through adulthood. Vilaseca and Ribes found that a distal physis of the first MT head is present in 75\% of children's feet and is visible in children aged 2-11 years. They also found that the first metatarsal bone is longer than the second in children who have had a longer persistence of this distal physis. Therefore, individual anatomic variations may play a role in causing functional changes in the MTP motion and position during gait.\textsuperscript{14}

An abnormally long first metatarsal bone (index-plus foot) increases the first MTP joint stress during toe-off, as proposed by Nilsonne in 1930. This predisposes an individual to hallux rigidus. Nilsonne et al suggested that the excessively long toe requires a longer shoe, which in turn requires constant contraction of the great-toe flexors to grip the shoe while the person is walking. This gripping can lead to inflammation and secondary spasm, therefore limiting motion at the MTP joint at the great toe. \textsuperscript{15}
In a study involving 110 patients with hallux rigidus, Coughlin and Shurnas examined possible associations between the disorder and various physical, health, and lifestyle factors. The authors saw no association between hallux rigidus and pes planus, first metatarsal bone length, metatarsus primus elevatus, first-ray hypermobility, hallux valgus, footwear, occupation, obesity, or metatarsus adductus. However, they did see an association between hallux rigidus and hallux valgus interphalangeus (mean 18°), family history (in bilateral cases of hallux rigidus), and trauma (in unilateral cases of the condition). No specific distinction was made between adolescent and adult patients. 2

**Clinical picture:**

**Presenting symptoms:**

Pain is the most common presenting symptom of hallux rigidus. Pain at the metatarso-phalangeal joint starts at the extremes of motions and may be also noticed at the lateral border of the foot due to shift of weight bearing on the lateral aspect to reduce the load over the first metatarso-phalangeal joint in which patients will often compensate with an antalgic or supinated gait and activity modification. **Figure (1-1)** Pain at the mid range of motion denotes severe affection and extensive arthritis. During gait, pain is exaggerated at toe off and with shoes of high heels. Swelling may also be noticed due to osteophyte formation at the sides of the metatarso-phalangeal joint. Numbness may be present at the medial aspect of the big toe due to compression of dorso-medial cutaneous nerve of the big toe by the medial osteophytes. 16
**Clinical examination:**

Physical examination reveals osteophyte prominences on metatarsal head and proximal phalanx, tenderness over the dorsal aspect of first metatarso-phalangeal joint, and limitation of range of motion compared with the other side or less than the typical 76 degrees of dorsiflexion and 45 degrees of planter flexion. **Figure (1-2) 2**

**Imaging assessment:**

The standard radiographic assessment of hallux rigidus is standing antero-posterior, lateral and supine oblique radiographs. Dorsal aspect of the first metatarso-phalangyeal joint is the first part to be affected. Progressive joint space narrowing with subchondral sclerosis and formation
of osteophytes together with periarticular cystic changes. **Figure (1-3), (1-4)** CT and MRI are not necessary for hallux rigidus evaluation except in cases with suspected osteochondral lesions before X-ray appearance.

![Lateral radiograph of the foot showing dorsal osteophytes](image1.png)

**Figure (1-3):** lateral radiograph of the foot showing dorsal osteophytes at the first MTP joint.

![A-P radiograph of the foot showing narrowing of the first MTP joint with subchondral sclerosis](image2.png)

**Figure (1-4):** A-P radiograph of the foot showing narrowing of the first MTP joint with subchondral sclerosis.
Classifications of hallux rigidus:

Coughlin and Shurans classification:

Coughlin and Shurans classify hallux rigidus according to the degree of range of motion, radiographic findings and clinical manifestations. This is the most widely used classification and the most comprehensive. Table (1-1), figure (1-5) 17

Table (1-1): Coughlin and Shurans classification of hallux rigidus. 19

<table>
<thead>
<tr>
<th>Grade</th>
<th>Dosiflexion</th>
<th>Radiographic findings</th>
<th>Clinical findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>40-60 degree and/or 10% loss compared with the normal side</td>
<td>Normal</td>
<td>No pain Only stiffness</td>
</tr>
<tr>
<td>1</td>
<td>30-40 degree and/or 20-50% loss compared with the normal side</td>
<td>Dorsal osteophyte is the main finding Minimal joint space narrowing Minimal periarticular sclerosis Minimal flattening of metatarsal head</td>
<td>Mild or occasional and stiffness Pain at the extremes of motion</td>
</tr>
<tr>
<td>A, B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>10-30 degree and/or 50-75% loss compared with the other side</td>
<td>Dorsal, lateral and possibly medial osteophytes Less than one fourth of the joint space is involved in the lateral radiograph</td>
<td>Moderate to severe pain and stiffness</td>
</tr>
<tr>
<td>C, D</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade</td>
<td>Description</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Less than 10 degree and/or 75-100% loss compared with other side</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>More than one fourth of the joint space in lateral radiograph is involved</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Substantial narrowing</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Periarticular cystic changes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nearly constant pain and stiffness at the extremes of range of motion but not at the midrange</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Same as grade 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Same as grade 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Same as grade 3, but there is definite pain at the mid range of passive motion</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure (1-5): Standing radiographs of hallux rigidus showing Coughlin and Shurnas classifications.

A and B, Coughlin and Shurnas grade 1.
A, AP view demonstrating minimal joint space narrowing. No osteophytes are seen.
B, Lateral view demonstrating a small dorsal osteophyte (arrow).

C and D, Grade 2.
C, AP view demonstrating lateral and medial osteophytes on the metatarsal head, as well as more pronounced joint-space narrowing than in panel A.
D, Lateral view demonstrating a larger dorsal osteophyte than is evident in panel B (arrow). Twenty-five percent of the dorsal cartilage has degenerated.

E and F, Grades 3 and 4.
E, AP view demonstrating nearly complete obstruction of the joint space, the presence of lateral and medial osteophytes, and bony periarticular cystic changes.
F, Lateral view demonstrating a large dorsal osteophyte and nearly complete joint-space narrowing.
Regnauld classification:

Table (1-2): Regnauld classification of hallux rigidus. A clinical/radiographic grading system was described by Regnauld and appears mainly in the European literature. 20

<table>
<thead>
<tr>
<th>Grade</th>
<th>Characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>functional limitation of MTP joint, no radiographic degenerative changes.</td>
</tr>
<tr>
<td>2</td>
<td>flattening of the metatarsal head, osteochondral defect, pain on end ROM, mild dorsal prominence.</td>
</tr>
<tr>
<td>3</td>
<td>severe flattening of the metatarsal head, osteophyte formation, narrowing of joint space, articular degeneration, pain on full ROM.</td>
</tr>
<tr>
<td>4</td>
<td>obliteration of joint space, osteophytes + loose bodies, less than 10 degrees ROM, deformity.</td>
</tr>
</tbody>
</table>
**Hattrup and Johnson classification:**

Table (1-3): Hattrup and Johnson classification of hallux rigidus (1988) described a radiographic classification which has become standard, and in fact correlates quite well with the Regnauld grading. **21**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Joint space maintained, Minimal Osteophytes.</td>
</tr>
<tr>
<td>2</td>
<td>Larger osteophytes, Subchondral Sclerosis.</td>
</tr>
<tr>
<td>3</td>
<td>Complete loss of visible joint space, Subchondral cysts, Osteophytes, Hypertrophy of sesamoids.</td>
</tr>
</tbody>
</table>

**Treatment of hallux rigidus:**

**Nonsurgical treatment:**

Non surgical treatment should be the first line of treatment especially in grades 1 and 2 on Coughlin and Shurans classification. It includes medications, injections, shoe modifications and activity limitations. Medications include non-steroidal anti-inflammatory drugs which reduce pain but don't modify the progress of the disease. Inta-articular steroid injections also reduce pain but it affect the joint cartilage. **19**

Studies reported that one third of patients with grade 1 hallux rigidus who injected with intra-articular steroid required surgery within 6 months and two thirds of grade 2 hallux rigidus and all grade 3 required surgery at a mean of two months. **22**
Sodium hyaluronate injection reduce pain at a mean of three months but in one study half of patients required surgical intervention at one year after injection. 23

Other randomised control study show that hyaluronic acid injection was not superior to saline injection for hallux rigidus. 24

Shoe modifications may help in reducing pain in hallux rigidus. It reduce pain either by limitation of painful dorsiflexion or taking pressure off prominent osteophytes. These shoe modifications are poorly tolerated especially by women. 19

Modifications of daily activities can make a great pain reduction but these changes in the daily routines and activities are not desirable for many patients. 19

All these non surgical treatment modalities cannot modify the natural progress of the disease and there is no modality that has been demonstrated superior to placebo in the treatment of hallux rigidus. 1

**Surgical treatment:**

**Chielectomy:**

A cheilectomy consists of excision of the dorsal osteophytes surrounding the first metatarsophalangeal (MTP) joint. These osteophytes often interfere with first MTP joint motion, primarily dorsiflexion. DuVries first described the cheilectomy technique in 1959. Cheilectomy has been indicated in hallux rigidus grades 1 to 3. Fig.(1-6) 25
It is not recommended to remove more than one third of the metatarsal head articular surface which may lead to phalanx subluxation or increase load of the remaining articular surface. The literature emphasises the technical simplicity of the procedure and the excellent results obtained in improvement of pain relief and functional range of motion at the first metatarsophalangeal (MTP) joint. Chielectomy is a joint preserving procedure allow for increasing joint motion and maintaining stability with satisfaction rate ranges from 88% to 95% except for patients with extensive joint affection as in grade 4 Coughlin and Shurans classification. 26

However there are also reports of complications including transfer metatarsalgia, plantar callus of the second MTP joint, cock-up deformity and shortening of the hallux, limitation of active flexion, and the development of hammer toe deformities of the second toe. 25

Feltham et al reported significant better results of American Orthopedic Foot and Ankle score (AOFAS score) in older patients treated with chielectomy with a mean follow up 5.4 years. High activity level of younger patients lead to lower scores. 20

Coughlin and Shurans study show the long term results of chielectomy after 9.6 years done for 93 feet in 80 patient. In this study the dorsiflexion range of motion increased from 14.5 degree preoperatively to 38.4 degree postoperatively with good to excellent results in 97% of the patients. They recommended chielectomy for hallux rigidus up to grade 3 especially if more than 50% of the joint articular surface is intact. 2

Roukis assessed the need of revision surgery after chielectomy for hallux rigidus in a systematic review from 1979 to 2009 and found that 20% of patients with grade 1 need revision, 14.8% with grade 2, 9.1% grade 3 and 55.6% with grade 4. 21
Figure (1-6): Standard cheilectomy resection of the dorsal metatarsal head may be performed with either the chisel or oscillating saw. Up to one-third of the head may be resected. 18

Cheilectomy with proximal phalanx osteotomy: Figure (1-7)

Proximal phalanx osteotomy was done with cheilectomy in order to increase the range of dorsiflexion and to decompress the joint. 27

Rees et al studied the results of isolated proximal phalanx osteotomy in 62 patients with grade 1 to grade 3 in Hattrup and Johnson classification. Good to excellent outcome were reported with mean follow up 6.8 years with low recurrence rate as only 6.8% of patients required revision surgery to control pain. In this study the outcome was not related to the preoperative clinical grade. 28

In a retrospective study, Lau and Daniels reviewed 19 patients with hallux rigidus grade 2 and 3 in Hattrup and Johnson classification operated with Chielectomy with proximal phalanx osteotomy. With mean follow up 2.1 year the visual analogue scale (VAS) was 2.9, the range of dorsiflexion increased from 14.1 degree preoperatively to 30.2 degree postoperatively and the patient satisfaction was 87.5%. 26
Arthrodesis of the first MTP joint:

Arthrodesis is the current standard treatment modality for grade 3 and grade 4 hallux rigidus. The articular surface is prepared and fixation method is used. Multiple fixation options were used as Krischner wires, staples, screws, dorsal plates or dorsal plates with lag screw which is the most stable construct. Fig.(1-8). 19

Figure (1-8): arthrodesis of the first MTP joint with dorsal plate and lag screw A: A-P view, B: lateral view. 29
Correct position during arthrodesis play the most important role in successful outcome. The ideal position is 10 to 15 degree dorsiflexion and 10 to 15 degree valgus. Valgus orientation in arthrodesis is vital in order to prevent straight hallux which can impinge against the shoe medially and produce interphalangeal arthritis. 30

Coughlin and Shurans reported patient satisfaction after arthrodesis from 81% to 100%, AOFAS scores range from 82 to 90 total points and VAS pain scores were less than 1.1 of 10 total score. 2

Nonunion after arthrodesis ranges from zero to 8.9% depending on the technique and fixation method. 31

Arthroplasty:

Keller resection arthroplasty:

Keller resection arthroplasty involves the resection of the base of the proximal phalanx. Beertema et al reviewed 28 patients with hallux rigidus grade 1, 2 and 3 in Regnauld classification who underwent keller resection arthroplasty. The mean AOFAS scores were more than 83 points of 100 total score points with a mean follow up 7 years. Figure (1-9). 32

Although keller resection arthroplasty achieve joint decompression and increase the range of dorsiflexion, but also it may lead to cock up deformity, toe-off weakness and transfer metatarsalgia due to instability and removal of the articular surface. 33

Keller resection arthroplasty is a better choice in hallux rigidus patients with limited activities and patients aged over 70 years due to the easy recovery associated with the procedure but care must be taken in patient selection. Patients with elevated first metatarsal or long second
metatarsal have high incidence for transfer metatarsalgia which can be avoided also by decreasing excessive resection. 19

Figure (1-9): A-P foot radiograph showing Keller resection arthroplasty. 34

**Interpositional Arthroplasty:**

Interposition arthroplasty usually involves cheilectomy, resection of the phalangeal base, and placement of a biologic spacer (e.g., tendon and joint capsule, free autograft, or allograft). Although the use of a spacer is believed to reduce pain and increase motion. Schenk et al found no significant difference in pain or range of motion between interposition arthroplasty and the Keller procedure in patients with Hattrup and Johnson grades II and III hallux rigidus. 35

Comparison of interposition arthroplasty studies is difficult because numerous different techniques are presented and because the techniques have changed over time. AOFAS scores of 71.6 to 93.6 have been reported following interposition arthroplasty, and postoperative dorsiflexion has been reported to increase by 24.6° to 45.4°. 19
One of the early techniques involved interposition of the joint capsule and extensor hallux brevis tendon in conjunction with release of the flexor hallucis brevis (FHB) tendon. Lau and Daniels reviewed 11 feet with Hattrup and Johnson grade III osteoarthritis that were managed with interposition arthroplasty. At approximately 2-year follow-up, hallux weakness was reported in 72.7% of cases, and the mean VAS was 3.9 out of 10. Patients treated with IA had increased lateral weight bearing and lower overall satisfaction than did patients who underwent cheilectomy.  

Kennedy et al modified the technique to incorporate removal of 10% of the phalangeal base, thereby maintaining the insertion of the FHB tendon. One of 21 feet developed metatarsalgia, and 89% of patients had little or no pain.  

Can Akgun et al presented 11 patients with grade 3 or 4 hallux rigidus, using an oblique phalangeal osteotomy that also retained the plantar insertions. At an average 2.3-year follow-up, no patient had cock-up deformity, all had good hallux pushoff strength, and 91% had little to no pain. Using the same technique, Mackey et al found a significantly higher AOFAS score following IA than following arthrodesis (89.6 and 64.5, respectively; P = 0.006) at 5.3 year follow-up. The results suggest that correct soft-tissue tensioning and hallux stability are important for positive outcomes and good hallux push-off strength.  

Coughlin and Shurnas introduced a technique that maintains the plantar attachments and makes use of a free tendon bundle as a biologic spacer. At an average 3.5-year follow-up, mild metatarsalgia was reported in four of seven patients. Although function improved and pain decreased, the joint biomechanics were not restored, and the authors recommended arthrodesis as a better option.  

References:

26

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Berlet et al retrospectively assessed nine patients with grade 3 hallux rigidus who underwent oblique ostectomy that preserved the plantar plate and in whom a human regenerative tissue matrix was used as the spacer. No failures, instability, loss of push-off strength, or metatarsalgia was reported at a mean 1.1-year follow-up. Pain level was reported as 34.4 on the AOFAS scale, where zero is the highest level of pain and 40 is the lowest level of pain. Positive outcomes were believed to be the result of early mobilization, resurfacing of the sesamoid articulation, and refraining from significantly shortening the metatarsal. Leaving the FHB tendon intact seems to result in a reduced incidence of metatarsalgia and hallux cock-up, although the mean pain levels are similar to those in patients who undergo FHB release. 38

**Implant arthroplasty:**

**Silastic:**

Short term studies of silastic implant arthroplasty reported success with a mean follow up 5.8 years but long term studies reported many complications includes osteolysis, subluxation, component fractures and immune reactions to the silastic implants. 39

**Total joint arthroplasty:**

Ess et al reported in a prospective study with 10 patients using three component implant which is non-constrained titanium-polyethylene prosthesis 60% satisfactory outcome and the total range of motion increased by 40 degrees in a mean follow up 2 years but this study did not
recommend further use of the total joint implant in active patients in order to avoid osteolysis, subluxation and malalignment. **Figure (1-10).**

Other study show good to excellent outcome using a non-constrained two prosthesis with dorsiflexion increased from a mean of 2 degrees preoperatively to a mean of 25 degrees postoperatively but the revision rate was 5.5 % and the prosthesis subsidence was 33% in a mean follow up 3.9 years. **41**

Good to excellent results were achieved only in 40.6 % of patient treated with total arthroplasty using ceramic-on-ceramic press fit implants that is coated with bone ingrowth material. This study include 29 patients with a mean follow up 2.8 years and 50 % of patients had less than 30 degree of total range of motion at the final follow up. **42**

![Figure (1-10): A-P radiograph show total joint replacement of hallux metatarsophalangeal joint with osteolysis and subcidence.](image)

**Figure (1-10): A-P radiograph show total joint replacement of hallux metatarsophalangeal joint with osteolysis and subcidence.** **19**

In a randomized control study, 39 feet were treated by non-constrained cobalt-chrome metatarsal component coated by titanium plasma spry and a solid titanium phalangeal component and compared with
38 feet treated by arthrodesis. Significant lower functional satisfaction and significant higher VAS pain score were observed in the arthroplasty group.

**Hemiarthroplasty:**

**Hemiarthroplasty of the proximal phalanx:**

At a mean follow up 2.8 % years, Taranow et al reported that 82.1 % of 23 patients treated by hemiarthroplasty of the proximal phalanx had complete satisfaction. 44

Other studies demonstrated that the life style of the patient is directly related to implant subsidence which was high in patient treated with Hemiarthroplasty of the proximal phalanx. 45

In comparison with arthrodesis, patients treated with hemiarthroplasty of the proximal phalanx had significant better AOFAS scores, VAS scores and patient satisfaction but, all patients showed some degree of implant subsidence and 24 % of total 20 patients need revision in a mean follow up 6.6 years. 5

**Hemiarthroplasty of the metatarsal head :**

Hasselman and Shields assessed 25 patients treated with hemiarthroplasty of the metatarsal head with a mean follow up 1.7 years and found that the mean AOFAS score was 82.1 and the mean total range of motion was 65 degrees postoperatively from 23 degrees preoperatively. Patient satisfaction was 100 %with no failure was noted. *Figure (1-11).* 46
**Figure (1-11):** A-P foot radiograph showing hemiarthroplasty of the first metatarsal head. 19

**Periarticular osteotomies:**

Periarticular osteotomies which are performed through the phalanx or the first metatarsal aim to preserve the joint and relieve pain through joint decompression. These osteotomies were primarily used to correct structural problems such as metatarsus primus elevates or long first metatarsal. 31

Many types of osteotomies were utilized as Green-Watermann osteotomy in which a dorsal wedge of the first metatarsal is removed to shorten the metatarsal head. **Figure (1-12).** 47
Weil type osteotomy includes linear osteotomy that begins distally and dorsally and is directed proximally and plantarly to shorten the metatarsal head and displace it plantarly. The mean AOFAS score was 82 and 95% of patient had good to excellent outcomes with the mean dorsiflexion increased from 8 degrees to 44 degrees in a mean follow up 11.1 years.

Kilmartin compared the metatarsal osteotomy and phalangeal osteotomy, group 1 with phalangeal osteotomy (49 patients) and group 2 with metatarsal osteotomy (59 patients). In group 1, 65% of patients reported complete satisfaction at a mean follow up 2.4 years but in group 2, 54% of patients reported complete satisfaction at a mean follow up 1.3 years. Metatarsalgia was reported in 8% of patients in group 1 and in 31% of patients in group 2. Dorsiflexion decreased in group 1. Metatarsal osteotomy may hasten the progress of interphalangeal arthritis.
Patients and Methods

Patients:

In the period between December 2014 and June 2016, a prospective study was conducted involving twenty patients to underwent modified oblique Keller capsular interpositional arthroplasty for hallux rigidus.

Inclusion criteria of the study included patients with hallux rigidus grade 3 and 4 on Coughlin and Shurans classification after failure of conservative treatment for 6 weeks. All patient described themselves as independent, active and were seeking treatment to maintain their quality of life.

Exclusion criteria include Patients with systemic inflammatory diseases (rheumatoid arthritis, systemic lupus erythematosus) were excluded together with patients who refused to join the study after explaining risks and benefits.

General contraindications include factors that would preclude one from undergoing any foot procedure. This includes poor vascular supply, open ulceration or wound, and medical co-morbidities that preclude a patient from undergoing elective surgery. As it pertains specifically to the hallux MTP joint, the MOKCIA should be avoided in patients with significant deformity at the MTP joint because of difficulty predicting correction of alignment and maintenance of that correction. Additionally, patients with atrophic tissues as a result of multiple steroid injections or scarred tissues as a result of previous surgeries are not good candidates for this procedure as the capsule will not function well as an interposition material and may not adequately advance distally to cover the metatarsal articular surface. Furthermore, patients who have symptomatic metatarso-sesamoid arthritis should be counseled that the procedure may not resolve
all of their pain as the MOKCIA does not allow for resurfacing of the metatarso-sesamoid articulation.

There were no selection limitations for age and sex. All patients had signed informed consent, and the study protocol was accepted by the staff members of orthopedic department, Benha university.

All patients were operated upon in Benha university hospital. The follow up of the cases ranged from 12 months to 24 months with a mean of 18 months.

**Age distribution:**

The youngest patient was 49 years old while the oldest was 70 years old with the mean age of patients was 59.25±6.06 years. Table (2-1)

Table (2-1): age distribution:

<table>
<thead>
<tr>
<th>Age group</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 – 50</td>
<td>3</td>
<td>15%</td>
</tr>
<tr>
<td>51 – 60</td>
<td>9</td>
<td>45%</td>
</tr>
<tr>
<td>61 – 70</td>
<td>8</td>
<td>40%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>20</strong></td>
<td><strong>100%</strong></td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>49 - 70</td>
<td></td>
</tr>
<tr>
<td><strong>Mean ± SD</strong></td>
<td>59.25±6.06</td>
<td></td>
</tr>
</tbody>
</table>

**Gender distribution:**

There were 4 males (20 %), and 16 females (80 %) in this study. Table (2-2), figure (2-1)
Table (2-2): gender distribution:

<table>
<thead>
<tr>
<th>Sex</th>
<th>Number of patients</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>male</td>
<td>4</td>
<td>20%</td>
</tr>
<tr>
<td>female</td>
<td>16</td>
<td>80%</td>
</tr>
</tbody>
</table>

Figure (2-1): gender distribution.

**Side of affection:**

In this study, 12 of the affected feet were left (60%), and 8 feet were right (40%). **Table (2-3), figure (2-2)**

Table (2-3): side of affection:

<table>
<thead>
<tr>
<th>Side</th>
<th>Number of patients</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right</td>
<td>8</td>
<td>40%</td>
</tr>
<tr>
<td>Left</td>
<td>12</td>
<td>60%</td>
</tr>
</tbody>
</table>
History of previous trauma:

Of the twenty patients in this study, only two patients had positive history of trauma.

Previous treatment received:

All of the patients received conservative treatment in the form of non-steroidal anti-inflammatory drugs. shoe modification in the form of shoes with wide toe box which can take pressure off prominent osteophytes. Activity modification was advised for all patients before the decision of surgery.

Duration of symptoms:

The duration of symptoms before proceeding to surgery ranged from 8 months to 3 years. The mean duration of symptoms ± SD was $18.9 \pm 7.81$. 

Figure (2-2): side of affection.
**Methods:**

**The preoperative clinical evaluation:**

The preoperative clinical evaluation includes assessment of pain score, range of motion and final assessment using scoring systems.

**Pain:**

Pain by means of visual Analogue Pain Scale (VAS) : **Figure (2-3)**

Patient is asked to evaluate his pain by using a scale or horizontal line. VAS can be used as 10 cm graphic rating scale from zero to 100 mm, or to use a simple descriptive pain intensity scale which consist of 5 grades, each grade equal 2 points. Another easier way is to use 0 – 10 numeric pain intensity scale with zero means no pain at all and 10 means the worst possible pain.

The preoperative mean visual analogue of pain score was 5.65±1.09 point. Two patients have scale 8 points, one patient has scale 7 points, seven patients have scale 6 points, eight patients have scale 5 points and two patients have scale 4 points.
Figure (2-3): visual analogue of pain score (VAS).
Range of motion:

Pre-operative range of motion were measured using goniometer. This includes active range of motion of the first metatarsophalangeal joint. Figure (2-4)

Figure (2-4): measurement of range of motion of the first MTP joint by goniometer.

The mean preoperative doriflexion range of motion was 10.85±3.25, which ranges from 6 degrees to 17 degrees.

The mean preoperative planter flexion range of motion was 34.05±5.09, which ranges from 29 degrees to 42 degrees.
**Scoring system:**

**Modified American Orthopedic Foot and Ankle Society score (AOFAS score):**

Modified American Orthopedic Foot and Ankle Society score (AOFAS score) which allows 40 possible points for pain, 40 possible points for function, and 20 possible points for alignment and cosmeses. The total maximum score possible is 100 points. **Table (2-4)**

The preoperative mean AOFAS score was 57.85±9.24 points. The preoperative score ranges from 43 points to 72 points, with one patient having 72 points, five patients having 67 points, one patient having 62 points, eight patients having 60 points, two patients having 52 points, one patient having 47, one patient having 44 points, one patient having 43 points.
Table (2-4): AOFAS score.

<table>
<thead>
<tr>
<th>Item</th>
<th>Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain (40 points)</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>40</td>
</tr>
<tr>
<td>Mild, occasional</td>
<td>30</td>
</tr>
<tr>
<td>Moderate, daily</td>
<td>20</td>
</tr>
<tr>
<td>Severe, almost always present</td>
<td>0</td>
</tr>
<tr>
<td>Function (45 points)</td>
<td></td>
</tr>
<tr>
<td>Activity limitations</td>
<td></td>
</tr>
<tr>
<td>No limitations</td>
<td>10</td>
</tr>
<tr>
<td>No limitation of daily activities, limitation of recreational activities</td>
<td>7</td>
</tr>
<tr>
<td>Limited daily and recreational activities</td>
<td>4</td>
</tr>
<tr>
<td>Severe limitation of daily and recreational activities</td>
<td>0</td>
</tr>
<tr>
<td>Footwear requirements</td>
<td></td>
</tr>
<tr>
<td>Fashionable, conventional shoes with no insert</td>
<td>10</td>
</tr>
<tr>
<td>Comfort footwear, shoe insert</td>
<td>5</td>
</tr>
<tr>
<td>Modified shoe or brace</td>
<td>0</td>
</tr>
<tr>
<td>MTP joint motion (dorsiflexion plus planterflexion)</td>
<td></td>
</tr>
<tr>
<td>Normal or mild restriction (75° or more)</td>
<td>10</td>
</tr>
<tr>
<td>Moderate restriction (30-74°)</td>
<td>5</td>
</tr>
<tr>
<td>Severe restriction (less than 30°)</td>
<td>0</td>
</tr>
<tr>
<td>IP joint motion (planterflexion)</td>
<td></td>
</tr>
<tr>
<td>No restriction</td>
<td>5</td>
</tr>
<tr>
<td>Severe restriction (less than 10°)</td>
<td>0</td>
</tr>
<tr>
<td>MTP-IP stability (all directions)</td>
<td></td>
</tr>
<tr>
<td>Stable</td>
<td>5</td>
</tr>
<tr>
<td>Definitely unstable or able to dislocate</td>
<td>0</td>
</tr>
<tr>
<td>Callus related to lesser MTP-IP</td>
<td></td>
</tr>
<tr>
<td>No callus or asymptomatic callus</td>
<td>5</td>
</tr>
<tr>
<td>Callus, symptomatic</td>
<td>0</td>
</tr>
<tr>
<td>Alignment (15 points)</td>
<td></td>
</tr>
<tr>
<td>Good, lesser toes well aligned</td>
<td>15</td>
</tr>
<tr>
<td>Fair, some degree of lesser toe malalignment observed, no symptoms</td>
<td>8</td>
</tr>
<tr>
<td>Poor, severe malalignment, symptoms</td>
<td>0</td>
</tr>
</tbody>
</table>
**Preoperative radiographic evaluation:**

Weight bearing antero-posterior, lateral and oblique views was done. All patients have grade 3 and 4 hallux rigidus on Coughlin and Shurans classification. Only two patients had grade 4 with pain at mid-range of motion, but the rest of the twenty patients had grade 3.
Operative technique

Anesthesia:

Regional anesthesia was used in the form of spinal anesthesia for all of the patients in this study. Tourniquet was used in all patients.

Positioning of the patient:

All patients were operated upon in supine position.

Operative procedure:

A dorsal medial longitudinal incision extends from the metaphysio-diaphyseal junction of the first metatarsal to the middle of proximal phalanx diaphysis. Figure (2-5)

Fig (2-5): dorsomedial incision.
Blunt dissection were used to reflect the subcutaneous fascia from the deep fascia with the dorsal-medial cutaneous nerve of the great toe is retracted laterally with protection of the integrity of extensor hood tissues. Figure (2-6)

![Figure (2-6): the dorso-medial cutaneous nerve of the great toe.](image)

A deep fascia incision was made along the same plane to the level of the bone. Periosteal elevator was used to reflect the periosteum and capsule tissues around the first tarso-metatarsal joint. A curved bone lever was then used to release any first metatarsal - sesamoidal adhesions.

![Figure (2-7): exposure of first MTP joint.](image)
Figure (2-8): arthritic changes in the first MTP joint.

With use of a saw, the dorsal one third of the metatarsal head was removed with any associated osteophytes. The dorsal capsule and the extensor hallucis brevis were detached from their attachments along the dorsal ridge of the base of proximal phalanx. Figures (2-9), (2-11)

Figure (2-9): removal of the dorsal one third of the first metatarsal head.
Osteotomy was done by an oscillating saw in the proximal phalanx to remove a wedge-shaped portion of its base. The base of the wedge was at the dorsal aspect in order to preserve the planter aspect for the insertion of short flexors on the planter aspect of the base of the proximal phalanx of the big toe. **Figures (2-10) and (2-11)**

![Figure (2-10): Oblique osteotomy of the proximal phalanx.](image1)

![Figure (2-11): Drawing of proximal phalanx and first metatarsal with resected bone fragments overlaid to demonstrate total bone resection.](image2)
Now, we can evaluate the range of motion intra-operatively by movement of proximal phalanx over the first metatarsal to ensure at least 80 degree of dorsiflexion. **Figure (2-12)**

**Figure (2-12): evaluation of improvement of passive dorsiflexion of the first MTP joint intra-operatively after osteotomies.**

The dorsal capsule was advanced over the metatarsal head and manual distraction of the joint was used to suture the capsule into the planter plate with the use of a small curved needle to place interrupted intracapsular absorbed sutures. **Figure (2-13) and (2-14)**

**Figure (2-13): the joint capsule covers the first metatarsal head**
Figure (2-14): suturing of the joint capsule into the planter plate and suturing of the medial capsule.

Layered closure was done for the subcutaneous fascia and skin. The wound was dressed with compression bandage. Figure (2-15) and (2-16)

Figure (2-15): skin closure.
Technical Pearls includes using dorsal-medial incision for best exposure of the joint and mobilization of joint capsule. Be meticulous in elevating the joint capsule and extensor hallucis brevis attachment from the proximal phalanx so as to maintain length and quality of this tissue for interposition. Resects bone from the proximal phalanx at an oblique angle so the plantar plate attachment to the proximal phalanx is not disrupted. Place sutures for the interposition of tissue from lateral to medial. Ensure adequate range of motion and posture of the toe before leaving the operating room.

Technical Pitfalls includes avoiding injury to the dorsal-medial cutaneous nerve. Avoid excessive bone resection, as this may lead to detachment of the plantar plate from the proximal phalanx or instability at the hallux MTP joint. Avoid the procedure in patients with significant deformity at the hallux MTP joint. Avoid injury to the FHL tendon when interposing the capsular tissue. Particularly, avoid “harpooning” the FHL when passing sutures through the plantar plate in preparation of capsular interposition. Begin passive and active range of motion as early as possible after surgery to avoid arthrofibrosis of the hallux MTP joint.
**Postoperative care:**

A stiff sold shoe was used for protected ambulation in the early postoperative 3 weeks. Each patient was advised to perform first metatarsophalangeal range of motion exercises daily for the postoperative 3 months.

Sutures were removed after two weeks from surgery.

**Postoperative evaluation:**

Post operative results were evaluated by:

**Pain:**

Pain was evaluated by VAS scale 6 weeks and 12 months postoperatively.

**Range of motion:**

Post-operative range of motion were measured using goniometer. This includes active range of motion of the first MTP joint. Range of motion was measured 6 weeks and 12 months postoperatively for both active doriflexion and active planter flexion.

**Scoring systems:**

Postoperative assessment by Scoring systems using AOFAS score.

**Radiographic evaluation:**

All patients returned for antero-posrerior, oblique and lateral radiographs.
Results

Assessment of the results:

All of the twenty patients included in this study had a follow up ranging from 12 to 18 months. The results of VAS score and range of motion were recorded for comparison at three stages, preoperative, at 6 weeks and finally at 12 months.

The results of AOFAS score were recorded for comparison at two stages, preoperative and 12 months postoperative.

Data management:

The clinical data were recorded on a report form. These data were tabulated and analyzed using the computer program SPSS (Statistical package for social science) version 20 to obtain:

Descriptive data

Descriptive statistics were calculated for the data in the form of:

1. Mean and standard deviation (\( \pm SD \)) for quantitative data.

2. Frequency and distribution for qualitative data.

Analytical statistics

In the statistical comparison between the different groups, the significance of difference was tested using paired t test and willcoxon test which used to compare mean of variables in different time periods of quantitative data of parametric and non-parametric respectively.

A \( P \) value <0.05 was considered statistically significant (*) while >0.05 statistically insignificant \( P \) value <0.01 was considered highly significant (**) in all analyses.
Visual Analogue Pain Score (VAS): Table (3-1), Figure (3-1)

The preoperative mean visual Analogue Pain Score was $5.65 \pm 1.09$ point. Two patients have scale 8 points, one patient has scale 7 points, seven patients have scale 6 points, eight patients have scale 5 points and two patients have scale 4 points.

**At 6 weeks postoperative:**

Visual Analogue Pain Score (VAS) was improved 6 weeks postoperative, the mean postoperative VAS at six weeks was $1.5 \pm 1.1$ ranging from zero to three with P value 0.001 which is highly significant. Four patients had score 3, seven patients had score 2, four patients had score 1 and five patients had score 0.

**At 12 months postoperative:**

Visual Analogue Pain Score (VAS) was improved 12 months postoperative, the mean postoperative VAS at 12 months was $0.35 \pm 0.67$ ranging from zero to three with P value 0.001 which is highly significant. Two patients had score 2, three patients had score 1, and 15 patients had score 0.
Table (3-1): VAS differences between pre-operative and post-operative follow up periods:

<table>
<thead>
<tr>
<th>VAS</th>
<th>Mean ±SD</th>
<th>Wilcoxon test</th>
<th>P1</th>
<th>Wilcoxon test</th>
<th>P2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative</td>
<td>5.65±1.09</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 weeks postoperative</td>
<td>1.5±1.1</td>
<td>3.95</td>
<td>0.001**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 months postoperative</td>
<td>0.35±0.67</td>
<td>3.97</td>
<td>0.001**</td>
<td>2.93</td>
<td>0.003**</td>
</tr>
</tbody>
</table>

Figure (3-1): VAS differences between pre-operative and post-operative follow up periods.
**Range of motion:** Table (3-2)

**Active dorsiflexion range of motion:** Figure (3-2)

The mean preoperative active dorsiflexion range of motion was 10.85±3.25, which ranges from 6 degrees to 17 degrees.

**At 6 weeks postoperative:**

The mean postoperative active dorsiflexion range of motion at six weeks was 22.85±4.96, which ranges from 13 degrees to 30 degrees with P value 0.001 which is highly significant.

**At 12 months postoperative:**

The mean postoperative active dorsiflexion range of motion at 12 months was 27.9±5.05, which ranges from 16 degrees to 35 degrees with P value 0.001 which is highly significant.

**Active planter flexion range of motion:** Figure (3-3)

The mean preoperative planter flexion range of motion was 34.05±5.09, which ranges from 29 degrees to 42 degrees.

**At 6 weeks postoperative:**

The mean postoperative active planter flexion range of motion at six weeks was 32.7±3.16, which ranges from 28 degrees to 40 degrees with P value 0.069 which is insignificant.

**At 12 months postoperative:**

The mean postoperative active planter flexion range of motion at 12 months was 33.9±2.97, which ranges from 30 degrees to 41 degrees with P value 0.86 which is insignificant.
Table (3-2): Degree of motion differences between pre-operative and post-operative follow up periods:

<table>
<thead>
<tr>
<th>Degree of motion</th>
<th>Preoperative</th>
<th>Mean ±SD</th>
<th>t1 test</th>
<th>t2 test</th>
<th>P1</th>
<th>P2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Dorsi-flexion</td>
<td>Preoperative</td>
<td>10.85±3.25</td>
<td>6 weeks postoperative</td>
<td>22.85±4.96</td>
<td>16.22</td>
<td>0.001**</td>
</tr>
<tr>
<td>12 months postoperative</td>
<td>27.9±5.05</td>
<td>19.69</td>
<td>0.001**</td>
<td>10.44</td>
<td>0.001**</td>
<td></td>
</tr>
<tr>
<td>Active Planter-flexion</td>
<td>Preoperative</td>
<td>34.05±5.09</td>
<td>6 weeks postoperative</td>
<td>32.7±3.16</td>
<td>1.93</td>
<td>0.069</td>
</tr>
<tr>
<td>12 months postoperative</td>
<td>33.9±2.97</td>
<td>0.18</td>
<td>0.86</td>
<td>3.09</td>
<td>0.006**</td>
<td></td>
</tr>
</tbody>
</table>

Figure (3-2): Degree of active dorsiflexion range of motion differences between pre-operative and post-operative follow up periods.
Figure (3-3): Degree of active planter flexion range of motion differences between pre-operative and post-operative follow up periods.
**AOFAS score:** Table (3-3), Figure (3-4)

The preoperative mean AOFAS score was 57.85±9.24 points. The preoperative score ranges from 43 points to 72 points, with one patient has 72 points, five patients have 67 points, one patient has 62 points, eight patients have 60 points, two patients have 52 points, one patient has 47, one patient has 44 points, and one patient has 43 points.

The postoperative AOFAS score was improved with the mean was 89.2±4.8, which ranged from 78 points to 95 points which is highly significant.

**Table (3-3): AOFAS differences between pre-operative and post-operative follow up:**

<table>
<thead>
<tr>
<th>AOFAS</th>
<th>Mean ±SD</th>
<th>Paired t test</th>
<th>P1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative</td>
<td>57.85±9.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12m postoperative</td>
<td>89.2±4.8</td>
<td>14.78</td>
<td>0.001**</td>
</tr>
</tbody>
</table>

**Figure (3-4): AOFAS differences between pre-operative and post-operative follow up periods.**
**Complications: figure (3-5)**

The complication rate in this study were few. It was 15% and considered as minor complications, regarding that satisfaction achieved in all patients.

Superficial skin infection occurred in two patients, which was improved with daily dressing and parenteral antibiotic for 3 days.

Neuropraxia of the dorsal-medial cutaneous nerve of the great toe occurred in one patient, it was mostly due to improper placement of retractors. The patient complained from burning pain which was improved after 8 weeks with neurotonic medications.

The possible other complications as metatarsalgia, postoperative stiffness, EHL injury and FHL injury were not reported in this study.

![complications](image)

**Figure (3-5): postoperative complications.**
Case 1 (patient ID: 3)

Female patient 59 years old, house wife, condition started 18 months ago by pain at the great toe of the which is progressive in nature. patient sought medical advice at Benha university hospital. Radiographs was done and the patient was diagnosed as hallux rigidus grade 3 at Coughlin and Shurans classification. The patient received treatment in the form of non steroidal anti-inflammatory drugs for 6 weeks and advised to modify her activities.

6 weeks later, pain is still present and even progressive. The patient is prepared for surgical treatment for hallux rigidus in the form of modified oblique Keller capsular interposition arthroplasty. the preoperative visual analogue of pain score was 6, the preoperative dorsiflexion of the first MTP joint was 12 degrees and the planter flexion was 37 degrees, and the preoperative AOFAS score was 52.

Figure (4-1): preoperative A-P and oblique radiographs of case 1 (patient ID: 3) showing grade 3 hallux rigidus.
Figure (4-2): preoperative photo showing the preoperative passive dosiflextion.

Figure (4-3): A-P and lateral radiographs of the foot immediately post operative.
Final evaluation:

Patient is evaluated finally after one year, the visual analogue of pain score was zero. The final postoperative doriflexion range of motion was 28 degrees and the planter flexion was 35 degrees. The final AOFAS score was 88.

Complications:

There were no complications apart from wound infection which appeared 8 days after surgery. It was superficial and treated by daily dressing and antibiotics.
Case 2 (patient ID: 8)

Male patient 59 years old, banker, the condition started 9 months ago by pain in the base of great toe of the right foot. Pain occurred during activities and climbing stairs. Pain was associated with a small swelling at the base of the great toe. The patient sought medical advice in a private clinics and treated as gouty arthritis. The patient sought medical advice at Benha university hospital and was diagnosed as hallux rigidus grade 3. The patient was prepared for surgery after failure of conservative treatment for 6 weeks. The preoperative visual analogue of pain score was 7. The preoperative active dorsiflexion range of motion was 7 degrees and the active planter flexion was 33 degrees. The preoperative AOFAS score was 43.

Figure (4-5): preoperative plain radiographs of the foot of case 2 (patient ID: 8) showing hallux rigidus grade 3.
Figure (4-6): preoperative photo of the foot showing limited passive dorsiflexion range of motion of first MTP joint.

Figure (4-7): immediate postoperative photo of the foot showing improved passive dorsiflexion range of motion of first MTP joint.

**Final evaluation:**

The postoperative visual analogue of pain score at one year follow up was 1. The final postoperative active dorsiflexion range of motion was 23 degrees and the active planter flexion was 33 degrees. The final AOFAS score was 85.

**Complications:**

The patient suffered from burning sensation at the medial border of the great toe which improved at 2 months follow up and addressed as neuropraxia from traction injury of the dorsal cutaneous nerve of the great toe.
Case 3 (patient ID: 18)

Female patient 58 years old, teacher, the condition started 18 months ago by pain in the base of great toe of the right foot. Pain was progressive and was increased during walking. The patient sought medical advice at Benha university hospital and was diagnosed as hallux rigidus grade 3. The patient was prepared for surgery after failure of conservative treatment for 6 weeks. The preoperative visual analogue of pain score was 5. The preoperative active dorsiflexion range of motion was 8 degrees and the active planter flexion was 28 degrees. The preoperative AOFAS score was 67.

Figure (4-8): A-P and oblique radiographs of the foot of case 3 (patient ID: 18) showing hallux rigidus grade 3.
Figure (4-9): standing lateral radiographs of right and left feet of case 3 (patient ID: 18) showing the difference between dorsiflexion of first MTP joint which is limited in the affected right side.

Figure (4-10): photos of the right and the left feet of case 3 (patient ID: 18) showing the difference between dorsiflexion of first MTP joint which is limited in the affected right side.

Figure (4-11): immediate postoperative photo of the foot of case 3 (patient ID: 18) showing improved dorsiflexion of the first MTP joint.
Figure (4-12): lateral radiograph of the foot of case 3 (patient ID:18) after surgery.

Final evaluation:

The postoperative visual analogue of pain score at one year follow up was zero. The final postoperative active dorsiflexion range of motion was 28 degrees and the active planter flexion was 31 degrees. The final AOFAS score was 95.

Complications:

No complications were reported in this patient.
Discussion

Hallux rigidus is the most frequent first ray disease after hallux valgus. Although conservative treatment may be effective, surgical treatment is often indicated. Cheilectomy results in good outcomes during initial phases of the disease, but the procedure has a higher rate of unsatisfactory results when used for more advanced stages. 19

Keller’s resection arthroplasty may be indicated for elderly patients with low physical demand, but the first-ray shortening and the high incidence of secondary metatarsalgia preclude its large-scale use. 32

Hallux MTP joint arthrodesis is still the gold standard for the treatment of advanced hallux rigidus. The procedure only addresses one of dysfunctional problems, which is the pain, with further loss of motion restricting shoe choice, particularly in females. Arthrodesis is a technically demanding procedure, with little tolerance for sagittal plane angular deviations, and may take from 60 to 90 days to achieve bone healing. In the long term, the procedure may overload the hallux interphalangeal joint, leading to arthrosis. 19

Besides being a technically very difficult and costly procedure, MTP joint partial or total replacement has a limited lifespan and potentially serious complications, as is true of all implant arthroplasties. 42

Interpositional arthroplasty has the advantage of approaching both key problems of hallux rigidus, namely loss of joint motion and pain, avoiding the need of non biological implants. Interpositional arthroplasties with autograft may be divided into capsular and bundle-techniques.
The MOKCIA procedure is indicated in middle-aged and older patients who have stage 3 and 4 first MTP arthritis on Coughlins and Shurans classification, minimal deformity, and a desire to maintain hallux MTP motion.

This study show significant improvement in VAS score 6 weeks after surgery and further significant improvement after 12 months follow up. The active dorsiflexion range of motion had significant improvement after the first 6 weeks together with further significant improvement after 12 months. Active planter flexion is decreased after the first 6 weeks of surgery but significant improvement occurred after 12 months follow up which had not reach the preoperative values. Significant improvement has been occurred in AOFAS score 12 months after surgery.

Results from this study may be favorably compared with other studies of interpositional arthroplasties. Hamilton et al. in 1997 reported on dorsal capsule and extensor hallucis brevis tendon interposition in 30 patients (37 feet) with a mean age of 56.2 years, and found that 93% (28/30) of the patients reported satisfaction with the procedure. 49

Lau and Daniels in 2001 published a study comparing interpositional arthroplasty performed in 11 patients with Grade III hallux rigidus and cheilectomy in 19 patients with Grade II hallux ridigus. Postoperative AOFAS scores after 2 years of follow up were higher in the cheilectomy group, but the mean age was lower, and the disease was less advanced as compared to the arthroplasty group, and the mean VAS was 3.9 out of 10. Lateral metatarsalgia was seen in three of 11 patients submitted to interpositional arthroplasty (27.3%), and the sensation of loss of strength of the hallux was the main complaint in this group of patients (8/11, 72.7%).
Kennedy et al in 2006 modified the technique to incorporate removal of 10% of the phalangeal base, there by maintaining the insertion of the FHB tendon. One of 21 feet developed metatarsalgia, and 89% of patients had little or no pain. 50

Schenk et al in 2007 found no significant difference in pain or range of motion between interposition arthroplasty and the Keller procedure in patients with Hattrup and Johnson grades II and III hallux rigidus. 35

Clews et al study in 2015 show that dorsiflexion range of motion can be increased significantly from the preoperative state using the autogenous capsular interpositional arthroplasty technique for primarily grade 2 and 3 types of hallux rigidus, classified using the system by Coughlin and Shurnas and demonstrated that the procedure is associated with a significant reduction in foot pain. 19

Thordarson and colleagues presented the result of interpositional arthroplasty using the medial capsule in 22 patients, with a mean age of 58 years and showed increased AOFAS postoperative scores, reporting as a complication only two cases of a stress fracture of a lesser metatarsal, after a mean follow up of 24 months. 51

In bundle soft-tissue interpositional arthroplasty, tendon structures such as the plantaris or gracilis are employed as spacers to fill a cavity that is created at the base from the proximal phalanx. Coughlin and Shurnas described a series of seven cases of gracilis tendon interposition
arthroplasty with 42 months of follow up. The AOFAS score improved from 46 preoperatively to 86 postoperatively. Lateral metatarsalgia was the most common complication, and was observed in more than half of the patients. 37

Berlet and colleagues published a retrospective study of nine patients who had an interpositional arthroplasty with allograft (regenerative tissue matrix, consisting of collagen and extracellular protein matrices created from human cadaver tissue), with 12 months of follow up. They reported AOFAS score improvement from 63.9 preoperatively to 87.9 postoperatively. They did not observe any complications at the short follow up of this series with a small number of patients. 38

The postoperative AOFAS score of 89.2 achieved in this study is better than the best possible outcomes with MTP joint arthrodesis, as 10 points are lost due to the loss of joint motion.

Mackey and colleagues in 2010 compared a cohort of ten patients that underwent a modified Keller’s arthroplasty with a group of twelve patients who had a first metatarsophalangeal joint arthrodesis at an average follow up of 63 and 68 months, respectively. The AOFAS score was significantly higher for the arthroplasty group than the arthrodesis group, and the plantar pressure data revealed significantly higher pressures under the great toe in the arthrodesis group. They concluded that interposition arthroplasty produced clinical outcomes that were equivalent to arthrodesis, having the added benefit of motion preservation and more normal plantar pressure during gait. 52
Mroczek and Miller presented the results of interposition arthroplasty with dorsal capsule combined with a modified oblique Keller arthroplasty with excellent results, and concluded that the procedure was a reasonable alternative for arthrodesis in cases of more advanced arthrosis. 54

The results of this study also compare favorably to studies with implant arthroplasty. Konkel and colleagues achieved AOFAS scores of 89 after 72 months of follow up with a Futura hemi-great toe implant in patients with hallux rigidus of Grades III and IV. Arbuthnot and colleagues had an AOFAS score of 84 after 24 months of follow up with a ceramic-coated endoprosthesis. 45

Table (5-1): comparison of AOFAS score outcome between the present study and 3 published capsular interpositional arthroplasty studies:

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Year</th>
<th>Number of patients</th>
<th>Follow up in months</th>
<th>Preoperative AOFAS score</th>
<th>Postoperative AOFAS score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present study</td>
<td>-</td>
<td>20-20</td>
<td>18</td>
<td>57.85</td>
<td>89.2</td>
</tr>
<tr>
<td>Schenk et al</td>
<td>2007</td>
<td>14-22</td>
<td>15.1</td>
<td>37.5</td>
<td>90</td>
</tr>
<tr>
<td>Lau and Danials</td>
<td>2001</td>
<td>11-11</td>
<td>25.2</td>
<td>-</td>
<td>56.8</td>
</tr>
<tr>
<td>Hamilton</td>
<td>1997</td>
<td>34-41</td>
<td>120</td>
<td>58</td>
<td>83.1</td>
</tr>
</tbody>
</table>
Table (5-2): comparison of range of motion outcome between the present study and 6 published capsular interpositional arthroplasty studies:

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Year</th>
<th>Number of patients</th>
<th>Follow up in months</th>
<th>ROM measurement</th>
<th>Preoperative dorsiflexion</th>
<th>Postoperative dorsiflexion</th>
<th>Preoperative planter flexion</th>
<th>Post operative</th>
<th>Preoperative total ROM</th>
<th>Postoperative total ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present study</td>
<td>2017</td>
<td>20-20</td>
<td>18</td>
<td>goniometer</td>
<td>10.85</td>
<td>27.9</td>
<td>34.05</td>
<td>33.9</td>
<td>38.75</td>
<td>67.95</td>
</tr>
<tr>
<td>Clews et al</td>
<td>2015</td>
<td>34-44</td>
<td>45</td>
<td>goniometer</td>
<td>11.1</td>
<td>26.6</td>
<td>38.8</td>
<td>37.5</td>
<td>49.1</td>
<td>64.1</td>
</tr>
<tr>
<td>Mackey et al</td>
<td>2010</td>
<td>10-10</td>
<td>63</td>
<td>goniometer</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>54</td>
</tr>
<tr>
<td>Schenk et al</td>
<td>2007</td>
<td>14-22</td>
<td>15.1</td>
<td>unreported</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>47.2</td>
<td>66.5</td>
</tr>
<tr>
<td>Kennedy et al</td>
<td>2006</td>
<td>18-21</td>
<td>38</td>
<td>goniometer</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>27</td>
<td>64</td>
</tr>
<tr>
<td>Lau and Danials</td>
<td>2001</td>
<td>11-11</td>
<td>25.2</td>
<td>unreported</td>
<td>5.4</td>
<td>30.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Hamilton</td>
<td>1997</td>
<td>34-41</td>
<td>120</td>
<td>unreported</td>
<td>&lt; 10</td>
<td>50</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</tbody>
</table>
Conclusion

The controversy about the treatment of hallux rigidus exist in the high grades of the disease. Arthrodesis of the first MTP joint which is the main stay treatment of advanced hallux rigidus has its own problems and limitations. Loss of motion and shoe wear limitations is not favored by a lot of patients apart from the delay in return to daily activities which are delayed for 2 or 3 months till complete union of the arthrodesis.

The complications which were addressed with implant arthroplasty of the first MTP joint together with technical difficulties make this treatment modality not popular.

This study shows the results of modified oblique Keller interposition arthroplasty as a treatment modality which avoid implant arthroplasty complications and limitations of arthrodesis. The procedure should be considered as a joint reconstructive procedure, because it preserves the first MTP joint plantar flexion and enhances first MTP joint dorsiflexion without shortening either the proximal phalanx or the first metatarsal.

Finally this study recommends usage of MOKCIA procedure as a treatment modality for advanced hallux rigidus grade 3 and grade 4 on Coughlin and Shurans classification. MOKCIA procedure significantly reduces pain and improve the postoperative range of motion.
Summary

Hallux rigidus is a common arthritic foot disorder. It affects females more than males. The exact cause of hallux rigidus is not known but it is believed to be multifactorial.

Typically, patients complain of pain at the first MTP joint with limitation of its range of motion or shoe wear limitations. Diagnosis done by the clinical findings and radiological assessment. The condition is classified according to the clinical and radiological findings into 4 grades. Grade 1 includes occasional pain and dorsal osteophyte, grade 2 has moderate pain at the extreme dorsiflexion with dorsal and lateral osteophytes, grade 3 has severe pain with dorsal, lateral and medial osteophtes together with subchondral sclerosis and cystic changes, grade 4 includes radiological changes as grade 3 but clinically pain occurs at the mid-range of motion.

Untreated hallux rigidus, it may result in notable limitations in gait, activity level, and daily function. Positive outcomes can be achieved with nonsurgical management in the form of non-steroidal anti-inflammatory drugs, shoe modifications or injections.

Surgery is recommended for the sufficiently symptomatic patient for whom nonsurgical measures are unsuccessful. Surgery is selected based on grade of involvement.

Early to mid-stage hallux rigidus is best managed with cheilectomy or cheilectomy and proximal phalanx osteotomy. Grade 3 and grade 4 hallux rigidus demonstrates inferior results when treated with a cheilectomy procedure. Arthrodesis and arthroplasty are reserved for late-stage hallux rigidus.
Surgical options in patients with advanced hallux rigidus have traditionally included arthrodesis and implant arthroplasty. While arthrodesis offers good clinical outcomes, patients sometimes find it less desirable secondary to prolonged weight bearing restrictions postoperatively and shoe wear limitations once the arthrodesis has healed. Implant arthroplasty has been shown to have a high complication rate and is not recommended by many orthopedic surgeons.

For these reasons, interposition procedures have been advocated. Capsular interpositional arthroplasty is, therefore, more anatomically acceptable and has been shown to be viable for joints that might have previously been thought suitable only for arthrodesis. However, arthrodesis could be of use to salvage a failed capsular interpositional arthroplasty procedure.

This study concentrated on the outcome of modified oblique Keller interposition arthroplasty for the treatment of high grades hallux rigidus involving 20 patients in the period between December 2014 and June 2016 with a mean follow up 18 months.

Preoperative state and postoperative results were evaluated using VAS pain score, active range of motion including dorsiflexion and planter flexion and finally by AOFAS score.

This study show significant improvement in VAS score 6 weeks after surgery and further significant improvement after 12 months follow up. The preoperative VAS score was 5.65 and became 1.5 at 6 weeks postoperative and.35 at final assessment.

The active dorsiflexion range of motion had significant improvement after the first 6 weeks together with further significant improvement after 12 months. It was 10.85 degrees preoperatively and became 22.85 degrees 6 weeks postoperative and 27.9 degrees 12 months postoperative.
Active planter flexion is decreased after the first 6 weeks of surgery but significant improvement occurred after 12 months follow up which had not reach the preoperative values.

Significant improvement has been occurred in AOFAS score 12 months after surgery which became 89.2 postoperative from 57.85 preoperative.

The complication rate was 15% in this study, but these complications considered as minor complications compared to patient satisfaction.
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