# RETROSPECTIVE AND PROSPECTIVE ANALYSIS OF FUNCTIONAL OUTCOME FOLLOWING VARIOUS MODALITIES OF ANKLE FUSION

***Dissertation submitted to***

**THE TAMILNADU DR.M.G.R. MEDICAL UNIVERSITYCHENNAI-TAMILNADU**

***In partial fulfilment of the requirements for***

**M.S. DEGREE**
**BRANCH-II: ORTHOPAEDIC SURGERY**

**MADRAS MEDICAL COLLEGE**
**INSTITUTE OF ORTHOPAEDICS AND TRAUMATOLOGY**
**RAJIV GANDHI GOVERNMENT GENERAL HOSPITAL,**
**CHENNAI-3.**

**APRIL – 2018**

# CERTIFICATE

This is to certify that this dissertation titled **"Retrospective and Prospective Analysis of Functional Outcome Following Various Modalities of Ankle Fusion"** is a bonafide record of work done by **DR.P.S.VIGNESH,** during the period of his Post graduate study from May 2015 to May 2018 under guidance and supervision in the INSTITUTE OF ORTHOPAEDICS AND TRAUMATOLOGY, Madras Medical College and Rajiv Gandhi Government General Hospital, Chennai-600003, in partial fulfilment of the requirement for **M.S.ORTHOPAEDIC SURGERY** degree Examination of The Tamilnadu Dr. M.G.R. Medical University to be held in April 2018.

**Prof.R.Narayana Babu, MD, DCH.,**
Dean,
Rajiv Gandhi Government General Hospital,
Madras Medical College,
Chennai - 600 003.

**Prof.N.Deen Muhammad Ismail**
**M.S.Ortho, D.Ortho.**
Director & Professor,
Institute of Orthopaedics & Traumatology,
Madras Medical College,
Rajiv Gandhi Government General Hospital, Chennai - 600 003.

# DECLARATION

I declare that the dissertation entitled **"RETROSPECTIVE AND PROSPECTIVE ANALYSIS OF FUNCTIONAL OUTCOME FOLLOWING VARIOUS MODALITIES OF ANKLE FUSION"** submitted by me for the degree of M.S.Orthopaedics is the record work carried out by me during the period of **June 2015 to September 2017** under the guidance of **PROF.N.DEEN MUHAMMAD ISMAIL., M.S.Ortho., D.Ortho.,** Director and Professor of Orthopaedics, Institute of Orthopaedics and Traumatology, Madras Medical College, Chennai.

This dissertation is submitted to the Tamilnadu Dr.M.G.R. Medical University, Chennai, in partial fulfillment of the University regulations for the award of degree of M.S.ORTHOPAEDICS (BRANCH-II) examination to be held in April 2018.

**Signature of the Candidate**

Place: Chennai
Date:

**(Dr.P.S.Vignesh)**

Signature of the Guide

**PROF.N.Deen Muhammad Ismail., M.S.Ortho., D.Ortho.,**
Director and Professor,
Institute of Orthopaedics and Traumatology,
Madras Medical College, Chennai.

# ACKNOWLEDGEMENT

I express my thanks and gratitude to our respected Dean **Prof.NARAYANABABU, M.D., DCH.,** Madras Medical College, Chennai – 3 for having given permission for conducting this study and utilize the clinical materials of this hospital.

I have great pleasure in thanking **PROF.N.DEEN MUHAMMAD ISMAIL, M.S.Ortho., D.Ortho.,** Director and Professor, Institute of Orthopaedics and Traumatology, for this valuable advice throughout this study .

I sincerely thank **Prof .M.SUDHEER, M.S.Ortho**., **D.Ortho.** for his advice, guidance and unrelenting support during the study.

My sincere thanks and gratitude to **PROF.R.SELVARAJ, M.S.Ortho., D.Ortho.,** Professor, Institute Of Orthopaedics and Traumatology, for his constant inspiration and advise throughout the study.

My sincere thanks and gratitude to **Prof.V.SINGARAVADIVELU, M.S.Ortho., D.Ortho**., **Ph.D.,** Professor, Institute Of Orthopaedics and Traumatology, for his guidance and constant advice provided throughout this study.

My sincere thanks and gratitude to **Prof.A.PANDIASELVAN, M.S.Ortho., D.Ortho**. Professor, Institute of Orthopaedics and Traumatology, for his valuable advice and support.

I am very much grateful to **Prof.NALLI R.UVARAJ, M.S.Ortho., D.Ortho**, for his unrestricted help and advice throughout the study period.

My sincere thanks and gratitude to my co guide **Dr.A.SARAVANAN, M.S.Ortho., D.ORTHO.,** for his constant advice and guidance provided throughout this study.

I sincerely thank **Dr.S.Senthil Sailesh, Dr.P.Kannan, Dr.Nalli R. Gopinath, Dr.P.Kingsly, Dr.N.Muthalagan, Dr.G.Hemanth Kumar, Dr.P.R.Dhanasekaran, Dr.G.Kaliraj, Dr.D.Suresh Anandhan, Dr.R.RajGanesh, Dr.A.N.SarathBabu, Dr.G.Karthik, Dr.S.Balasubramaniam**, **Dr.J.Pazhani, Dr.K.Muthukumar, Dr.Mohammed Sameer,** Assistant Professors of this department for their valuable suggestions and help during this study.

I thank all anaesthesiologists and staff members of the theatre and wards for their support during this study.

I am grateful to all my post graduate colleagues for helping in this study. Last but not least, my sincere thanks to all our patients, without whom this study would not have been possible.

# CONTENTS

# INTRODUCTION

The Ankle is a hinge type of joint. It consists of distal tibia, distal fibula and talus which articulates with each other[4]. The lateral circumference of the talar dome is larger than the medial circumference. The dome is wider anteriorly than posteriorly. The syndesmotic ligaments allow widening of the joint with dorsiflexion of the ankle, into a stable, close-packed position. In tibiotalar joint there is continuous change in axis of rotation during walking, but fixation in neutral position does not produce any severe biomechanical consequences in the limb. Talus is surrounded by medial malleolus, tibial plafond and lateral malleolus, all of which provide potential bone surfaces for healing of arthrodesis.

Arthrodesis is a term derived from the latin word “arthron” meaning joint and the Greek word “Desis” meaning binding. Ankle Arthrodesis is a surgical procedure wherein the arthritic ankle joint gets converted into an immobile bone segment[1]. This provides a painless, plantigrade stable foot[2]. Wu and his colleagues found that after an ankle fusion, the sagittal plane motion of forefoot and the transverse plane motion of the rearfoot increased[3].

A growing population with ankle arthritis has led to the imperative need for effective ankle reconstruction surgeries. Ankle arthrodesis, which accounts for more than 85% of ankle surgeries , has been reported to be an effective surgery for pain relief and retaining plantigrade foot function.

Ankle arthrodesis fixation techniques includes cross screw,external fixation, intramedullary nailing and plating .The most commonly used construct of ankle arthrodesis fixation is by using 2 or more internal fixation screws.[7]. The end result of ankle arthrodesis should be a well aligned ankle joint with foot at a 90 degree to leg. A well positioned ankle fusion can be very helpful in alleviating pain, correcting the deformity, as well as restoring a functional limb[8].

In extra articular arthrodesis the joint surface is not prepared,so it depends on osteoconduction along a bone graft. It is not usually useful in foot and ankle surgery ,except in paediatric cases. In Intra articular arthrodesis all cartilage is denuded and primary bone healing proceeds between the two opposed cancellous surfaces. Dowel grafting is a technique where only part of joint surface is prepared and union is attempted by osteoconduction along an interposed bone graft[11].

# AIM OF THE STUDY

To study the Functional and Radiological outcome following various modalities of ankle fusion.

# REVIEW OF LITERATURE

Henry Park is said to have performed the first arthrodesis of a tuberculous knee joint with a fixed flexion deformity, in Liverpool in 1781[14]. Ankle arthrodesis was first described by Albert in 1879.Before that for several subsequent decades, cast immobilization was used to maintain the position of the fusion. In some cases arthrodesis yielded surprisingly good results. For instance, Hallock was able to achieve a successful fusion in 30 of 39 patients (77%) undergoing ankle arthrodesis for “severe malunited fractures.”[15]

In 1948, Adams described a transfibular approach via fibular osteotomy. Internal fixation, incorporating the resected fibula as an onlay graft, was obtained with transverse screws. Although the screws did not cross the fusion, Adams described carefully apposing the joint surfaces and reported an impressive 93% fusion rate in 28 of 30 cases. Three years earlier, Anderson described the use of a transmalleolar approach, in which the malleoli were resected. In this series “castless immobilization” was obtained in some cases using an external fixator, but without compression. In 1951, Charnley subsequently published his frequently cited series in which an external compression device was used for fixation. He achieved a solid fusion in 15 of 19 patients (79%) and argued that compression was critical because it eliminates shear across the fusion and prevents gap formation between the bone surfaces.

Interestingly, Charnley used a transverse anterior incision, with ligation of the anterior tibial artery and transection of the extensor tendons[16].

With the advent and advances of the Association for Osteosynthesis (AO)/Association for the Study of Internal Fixation (ASIF) group, the use of internal fixation gained continous popularity for ankle arthrodesis, especially compression screw fixation. Screw fixation allows for compression yet entails less soft-tissue stripping than plates. Furthermore, the ability to insert screws percutaneously enables minimally invasive arthrodesis techniques. Arthroscopic ankle fusion was first described in 1983 by Schneider, whereas a minimally invasive, or "mini-arthrotomy" technique was described by Myerson and colleagues. These 2 techniques minimize soft-tissue stripping and have high fusion rates[17].

In 1979, the long-term problems of post-ankle arthrodesis was investigated using gait analysis by Mazur et al. In their model, the ankle-foot complex was constructed using three markers around the foot and a method of two-dimensional projected coordinates of each point was used to establish the local coordinate system. The gait results were combined with the roentgenograms of the fused ankle with dorsiflexion and plantar-flexion stress applied. Their results demonstrated that the lost ankle motion of patients having undergone ankle fusion was compensated by motion at the small joints of the ipsilateral foot and resulted in altered motion of the ankle in the contralateral limb[18].

In 1987, a study concerning the optimum position of arthrodesis of the ankle was published by Buck et al. Three-dimensional electro goniometers were used to measure the motion of the ankle-foot complex and knee joint. Results indicated that a valgus position of the arthrodesis is advantageous and provides a more normal gait[19].

# SURGICAL ANATOMY OF ANKLE JOINT

The ankle joint is a complex joint (Fig.1). It consists of

- ❖ The tibial plafond (including the posterior malleolus articulating with the body of the talus)
- ❖ The medial malleolus
- ❖ The lateral malleolus.

The joint is saddle-shaped, with a larger circumference of the talar dome circumference laterally than medially. The dome itself is wider anteriorly than posteriorly, and as the ankle dorsiflexes, the fibula rotates externally through the tibiofibular syndesmosis, to accommodate this widened anterior surface of the talar dome[20].

## TIBIA

The lower end of the tibia has five surfaces: inferior, anterior, posterior, lateral, and medial. The inferior surface is articular, concave anteroposteriorly, and slightly convex transversely, dividing the surface into a wider lateral and narrower medial segment. The posterior border of the ankle joint is lower than the anterior border. The posterior border is in continuity with the posterior surface of the medial malleolus[21]. This segment has an oblique groove medially, that corresponds to the tendon of the tibialis posterior muscle. Osteotomies of the medial malleolus regularly violate this groove, and the tendon should be identified and protected.

The distal lateral border of the tibia is concave, consisting of anterior and posterior tubercles. The anterior tubercle is the site of origin of the anterior tibiofibular ligament. It overlaps the fibula. This relationship is the basis for the radiologic interpretation of tibiofibular syndesmosis alignment [22].

The more superficial aspect of the posterior tubercle is the site of attachment of the posterior tibiofibular ligament, which extends around to the posterior surface of the distal tibia. This ligament usually remains intact in trimalleolar fractures; it tethers the posterior malleolus to the lateral malleolus, and it is the basis for the indirect reduction of a posterior malleolar fragment after operative reduction of the fibular fracture[23].

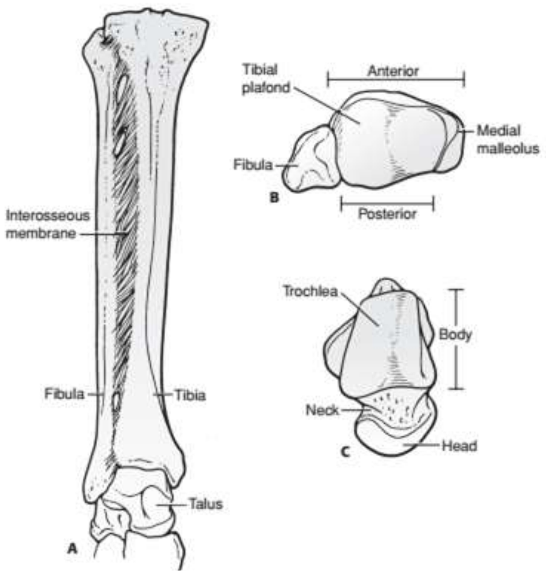



***Figure-1: Bony anatomy of the ankle. Mortise view (A), inferior superior view of the tibiofibular side of the joint (B), and superior inferior view of the talus (C).***

The medial surface of the distal tibial articulation is directed obliquely downward and inward. The medial surface is prolonged distally by the medial malleolus. The articular surface of the medial malleolus is comma shaped, with a larger surface anteriorly. The posterior border of the medial malleolus includes the groove for the tibialis posterior tendon[24].

The medial malleolus is composed of two colliculi separated by the intercollicular groove. The anterior colliculus is larger, extending approximately 0.5 cm distal to the more diminutive posterior colliculus. The deep talotibial component of the deltoid ligament inserts in the intercollicular groove and on the contiguous surfaces of the adjacent colliculi. The superficial deltoid ligament inserts on the medial surface and the anterior border of the anterior colliculus[25].

## FIBULA

The lower end of the fibula gives rise to multiple ligaments and housing the lateral articular surface of the ankle. The distal fibula has two major surfaces, lateral and medial, which widen into the three-surfaced lateral malleolus at the level of the tibial plafond. The interosseous ligament attaches where the lateral surface twists and becomes the posterior border of the lateral malleolus. The lateral malleolus is encased in strong ligamentous attachments anteriorly, posteriorly, inferiorly, and superiorly[26]. Anteriorly, these ligamentous attachments include the anterior tibiofibular ligament and the main and secondary bands of the anterior talofibular ligament. Inferiorly, the main attachment is through the stout calcaneofibular ligament. Posteriorly, the fibula is firmly connected to the talus and tibia through the posterior talofibular ligament, the superficial and deep components of the posterior tibiofibular ligament. Superiorly, the fibula is held in continuity to the tibia by the tibiofibular interosseous ligament[27].

## TALUS

The talus is almost covered by articular cartilage, with no musculotendinous attachments. The superior surface is convex from front to back, and it is slightly concave from side to side. The dome of the talus is trapezoidal, with its anterior surface wider than its posterior surface (28). This shape confers increased ankle stability with dorsiflexion. The medial and lateral articular facets of the talus are contiguous with the superior articular surface.The Talar dome bone is denser than tibial plafond bone, and generally it is not injured in ankle fractures. Because the lateral border is larger than the medial border, and the anterior border is longer than the posterior, **Inman** described this surface as a section of a frustrum of a cone, with a medial apex. This is partially responsible for the ankle joint's variable axis of rotation[29].

## LIGAMENTS

Ankle stability is conferred by bony architecture and ligament capsular structures. There are three distinct groups of ligaments supporting the ankle joint: (a) the syndesmotic ligaments; (b) the lateral collateral ligaments; and (c) the medial collateral ligament.

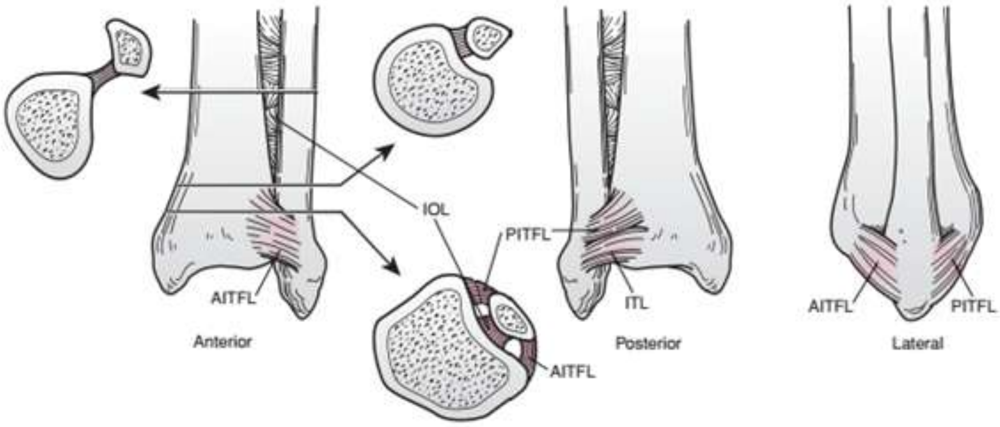



***Figure-2: Three views of the tibiofibular syndesmotic ligaments .***

The syndesmotic ligaments are composed of three distinct portions (Fig.2). Anteriorly, the anterior inferior tibiofibular ligament originates on the anterior tubercle and the anterolateral surface of the tibia, and it runs obliquely to the anterior fibula. The posterior tibiofibular ligament is composed of superficial and deep components that originate from the posterior tubercle of the lateral malleolus and extend upward, medially, and posteriorly to insert on the posterolateral tubercle of the tibia[30].

The superficial component has broad attachment across the posterior tibia. The thick, strong, deep component inserts on the lower part of the posterior border of the tibial articular surface and constitutes a true posterior labrum of the ankle joint. The posterior tibiofibular ligament is far stronger than the anterior tibiofibular ligament, and because of this difference, torsional or translational forces cause avulsion fractures of the posterior tibial tubercle, often leaving the posterior ligament intact when the anterior tibiofibular ligament ruptures[31]. The third component of the distal tibiofibular syndesmosis is the stout interosseous ligament, which extends upward and blends in continuity with the interosseous membrane. These structures are largely responsible for the integrity of the ankle mortise[32].

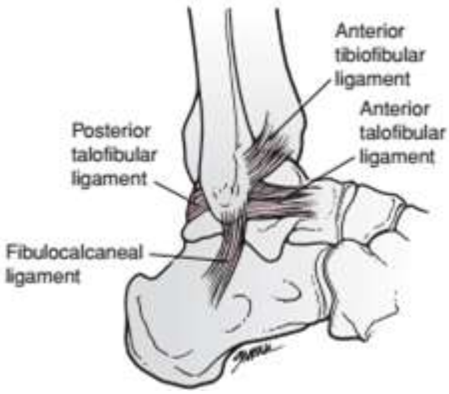



***Figure-3: Lateral collateral ligaments of the ankle and the anterior syndesmotic ligament.***

The major lateral collateral ligaments are the anterior talo-fibular ligament, the calcaneofibular ligament, and the posterior talofibular ligaments (Fig.3). The anterior talofibular ligament is formed within the anterolateral capsule of the ankle joint and originates from the inferior oblique segment of the anterior border of the lateral malleolus; it inserts onto the talar body, just anterior to the lateral malleolar articular surface. This ligament resists anterior subluxation of the talus when the ankle is plantar flexed, and it is susceptible to injury in inversion ankle sprains[33].

The calcaneofibular ligament is a strong, flat, oval ligament originating from the lower segment of the anterior border of the lateral malleolus, running deep to the peroneal tendons and inserts on the posterior aspect of the lateral calcaneus. This ligament resists inversion with the ankle in dorsiflexion and stabilizes both the ankle and subtalar joint.

The posterior talo-fibular ligament is a very strong ligament that is nearly horizontal. It originates on the medial surface of the lateral malleolus, inserts on the posterior surface of the talus, and is in continuity with fibers coursing from the superficial talotibial ligament to form a posterior ligamentous sling. It is the strongest of the lateral ligaments and prevents posterior and rotatory subluxation of the talus[34].

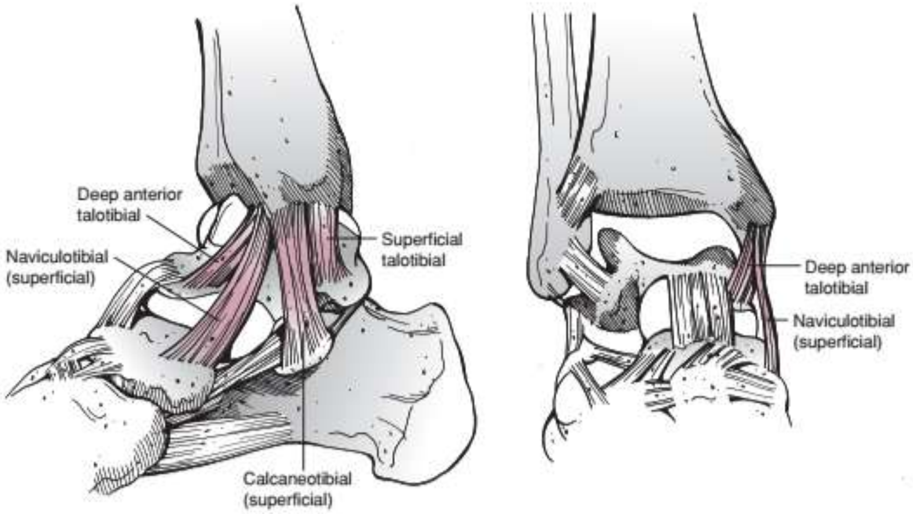



***FIGURE 4 Medial collateral ligaments of the ankle. Sagittal plane (A) and transverse plane (B) views.***

The deltoid ligament provides the medial ligamentous support of the ankle (Fig.4). The deltoid ligament has a superficial and a deep component. The superficial fibers arise from the anterior colliculus and the anterior aspect of the posterior colliculus, and they attach into the navicular, the neck of the talus, the medial border of the sustentaculum tali, and the posteromedial talar tubercle. The tibiocalcaneal ligament is the strongest component of the superficial layer of the deltoid ligament, and it is responsible for resisting eversion of the calcaneus[35].

The deep layer of the deltoid ligament is the primary medial stabilizer of the ankle joint. It is a short, thick ligament that originates from a wide area between the anterior and posterior colliculi. The strongest fibers insert on the medial surface of the talus, under the tail of the comma-shaped articular surface. This ligament is virtually inaccessible from outside the joint, and it cannot be repaired unless the talus is displaced laterally or if the medial malleolus is inverted distally through fracture or osteotomy[36].

## TENDONS AND NEUROVASCULAR STRUCTURES

Five nerves, two major arteries and veins, and 13 tendons cross the ankle joint (Fig.5). These tendons are divided into four groups: the posterior group, the medial group, the lateral group, and the anterior group. The posterior group - Achilles and plantaris tendons. The Achilles is the most power plantar flexor of the ankle, and the plantaris is a small, perhaps vestigial and inconstant tendon that can be used to supplement tendon or ligament repairs in the ankle or elsewhere. Immediately lateral to the Achilles tendon lies the sural nerve, which innervates the skin on the lateral heel and lateral border of the foot[37].

On the medial side of the ankle, the flexor tendons are transmitted under cover of the laciniate ligament(Calcaneum to Medial malleolus) (Fig. 5A).Immediately posterior to the medial malleolus lies the posterior tibial tendon, which is lacerated, incarcerated, or ruptured from medial malleolar fractures or osteotomies performed for visualization or reduction of talar fractures. Posterior and lateral to the tibialis posterior are, in order, the flexor digitorum longus tendon, the posterior tibial artery and associated veins, the tibial nerve, and the flexor hallucis longus tendon[38].

Anterior to the medial malleolus courses the saphenous vein and accompanying nerves (Fig. 5B). Typically, these lie immediately medial to the tibialis anterior tendon. The saphenous vein is an excellent portal for re-establishment of intravenous access in cases of trauma with shock. The accompanying nerves can be inadvertently injured by incisions placed around the anterior aspect of the medial malleolus. Because the resultant neuromas can be painful and difficult to treat, meticulous care should be exercised when the surgeon dissects along the anterior aspect of the medial malleolus[39].

On the lateral side of the ankle, the peroneal tendons are transmitted under the superior peroneal retinaculum, posterior to the fibula (Fig. 5C). At the level of the ankle, the peroneus longus tendon is more external, and the peroneus brevis lies up against the lateral malleolus. In cases of severe sprains, and some fractures of the ankle and calcaneus, the peroneus longus and brevis tendons can become dislocated anterior to the fibula. Early recognition of these subluxations or dislocations is critical for restoring normal, painless function of these tendons. Lateral approaches to the fibula can injure the superficial peroneal nerve proximally and the sural nerve distally. These nerves and their terminal branches sometimes are best exposed and protected during fixation of fibular fractures[40].

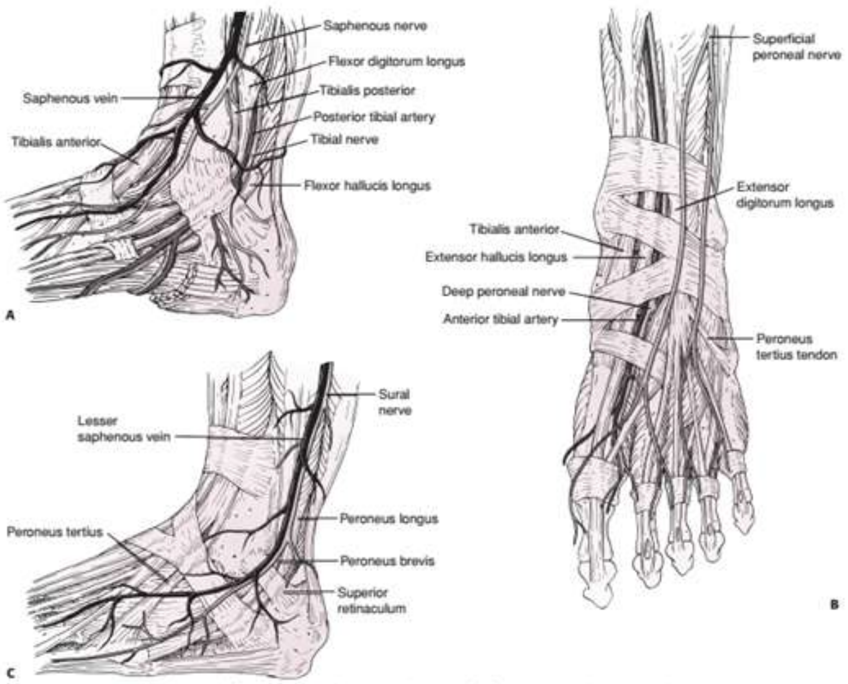



***FIGURE 5 A. Structures crossing the medial ankle. B. Structures crossing the anterior ankle. C. Structures crossing the lateral ankle.***

On the anterior aspect of the ankle, the extensor retinaculum restrains the extensor tendons, anterior tibial vessels, and the deep peroneal nerve. The extensor retinaculum proximal to the ankle runs from the anterior medial subcutaneous surface of the tibia to the anterolateral surface of the fibula. Distal to the ankle, the inferior extensor retinaculum is Y-shaped, with its base lateral on the calcaneus. Under the extensor retinaculum are transmitted, from medial to lateral, the tibialis anterior tendon, the extensor hallucis longus tendon, the deep peroneal nerve and anterior tibial vessels, the extensor digitorum longus tendon, and the peroneus tertius tendon. In approaches to the anterior aspect of the ankle, a relatively safe interval is between the tibialis anterior tendon and the extensor hallucis longus tendon[41].

Superficial to the extensor retinaculum lie the terminal branches of the superficial peroneal nerve. The superficial peroneal nerve fans into two or three major terminal branches that cross the ankle joint to innervate the dorsum of the foot. Because injuries to these branches can cause considerable pain and dysfunction, extreme care should be exercised when approaching the anterior aspect of the ankle or the distal fibula[42].

## INDICATIONS

The Preferred Position for an ankle arthrodesis is neutral in sagittal plane, neutral to 5 degree valgus in coronal plane,5-10 degree external rotation in horizontal plane, talus centered exactly below the tibia[6].

Originally ankle arthrodesis was devised for poliomyelitis and tuberculosis, but lately ankle fusion is the main indication for fusion of the ankle joint in post traumatic arthritis. The other indications are chronic instability, rheumatoid arthritis, charcots neuropathy with instability of ankle joint, failed total ankle arthroplasty with implant, septic arthritis of the ankle joint, avascular necrosis of talus and paralytic deformities when muscle tendon rebalancing is not possible[9]. The end stage of any diseased condition in ankle joint is cartilage degeneration or severe dysfunction which affects 15% of the adult population. The main benefactors of this procedure are those who have persistent and functionally disabling ankle joint pain and an unaffected subtalar joint.[10].

## CLASSIFICATION

Ankle osteoarthritis classification system (as suggested by Takakura and colleagues)

| Stage | Radiographic Osteoarthritis Signs |
|---|---|
| Stage-1 | No joint-space narrowing, but early sclerosis and osteophyte formation. |
| Stage-2 | Narrowing of the joint space medially. |
| Stage-3 | Obliteration of the joint space with subchondral bone contact medially. |
| Stage-4 | Obliteration of the whole joint space with complete bone contact. |

Ankle osteoarthritis classification system (as suggested by Giannini and colleagues)

| Stage | Radiographic Osteoarthritis Signs |
|---|---|
| Stage-0 | Normal joint or subchondral sclerosis |
| Stage-1 | Presence of osteophytes without joint-space narrowing |
| Stage-2 | Joint-space narrowing with or without osteophytes |
| Stage-3 | Subtotal or total disappearance or deformation of joint space |

Ankle osteoarthritis classification system based on weight-bearing radiographs (as suggested by Cheng and colleagues)

| Stage | Radiographic Osteoarthritis Signs |
|---|---|
| Stage-0 | No reduction of the joint space. Normal alignment . |
| Stage-1 | Slight reduction of the joint space. Slight formation of deposits at the joint margins. Normal alignment. |
| Stage-2 | More pronounced change than mentioned above Subchondral osseous sclerotic configuration. Mild malalignment. |
| Stage-3 | Joint space reduced to about half the height of the uninjured Rather pronounced formation of deposits Obvious varus or valgus alignment |
| Stage-4 | Joint space has completely or practically disappeared COFAS classification system for end-stage ankle osteoarthritis (as suggested by Krause and colleagues) |

| Type | Description |
|---|---|
| Type-1 | Isolated ankle arthritis |
| Type-2 | Ankle arthritis with intra-articular varus or valgus deformity or a tight heel cord or both |
| Type-3 | Ankle arthritis with hindfoot deformity, tibial malunion, midfoot abductus or aductus, supinated midfoot, plantar flexed first xray et |
| Type 4 | Types 1–3 plus subtalar, calcaneocuboid, or talonavicular Arthritis |

## CLINICAL AND RADIOLOGICAL EXAMINATION

- ❖ History and Physical Examination.

- ❖ Anteroposterior, mortise, and lateral weight-bearing radiography of the ankle.

- ❖ Computed tomography (CT) and magnetic resonance imaging (MRI).

- ❖ Arthroscopic evaluation is an invasive diagnostic procedure and is used for temporary pain relief and to delay ankle arthrodesis.

- ❖ Fluoroscopically guided injection of the ankle or subtalar joint with a local anesthetic drug (lignocaine, 1% or bupivacaine, 0.5%, with no epinephrine), mixed with a contrast agent to confirm intra-articular site of the injection and exclude the potential for communication between the ankle joint and adjacent joints or tendon sheaths, may confirm or exclude the ankle joint as the primary source of pain[43].

- ❖ Preoperative planning for an ankle fusion is extensive. The integrity of the surrounding joints, particularly subtalar joint, the amount of compensation from mid tarsal joints, tarsal-metatarsal joints and subtalar joints should all be taken into account before taking a decision to fuse the ankle joint. Preoperative radiographs include foot, ankle and leg films are taken. This is especially important if intramedullary nail fixation is considered along with ankle arthrodesis, as deformity of the tibia can make insertion of the nail challenging. Successful ankle fusion requires meticulous preparation of the bony surfaces ,careful positioning of joint, rigid fixation and non weight bearing until early bone consolidation[12].

## EVALUATION OF DEFORMITY

Persistent pain may occur after a solid arthrodesis,if there is foot malalignment. If the foot is not fixed in neutral position, heelpain , ulcer, metatarsalgia and genu recurvatum will occur.Valgus, varus, internal rotation, or external rotation malunion results in increased stresses and laxity of the collateral ligaments of the knee. Valgus or varus malunion produces painful callus at the first and fifth metatarsal.Valgus malunion can lead to subtalar joint arthritis and posterior tibial tendon dysfunction that is treated with realignment subtalar arthrodesis. Limb shortening may occur[44].

Preoperative planning for all ankle arthrodesis cases should evaluate the patient’s mechanical axis and any potential malalignment. Normal alignment in the frontal plane is such that the anatomic axis of the tibia shaft falls just medial to the midbody of the talus and just medial to the weight-bearing point of the calcaneus. Normal alignment in the sagittal plane, noted on a lateral radiography, should show that the anatomic axis of the tibia intersects the lateral talar process. During the arthrodesis, all attempts made to preserve normal alignment; on the lateral view, the foot may be translated slightly posterior to the normal sagittal line to decrease stress on the midfoot joints during gait.Bone loss in the distal tibia or talus that alters these relationships may lead to arthrodesis malunion.

Correct alignment is achieved by careful positioning of the talus beneath the distal tibia following resection of cartilage and preparation of the bone surfaces with small osteotomes or drilling the subchondral plate. In some cases of avascular necrosis of the entire talar body, the talus is left in place if it remains structurally intact without collapse. Defects are addressed with bone grafts or greater bone resection opposite the defect to create stable and parallel surfaces for arthrodesis. In general, deformities that would create unacceptable limb shortening from extensive bone resection is treated with larger bone grafts and supplemental stabilization with an Ilizarov-type multiplanar external fixator. In cases of limb shortening greater than 2.5 cm, limb lengthening with distraction osteogenesis is considered[45].

## APPROACHES FOR ANKLE ARTHRODESIS

The cutaneous nerves around the foot and ankle are superficial and can easily be cut, caught up within scar tissue, or stretched at the time of surgery. The location of these nerves should be kept in mind when approaching the ankle for arthrodesis, but avoiding all cutaneous nerves embedded in scar is impossible in many instances[46].

## ANTERIOR APPROACH

Patient is placed in supine position.Make a 15cm longitudinal incision over anterior aspect of ankle joint.Begin a incision 10cm proximal to joint and extend the incision distally so that it crosses the joint midway between both malleoli.Incise the skin and cut the extensor retinaculum.Dissect between Extensor Hallucis Longus and Extensor Digitorum Longus, identify the neurovascular bundle medial to EHL.Retract EHL/neurovascular bundle medially and EDL laterally.Incise the remaining soft tissues.Cut the anterior capsule to expose the ankle joint[47].

## TRANSMALLEOLAR (TRANSFIBULAR) APPROACH

An incision, five inches in length, is made over the lower third of the subcutaneous surface of the fibula. It is prolonged downwards to a point half an inch distal to the tip of the lateral malleolus. The fibula is exposed subperiosteally and divided three to four inches from its lower end. The distal fragment is removed and prepared for use as an onlay graft by splitting off the inner cortex throughout its length. After stripping ligamentous tissues from the lateral aspect of the lower end of the tibia the ankle joint is clearly exposed in the lower half of the wound. The articular cartilage of both tibia and talus is then erased down to vascular bone, working from the lateral side with a gouge or osteotome. Trimming of the bones is carried out in such a manner that when the intervening gap is closed the foot rests in the optimal plantigrade position with a few degrees of equinus. Small spaces remaining between the bone ends are filled with cancellous bone chips. A bed is prepared for the fibular graft by freshening the lateral aspect of the tibia and astragalus. The cancelious aspect of the graft is applied to the graft-bed, bridging the joint space. The graft is secured by three screws, two of which grip the tibia and one the astragalus. The wound is closed and a plaster is applied. Weight-bearing in plaster is encouraged within a few weeks of operation. After twelve weeks, the plaster is removed for clinical and radiographic tests of fusion. [48].

## POSTERIOR APPROACH

Posterior approach allows access to distal end of tibia,posterior aspect of ankle joint,posterior end of talus,subtalar joint and posterior part of superior surface of calcaneus.Patient is placed in prone position.Make a 12cm incision along the posterolateral border of the tendocalcaneus down to the insertion of the tendon on the calcaneus. Extensor retinaculum and tendon sheath are not entered.Plane between peroneal muscles and FHL reached.Dissection is kept lateral to FHL tendon, posterior tibial vessels & tibial nerve, will not be damaged, since this tendon protects them.Expose posterior surface of the tibia and the joint capsule [49].

## PREPARATION OF JOINT SURFACES

The joint surfaces are prepared for arthrodesis by denuding the remaining articular cartilage and “fish-scaling” the subchondral bone with a small osteotome or gouge. This preserves the normal ankle joint contour and results in minimal shortening of the extremity. Two parallel cuts, one through the distal tibia and one through the talar dome, that resect a minimal amount of bone allow excellent apposition of large cancellous surfaces and allow translation of the talus posteriorly beneath the tibia. The overall shortening generally is less than 1 cm. Schneider et al. described the use of an extramedullary alignment guide from a total knee arthroplasty system (placed upside down) to aid in making precise bony cuts for maximal cancellous contact[50].

## FIXATION OF ARTHRODESIS

Fixation can be obtained by one of three methods: compression with an external fixator, large cancellous screws, or intramedullary nail fixation. In rheumatoid bone, it is difficult to achieve good purchase with large screws. External fixation carries with it the concern of pin track infection in a patient who is taking corticosteroids and antimetabolites (prednisone and methotrexate). Adequate compression of the arthrodesis site is possible even in osteoporotic bone; however, the amount of compression (which is difficult to measure) necessary for firm apposition of cancellous surfaces differs in patients with posttraumatic arthritis, osteoarthritis, and rheumatoid arthritis[51].

## EXTERNAL FIXATION

Charnley first described the use of an external fixation device for compression ankle arthrodesis, but this uniplanar device did not provide rotatory stability. To overcome the lack of adequate rigidity in all planes that was present with the single-axis frame used by Charnley, Calandruccio designed a triangular frame to produce compression and control motion in all three planes (Fig.6). A modified design, the Calandruccio II compression device (Smith & Nephew, Memphis, Tenn), is easier to apply and allows more latitude in pin placement to avoid compromised areas of skin or bone;Berman et al. described a triangular external fixation frame that included a pin in the midtarsal area in addition to pins in the talus and tibia. They suggested that this frame eliminates the lever action of the foot and provides more rigid fixation, producing a higher rate of fusion (91% of 23 patients in their series). The unilateral Orthofix external fixator uses conically tapered pins to improve purchase and a tensioning device to apply compression. Many commercially available devices provide compression and stability in multiple planes[52].

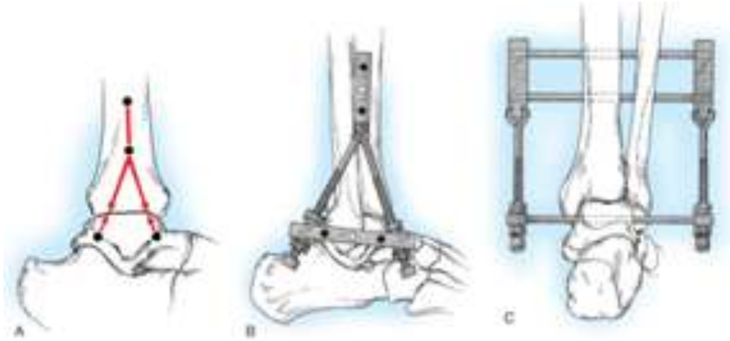



**Fig.6** Calandruccio triangular compression device. **A,** Two pins are inserted through talus and two through tibia for additional compression and more rigid fixation. Device allows for some correction of equinus or dorsiflexion and varus or valgus angulation. **B** and **C,** Lateral and posterior views of ankle with device in place.

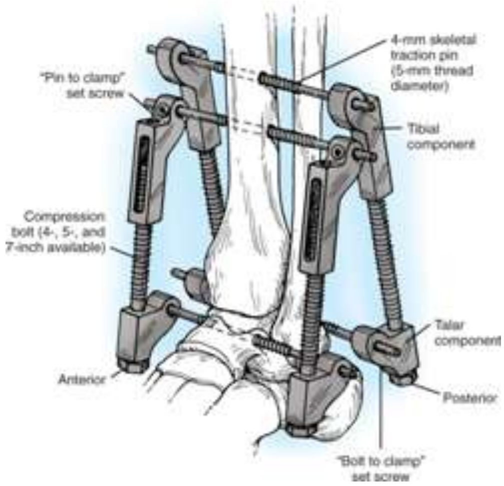



Fig. 7 The Calandruccio II compression device is easier to apply, allows more latitude in pin placement, and eliminates difficulty in seeing arthrodesis on radiographs.

Ring or circular external fixators also have been used to minimize pin track infection, but they are cumbersome for the patient, require careful pin track care, and are expensive. They can be used effectively, however, in patients with poor bone quality, in revisions for nonunion, or in salvage situations, such as failed total ankle arthroplasty or active infection. Hammerschlag reported successful fusion in 10 such patients with the use of a ring fixator; all patients were able to retain weight bearing ability while the fixator was in place. To minimize the risk of damaging neurovascular structures or tendons during pin insertion, the cross-sectional anatomy of the lower leg and ankle must be kept in mind when applying an external fixator for ankle arthrodesis[53].

## INTERNAL FIXATION

Proponents of internal fixation cite several advantages over external fixation, including ease of insertion; patient convenience; comparable rates of delayed union, malunion, nonunion, and infection; and greater resistance to shear stress. Moeckel et al. reported a 95% union rate in 40 arthrodeses with internal fixation compared with a 78% union rate in 28 arthrodeses with external fixation. At follow-up, both groups had good to excellent clinical results in 93% of patients. Maurer et al. also reported a higher rate of union using internal fixation (35 of 35 arthrodeses) than with external fixation (10 of 12 arthrodeses).

Cancellous screws in various configurations are most commonly used for internal fixation. Moran et al. reported a 95% fusion rate in 101 arthrodeses secured with two cancellous screws, and Moeckel et al.

reported successful fusion in 39 of 40 arthrodeses fixed with two tibiotalar screws inserted from the anteromedial to anterolateral aspect of the tibia into the body of the talus. Mann et al. recommended two parallel cancellous screws inserted from the lateral process of the talus to engage the posteromedial tibial cortex, emphasizing the excellent compression obtained by the parallel orientation of the screws. Friedman et al. found, however, that crossed screws were more rigid than parallel screws, especially in resisting torsional stress. Maurer et al. recommended transarticular cross-screw fixation inserted through anteromedial and anterolateral incisions (Fig.8). Dennis et al. used one lateral tibiotalar screw and one talotibial screw (Fig.9) to obtain fusion in 15 of 16 arthrodeses; both screws can be inserted through an anterolateral incision[54].


***Fig.8 A–C, Transarticular cross-screw fixation.***

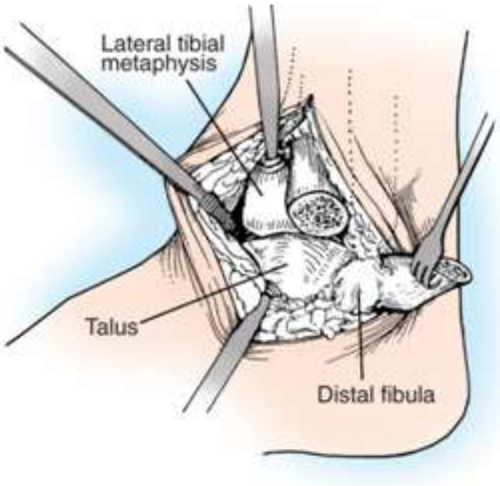



***Fig. 9 Fixation with one tibiotalar screw and one talotibial screw.***

Holt et al. used an "inside-out" drilling technique to place a posterolateral tibiotalar screw through the posterolateral tibial cortex into the head of the talus (Fig. 9A). After the hole is drilled from the plafond out through the posterolateral cortex, a small posterior skin incision is made over the drill tip, and the drill is placed through the posterolateral tibial hole and advanced into the talus (Fig. 9B). Medial and lateral screws are added as needed to secure fixation (Fig. 9C).

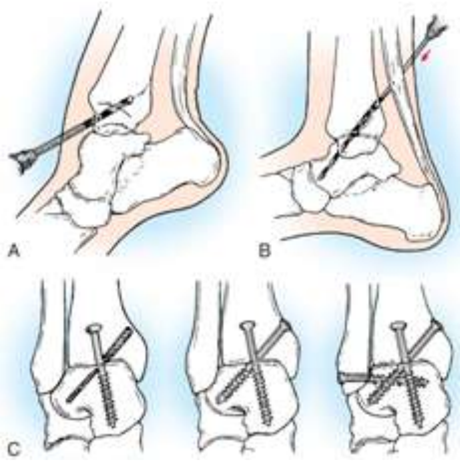



***Fig.9 A–C, "Inside-out" technique for screw fixation***

Monroe et al. reported a fusion rate of 93% using rigid internal fixation with cancellous screws. Their technique is a modification of that described by Holt et al. They used a lateral transfibular approach, but preserved the posterior soft-tissue sleeve on the fibula. The fibula was split in the sagittal plane and fixed to the lateral tibia and talus using 6.5-mm or 3.5-mm screws.

Swärd et al. described a technique of posterior internal compression using two posterior cancellous screws with washers inserted obliquely across the tibiotalar joint and down into the neck of the talus. They added autogenous cancellous bone chips from the iliac crest packed into a deep slot cut in the joint (Fig.10).

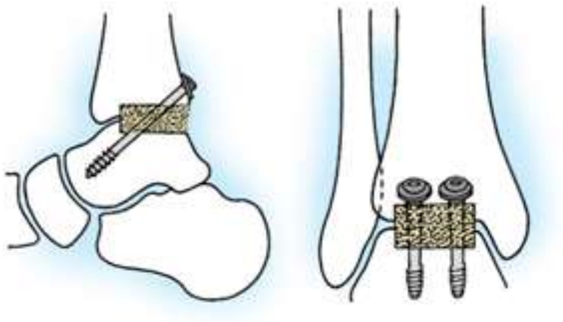


***Fig.10 Posterior screw fixation.***

Ogilvie-Harris et al. showed in a biomechanical cadaver study that three crossed screws generated significantly more compression and resistance to torque across the arthrodesis site than did two screws. They also found that better compression was obtained when the lateral screw was inserted first. They recommended placing one screw laterally, one medially, and one anteriorly from the tibia to the talus (Fig.11). Kish et al. also recommended using three cannulated screws to fix the ankle, one screw in each of three columns: lateral, central, and medial (Fig.12).

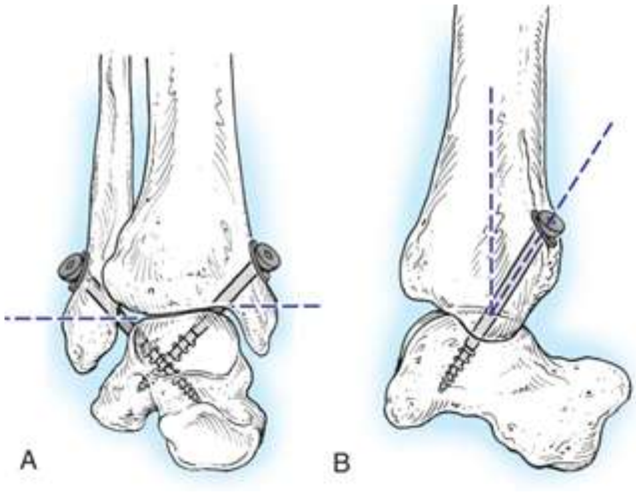



**Fig. 11** **A** and **B,** Screw position recommended by Ogilvie-Harris et al. Three screws were found to generate more compression and resistance to torque than two screws.

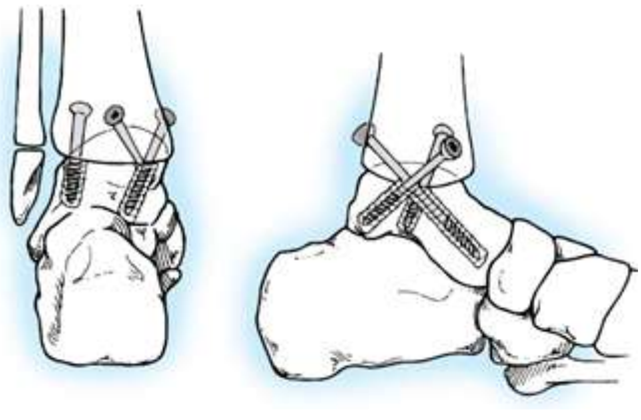


***Fig. 12 Placement of screws in three "columns" of talus: lateral, central, and medial.***

Various authors have reported the use of plates, screws, Kirschner wires, Steinmann pins, intramedullary rods, and absorbable screws, with varying degrees of success. Braly et al. and Wang et al. reported good results with the use of a lateral T-plate and cited as advantages better cosmetic result, quicker fusion, and fewer complications than with other fixation methods. Rowan and Davey also reported a high fusion rate (94%) and few complications with the use of anterior AO T-plates in 33 patients. Gruen and Mears used a posterior blade plate for late reconstruction of five ankles with complex deformity (Fig.13); three had excellent results, and two had good results. They recommended posterior blade-plate fixation for ankles with segmental bone loss, infected nonunion, or collapsed talar body. Weltmer et al. reported good results with the use of an anterior Wolf blade plate because of the minimal dissection required, and Mears et al. used an anterior tension plate (Fig. 14) to obtain fusion in 14 of 17 arthrodeses; they recommended this method for ankles with minimal deformity or bony destruction[55].

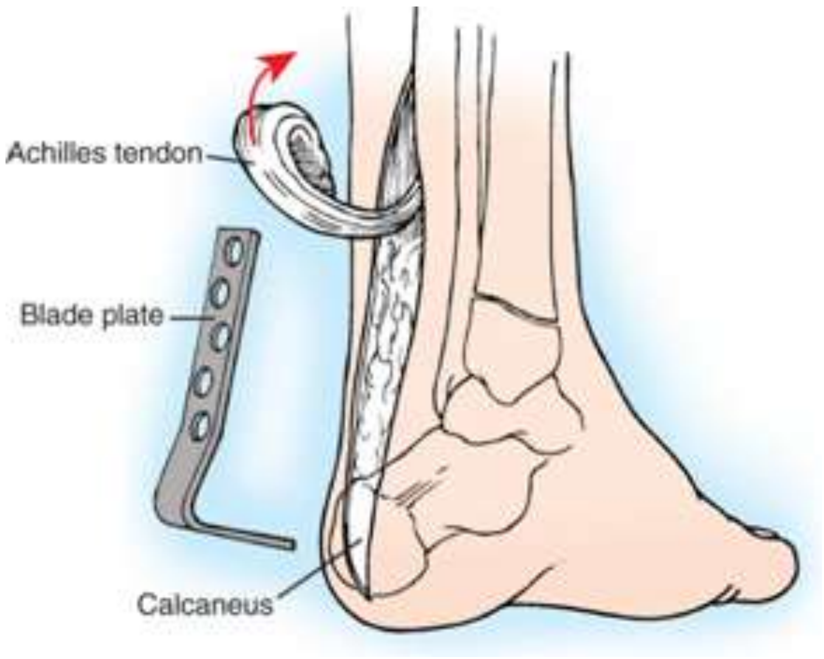



***Fig.13 Posterior blade plate fixation.***

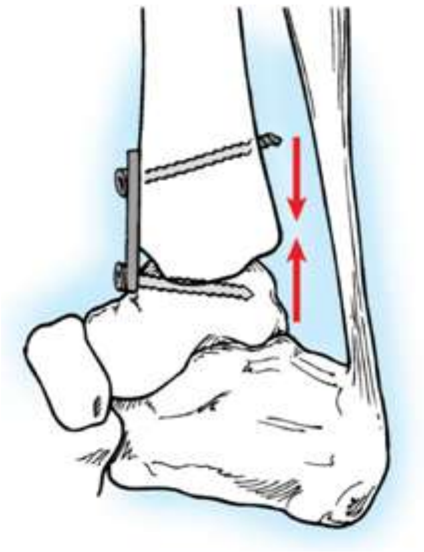


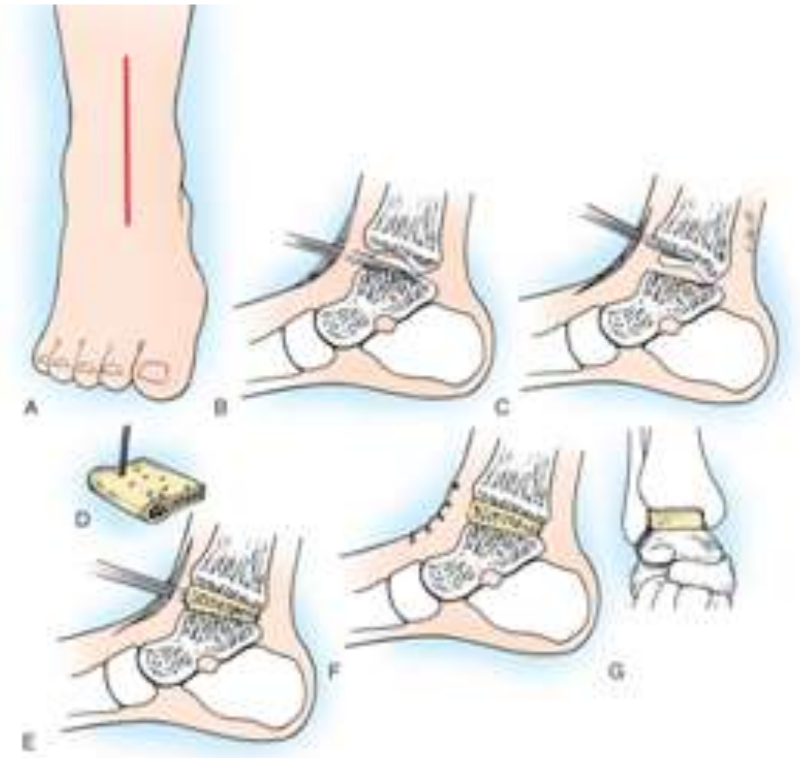
***Fig. 14 Anterior tension plate fixation.***

Moore et al. used intramedullary nails to obtain fusion in 14 of 19 arthrodeses, all of which were performed as salvage procedures. They recommended that this technique be reserved for significant posttraumatic arthrosis and bone loss after tibial plafond fracture, concomitant subtalar arthrosis, severe osteopenia (e.g., in patients with rheumatoid arthritis), and neuropathic arthropathy. Stone and Helal suggested that long trifins are appropriate in elderly patients, in whom early weight bearing is desirable; they should not be used in patients with subtalar joint motion that should be preserved. Fujimori et al. also described an intramedullary nail with finlike longitudinal ridges that they developed for use in patients with rheumatoid arthritis. The four fins were added to the distal part of the nail to stabilize the tibiotalar and subtalar joints and produced solid fusions in all 15 of their patients. Carrier and Harris used vertical Steinmann pins for fixation of five arthrodeses in patients with severe rheumatoid arthritis, and all five fused; they recommended this technique for rheumatoid patients with osteopenia and decreased bone density. Quill reported successful fusion in 36 (90%) of 40 tibiotalocalcaneal arthrodeses using an intramedullary nail. Their best results (100% union, no complications) were in patients with primary fusions for osteoarthritis or rheumatoid arthritis. Kile et al. used straight, interlocked, intramedullary nails for tibiotalocalcaneal arthrodesis in 30 patients with a variety of painful and disabling disorders, including posttraumatic arthritis, failed ankle arthrodesis and failed ankle arthroplasty, and osteonecrosis of the talus. They preferred a posterior approach because it avoided previous incisions, gave maximal exposure, allowed correction of significant deformities, and provided a large surface area for bone grafting; 26 (86%) of the 30 patients were satisfied with their results[56].

## TECHNIQUES

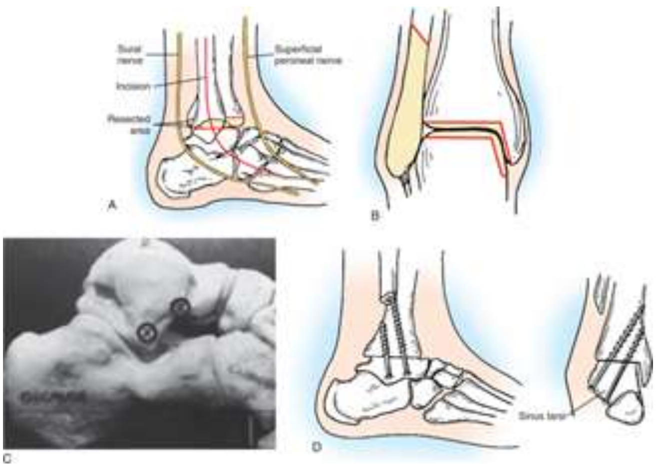
### *Tibiotalar Arthrodesis with an Iliac Crest Bone Graft-Chuinard and Peterson*

Make an anterior longitudinal incision over the ankle joint, and develop the approach between the extensor hallucis longus and the extensor digitorum longus tendons (Fig.15A).Retract medially the anterior tibial vessels and nerve, and detach the capsule of the ankle joint from the anterior margin of the tibia.With an osteotome and mallet, remove the articular cartilage from the horizontal surfaces of the tibia and talus, but not from the vertical surfaces of these bones or the fibula (Fig. 15B and C). Correct any deformity by removing appropriate wedges of bone. Take care to avoid injuring the distal tibial physis in children. With an osteotome the same width as the ankle mortise, remove a full-thickness graft from the anterior iliac crest as wide as the mortise and as long as the anteroposterior dimension of the ankle. Do not include the anterior superior iliac spine. Tailor the graft to fit the mortise, and perforate it with a drill (Fig. 15D).Manually distract the ankle joint, and pound the graft into place with the wide rim facing anteriorly and the surfaces of the graft firmly apposed to the surfaces of the tibia and talus (Fig. 15E to G). Check the position of the foot and adjust it to neutral. Fill any remaining recesses with cancellous bone from the ilium.Close the wound, and apply a cast from the base of the toes to the proximal thigh with the knee flexed 15 degrees[57].



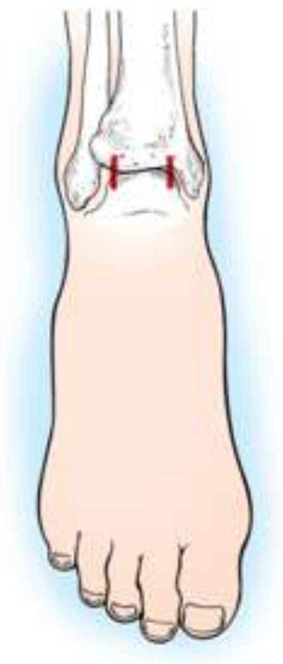

**TIBIOTALAR ARTHRODESIS WITH SCREW FIXATION (MANN ET AL.)**

Before surgery, carefully evaluate the alignment of the normal and abnormal limbs to determine correct rotation. This usually can be done by aligning the tibial tubercle with the second metatarsal.Apply and inflate a thigh tourniquet, and place a sandbag under the ipsilateral hip to improve exposure of the lateral side of the foot and ankle. Begin the skin incision approximately 10 cm proximal to the tip of the fibula, and carry it down along the fibular shaft, then slightly distally another 10 cm toward the base of the fourth metatarsal (Fig. 16A). This incision passes through an internervous space between the sural nerve posteriorly and the superficial peroneal nerve anteriorly. Develop skin flaps to create a full-thickness flap along the skeletal plane.Strip the periosteum from the fibula anteriorly and posteriorly, and carry the incision distally to expose the posterior facet of the subtalar joint and the sinus tarsi area. Carry the dissection across the anterior aspect of the tibia and the ankle joint.With a periosteal elevator, strip the soft tissue from the distal end of the tibia, ankle joint, and talar neck to the area of the medial malleolus.Osteotomize the fibula approximately 2 cm proximal to the level of the ankle joint, and bevel it so as not to leave a sharp prominence. Remove the distal portion of the fibula by sharp and blunt dissection to expose the lateral aspect of the tibia and ankle joint and the posterior facet of the subtalar joint.Make an incision through the deep fascia along the posterior aspect of the tibia (which was exposed by removal of the end of the fibula), and gently move a periosteal elevator across the posterior aspect of the tibia and then toward the calcaneus medially to strip the soft tissue from the posterior aspect of the tibial and ankle joint.Place malleable retractors anteriorly and posteriorly around the distal end of the tibia to expose the ankle mortise.Make the initial cut in the distal part of the tibia with a small sagittal saw, cutting as perpendicular as possible to the long axis of the tibia. Remove as little bone as possible from the dome of the ankle joint. Bring the cut across the ankle joint, stopping just where the curve of the medial malleolus begins (Fig. 16B). Free the tibial fragment medially by placing a broad osteotome into the osteotomy and gently levering distally to break its attachment to the medial malleolus; remove the fragment. If the bone is porotic or if the deformity is significant, continue cutting across the ankle joint, and remove the entire medial malleolus through a separate medial incision.Place the foot into proper alignment (0 degrees of dorsiflexion–plantar flexion and about 5 degrees of valgus), and make a cut in the superior aspect of the talus to remove 3 to 4 mm of bone. Make this cut parallel to the one in the distal end of the tibia.Bring the bone surfaces together, and carefully check alignment. If any malalignment is present, remove more bone from the distal end of the tibia or occasionally from the talus to align the joint properly. If the joint surfaces do not come together without any tension, the medial malleolus is too long and should be shortened.Approach the medial malleolus through a longitudinal 6-cm anteromedial incision. Taking care to avoid the saphenous nerve, carry the incision down through subcutaneous tissue and fat to expose the medial malleolus.Remove the periosteum and deltoid ligament to expose the tip of the malleolus and use a sagittal saw or osteotome to remove the distal 1 cm. Take care not to cut the posterior tibial tendon inadvertently; it lies just posterior to the medial malleolus. The joint surface now can be easily apposed to obtain satisfactory alignment. Line up the anterior edge of the tibia and the anterior cut edge of the talus to align the ankle joint in the anteroposterior plane. If the talus is not placed far enough posteriorly, the normal posterior slope of the calcaneus will be absent.Stabilize the talus to the tibia with a towel clip, a bone clamp, or Kirschner wires. Carefully check alignment to ensure correct varus-valgus and dorsiflexion–plantar flexion and the proper degree of rotation.With a 3.5-mm bit, drill two holes across the arthrodesis site, one beginning within the sinus tarsi area and the other just above the lateral process (Fig. 16C). As the initial hole is drilled in the sinus tarsi, invert the calcaneus as much as possible, and hold the drill bit almost parallel to the floor as it passes out medially through the distal end of the tibia. Disconnect this bit from the drill, and use a second bit to drill a hole just above the lateral process, almost parallel to the first drill bit. Carefully check alignment again. Remove one of the drill bits and measure the depth of the hole; tap the hole and insert a 6.5-mm screw (Fig. 16D).Usually a 50- to 60-mm long compression screw with 32-mm threads is used. If the threads do not completely cross the arthrodesis site, use a short threaded screw. It is important that the threads engage the cortex of the tibia to gain maximal compression. Place the screw in the lateral process high enough that it does not impinge against the posterior facet. In patients with soft bone, a washer can be used.The fibula is not replaced, and generally no problems with peroneal tendon function occur. If there is room for any bone graft, some can be packed into the space between the medial malleolus (if it was left in place) and the medial aspect of the talus.Close the wound in layers over a suction drain, and apply a thick compression dressing with plaster splints[58].



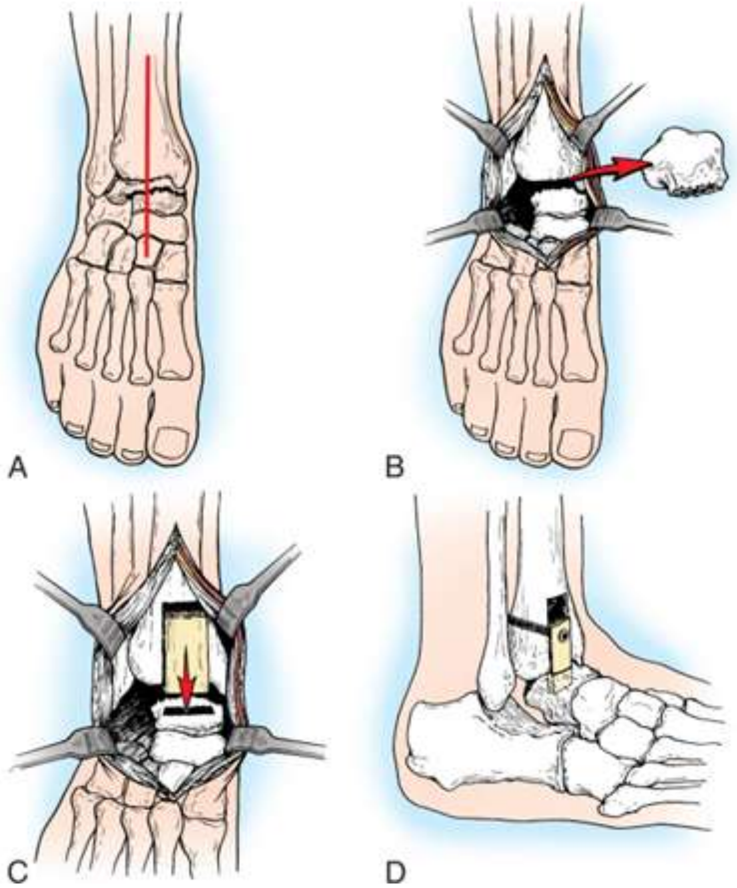

## TIBIOTALAR ARTHRODESIS THROUGH MINIARTHROTOMY

With the patient supine, administer a regional ankle block with intravenous sedation; general anesthesia can be used if necessary.Make two 1.5-cm incisions, one anteromedial and one anterolateral, in approximately the same positions as the portals for the standard arthroscopic technique (Fig.17). Make the first incision medial to the anterior tibial tendon and the second lateral to the peroneus tertius tendon (to avoid the dorsal cutaneous branch of the superficial peroneal nerve). Using angled curets, resect the cartilage of the anterior ankle joint; small rongeurs are helpful in débriding the synovium and cartilage.Place a small lamina spreader, modified by having the teeth removed, alternately in the medial and lateral incisions to view the joint surface to be resected.Irrigate the ankle with saline. Place a pneumatic long-burr resector into the joint, and débride any further cartilage and bone to the subchondral level. This burr generates a bone “slurry” that can be collected for later use as a bone graft. The posterior third of the ankle joint cannot be resected with this technique.Using the burr, carefully débride the medial and lateral gutters.Position the ankle in 5 degrees of valgus, 0 degrees of dorsiflexion, and neutral rotation.Place guidewires for 6.8-mm or 7.3-mm cannulated self-drilling, self-tapping screws from the anteromedial tibia into the body of the talus and from the distal posterolateral tibia into the head of the talus. A third screw can be placed from the fibula into the talus if needed for stability.Alternatively, place three cannulated screws percutaneously from the tibia into the talus with fluoroscopy to confirm placement and screw length.Pack the bone “slurry” around the joint, and close the joint capsule carefully to prevent leakage of the slurry.After routine closure, apply a bulky cotton dressing with a coaptation-type splint and posterior mold of plaster[59].



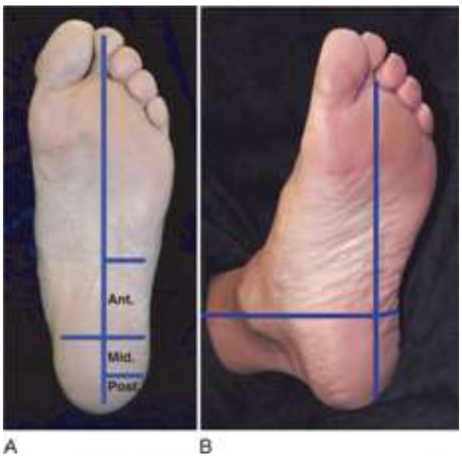
## TIBIOTALAR ARTHRODESIS WITH A SLIDING BONE GRAFT (BLAIR TECHNIQUE)

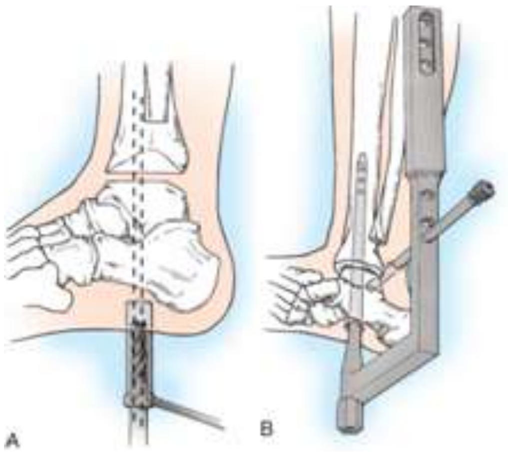
Make an anterior longitudinal incision beginning 8 cm proximal to the ankle and ending at the medial cuneiform (Fig. 18A).Dissect the interval between the extensor hallucis longus and extensor digitorum longus, and retract the neurovascular bundle medially.Incise the capsule and periosteum in line with the skin incision.Remove the avascular talar body if present (Fig. 18B); morcellize it if necessary. Do not damage the talar head or neck. Using a power saw, cut a rectangular graft 5 cm × 2.5 cm from the anterior aspect of the distal tibia. Make a transverse slot 2 cm deep in the superior aspect of the talar neck, and slide the tibial graft into it (Fig. 18C). Hold the foot in neutral dorsiflexion, 5 degrees of valgus, and 10 degrees of external rotation, and fix the proximal part of the graft to the tibia with a screw (Fig. 18D).Insert a Steinmann pin vertically through the calcaneus and 3 to 10 cm into the distal tibia for added stability.Pack cancellous bone grafts around the fusion site.Apply a long leg cast with the knee flexed 30 degrees[60].




## TIBIOCALCANEAL ARTHRODESIS WITH INTRAMEDULLARY NAILING (GRAVES ET AL.)

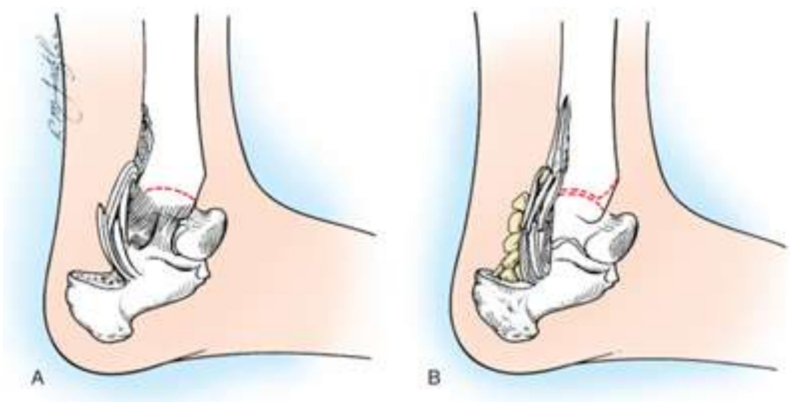
The position of the patient, medial and lateral skin incisions, soft-tissue dissection, removal of the body of the talus, and fixation of the head and neck of the talus to the anterior tibia are the same as described for compression arthrodesis. A posterior approach can be used if wide exposure is necessary for removal of total ankle components or in patients with osteonecrosis of the talus or significant deformities that require correction.After the arthrodesis site is prepared, determine the position by holding the patella straight up and placing the foot in neutral dorsiflexion–plantar flexion, 8 to 10 degrees of valgus at the heel, and slight posterior displacement of the calcaneus on the tibia. Hold the foot on the tibia in the proper position (usually with folded towels across the plantar surface of the midfoot).Place a guidewire through the heel pad in line with the center of the tibia. This pin exits the calcaneus just anterior to the posterior facet. Drive the pin into the center of the medullary canal of the tibia under image intensification.Stephenson et al. described a simple, reproducible method of determining the correct entry site. In the sagittal plane, draw a line from the second toe to the center of the heel; in the coronal plane, draw a line at the junction of the anterior and middle thirds of the heel pad (Fig.19). The intersection of these lines indicates the correct entry portal for the nail. Check the position of the guide pin with image intensification in the anteroposterior plane.Drill a hole in the calcaneus through a tissue protector that has been pushed all the way to the bony surface of the calcaneus.Place the guidewire in the center of the medullary canal of the tibia on the anteroposterior and lateral planes, and place an 8- to 9-mm reamer over the guide pin (Fig. 20A). Ream the calcaneus and tibia in 1-mm increments. We usually ream 1 mm wider than the nail (13 mm).After the reaming is completed, load an intramedullary straight ankle fusion nail onto a guide. This nail is available in 11-mm, 12-mm, and 13-mm diameters and 15-cm, 18-cm, and 21-cm lengths.Place the drill guide sleeves through the drill guide on a back table to ensure that they line up correctly with the holes in the nail (Fig. 20B). It is essential that the drill pass concentrically through the drill guide and the nail without impinging on the borders of the nail.Hold the ankle in the proper position, and place the nail over the guidewire with the outrigger guide on the lateral surface of the leg. Position the nail in the calcaneus, and reevaluate the position of the arthrodesis before driving the nail into the tibia. Evaluate the position of the nail and the position of the arthrodesis using image intensification. Ensure that the portals of the outrigger guide rest just anterior to the fibula or else the anterior cortex of the fibula will force the drill for the proximal screws slightly anteriorly, causing the outrigger portal to not be exactly concentric with the designated portal of the nail.Before final seating of the nail, place bone graft from the morcellized malleoli in the arthrodesis and in the sinus tarsi area of the calcaneus. Impact the nail after the bone graft has been applied. The tip of the nail should rest anywhere from slightly inside the cortex of the calcaneus to approximately 1 cm outside the plantar surface of the calcaneus. Do not allow it to protrude so far that it would impede ambulation.With the body of the talus removed, two modifications of the technique may be required: Because the calcaneus rests more laterally in relation to the ankle joint than does the talus, it may need to be translated medially 1 to 2 cm so that the lateral edge of the prepared surface of the tibia has no bony apposition with the calcaneus. Placing the pin in the calcaneus anywhere but in the midline is difficult because of the contours of the plantar surface of the calcaneus. Consequently, moving the pin medially in the calcaneus and leaving it in its anatomical position is more difficult than placing the pin in the plantar midline surface of the calcaneus and translating the whole calcaneus slightly medially.This is done easily with both malleoli removed. In severe subluxations of the subtalar joint, the calcaneus is so far lateral that the nail will purchase only the lateral third of the talus. In this situation, a compression device probably is a better choice of fixation. If only one screw can be placed distally (because there is no talar body), try to drill the hole with a 3.5-mm bit, then use a 5-mm screw to give better purchase in the cancellous bone of the calcaneus. Try to place two self-tapping screws in the calcaneus.When the talus has been left intact, place one self-tapping screw in the calcaneus and one in the talus in the following manner. Begin on the calcaneal side of the arthrodesis, and place the most distal screw near the plantar cortex of the calcaneus. After the hole has been drilled through the calcaneus, exiting on its medial cortex, remove the inside barrel of the double-barrel soft-tissue guide.Measure the length of the screw with a depth gauge. The screws in the calcaneus usually are 40 to 50 mm long, but this varies with the size of the calcaneus.Ensure that the drill guide opposes the lateral surface of the calcaneus; if it does not, a false reading of the length of the screw results, with subsequent protrusion into the soft tissue.After the screw has been seated, evaluate its length using image intensification.For the proximal screws, start at the 15-cm marker on the outrigger guide, and place a drill through a drill sleeve in the portal just distal to the 15-cm marker in the proximal portal of the nail.Make an incision through the skin, spread the soft tissue down to bone, and snug the drill guide up to the lateral side of the tibial cortex.Use an outrigger guide and drill sleeves to prevent drilling through the anterior cortex. Place two screws proximal to the arthrodesis through separate stab wounds laterally, taking care not to injure the superficial peroneal nerve. The tibial screws usually are 22 to 26 mm long. Penetrate the medial cortex of the tibia with the screw, but do not allow more than a few threads to exit because this irritates the skin over the medial end of the screw.Deflate the tourniquet, and place drains as previously described for the compression technique. Wrap a bulky soft-tissue dressing from the toes to the upper tibia, and apply a short leg cast[61].




## POSTERIOR ARTHRODESIS OF THE ANKLE(CAMPBELL)

Make a 7.5-cm longitudinal incision medial to and parallel with the Achilles tendon over the posterior aspect of the ankle.Retract the flexor hallucis longus medially, and expose the posterior capsule of the ankle and subtalar joints.If the procedure is to be kept extraarticular, do not incise the capsule. Otherwise, incise the capsule transversely, and remove the most posterior portion of the talus and the posterior portion of the articular surfaces of the ankle and subtalar joints.With an osteotome, turn large flaps of bone distally from the posterior aspect of the tibia and proximally from the superior aspect of the calcaneus, overlapping them successively (Fig. 21A).Add additional bone from the ilium or bone bank if necessary to make a large bony bridge across the ankle and subtalar joint (Fig. 21B)[62].




**ROLE OF BONE GRAFT IN ANKLE FUSION**

Bone graft is an important component of an ankle arthrodesis if the potential for the union is compromised by factors such as infection, osteonecrosis of the talus, bone defects, and previous nonunion. However, a bone graft is not routinely required in primary ankle arthrodesis is the absence of these complicating factors. In

Charnley's primary compression ankle arthrodesis, the bone graft was not used [63].

Open trans-fibular ankle arthrodesis with internal screw fixation may achieve union in greater than 90% of cases without bone graft. Arthroscopic ankle arthrodesis usually does not require a bone graft because of the extensive cancellous surface exposed with minimal soft tissue disruption. Potential sources of autogenous bone graft for ankle arthrodesis may vary depending on the type and amount of graft required. An available bone stock may depend on previous trauma or surgery. The iliac crest is a reliable source of cancellous and cortical bone but is associated with donor site morbidity. The local bone graft may be used from the distal fibula or tibia. Arthrodesis with an anterior tibial sliding bone graft may avoid the morbidity of iliac crest bone graft [64].

If the non-structural bone graft is required, the excised distal fibula or medial malleolus may be ground in a bone mill to increase the bony surface area for promotion of union. The distal tibia is an excellent source of cancellous bone graft for procedures in the foot, but this site is usually unavailable for ankle arthrodesis because of proximity to the arthrodesis. The proximal tibia may offer an adequate cancellous graft for ankle arthrodesis and avoid iliac crest morbidity. Demineralized bone matrix has been used for ankle arthrodesis, with union rates comparable to autogenous bone graft [65].

## SEQUELAE OF ANKLE ARTHRODESIS

Decreased subtalar motion and long-term degenerative changes may occur in the subtalar, talonavicular, calcaneocuboid, naviculocuneiform, tarsometatarsal and first metatarsophalangeal joints.

Long-term follow-up at an average of 22 years after ankle arthrodesis showed more activity limitation, pain, and disability with the fused than the opposite limb. Appropriate preoperative counseling about the potential development of arthritis in the foot is advised for patient education before ankle arthrodesis [66].

## TREATMENT PROTOCOL

Postoperative care differs from patient to patient.Patients are kept on non–weight bearing for 8 to 12 weeks or until radiographic consolidation is visualized. A transition to partial weight bearing in a walker is often started once bony trabeculation is visualized across the fusion site on radiographs. Once the patient has transitioned to regular shoe gear, modification of the shoe wear may be a necessity. Most of the time these patients require custom orthotics with a heel lift or heel cushion. They may even require a rocker bottom shoe to allow for a normal gait pattern. Once a patient transitions into a shoe, it is beneficial to place him or her into a full-length rocker sole until the patient adapts to ambulating with a fused ankle[67].

## COMPLICATIONS

There can be many complications for any type of major joint fusion.

- Overcompensation of neighboring joints is unavoidable with a large joint fusion.
- Arthritis in the subtalar joint (STJ), midtarsal joint, and the tarsometatarsal joint adjacent to ankle joint fusion is very common
- Pseudoarthrosis.
- Postoperative infection  reoperation rate in patients with diabetic neuropathy[68].

# SCORING SYSTEM

***AOFAS score ( American orthopedic foot and ankle society score)***

| Parameter | Degree | Score |
|---|---|---|
| Pain | None | 40 |
| | Mild, Occasional | 30 |
| | Moderate, Daily | 20 |
| | Severe, Almost Always | 0 |
| Function Activity limitation, support requirement | No limitation,no support | 10 |
| | No limitation of daily activities, limitation of recreational activity, no support | 7 |
| | Limited daily and recreational activity, cane | 4 |
| | Severe limitation of daily and recreational activities, walker, crutches, wheel chair | 0 |
| Maximum walking distance ,blocks | >6 | 5 |
| | 4-6 | 4 |
| | 1-3 | 2 |
| | Less than 1 | 0 |
| Walking surface | No difficulty on any surface | 5 |
| | Some difficulty on uneven terrain, stairs, ladders | 3 |
| | Severe difficulty on uneven terrain, stairs, ladders | 0 |

| Parameter | Degree | Score |
|---|---|---|
| Gait abnormality | None ,slight | 8 |
| | Obvious | 4 |
| | Marked | 0 |
| Sagittal motion (flexion and extension) | Normal or mild restriction(30 degrees or more) | 8 |
| | Moderate restriction( 15 - 29 degrees) | 4 |
| | Severe restriction (less than 15 degrees) | 0 |
| Hind foot motion (inversion and eversion) | Normal or mild restriction(75 -100% normal) | 6 |
| | Moderate restriction(25- 74% normal ) | 3 |
| | Marked restriction (less than 25 % normal ) | 0 |
| Ankle – hindfoot stability( AP , varus – valgus) | Stable | 8 |
| | Definitely unstable | 0 |
| Alignment | Good, plantigrade foot, mid foot well aligned | 10 |
| | Fair, planti grade foot ,some degree of mid foot mal alignment, no symptoms | 8 |
| | Poor , non plantigrade foot, severe mal alignment , symptoms | 0 |

# MATERIALS AND METHODS

The Present Study was performed with approval from IOT Ethical Committee and Madras Medical College Ethical Committee and all participants signed an approved informed-consent form. Twenty one patients who presented with arthritic changes in the ankle joint to our institute of Orthopaedics and Traumatology during the period of 2014-2017 are studied retrospectively and prospectively. Among the 21 patients with arthritic changes in ankle joint 17 patients were males and 4 patients were females. A complete clinical and neurological examination is done for all the patients. The symptoms and signs were local symptoms, such as Pain, Swelling and restriction of motion. The American Orthopaedic Foot and Ankle Society (AOFAS) scale was used for ankle evaluation. All patients are taken radiographs of Ankle both Antero-posterior, lateral and Mortise views. Xray Foot AP and Lateral views is also taken for all patients to rule out associated Subtalar arthritis.CT scan of the ankle joint is taken. Patients with arthritis, fusion done using percutaneous or transfibular or anterolateral approach.Methods of Fusion are Cancellous screw fixation/intramedullary nailing/Triplanar External Fixation.Bone Graft harvested from Ipsilateral Iliac Crest .

## INCLUSION CRITERIA

- Post traumatic Arthritis.
- AVN Talus.
- Post Infective Sequelae of Ankle Joint.
- Paralytic Deformities.
- Rheumatoid Arthritis.
- Charcot’s Arthropathy

## EXCLUSION CRITERIA

- Uncontrolled Diabetes Mellitus.
- Vascular TAO.
- Children.

# CASE ILLUSTRATION
# CASE-1

| | | |
|---|---|---|
| Name | : | Mr.Rafik |
| Age/sex | : | 47/M |
| IP No | : | 41085 |
| Diagnosis | : | Post Traumatic Arthritis Left Ankle |
| Procedure | : | Ankle arthrodesis – Cannulated Cancellous screw fixation |

***Pre- operative X ray***


***Immediate Post operative Xray***

***6 weeks follow up:***

***12 weeks follow up***


***3 months follow up***

# CASE-2

| | | |
|---|---|---|
| Name | : | Mr.Rajendran |
| Age/sex | : | 48/M |
| IP No | : | 7810 |
| Diagnosis | : | Post Traumatic Arthritis Right Ankle |
| Procedure | : | Ankle arthrodesis |

***Pre operative Xray***

***Pre Operative CAT scan***

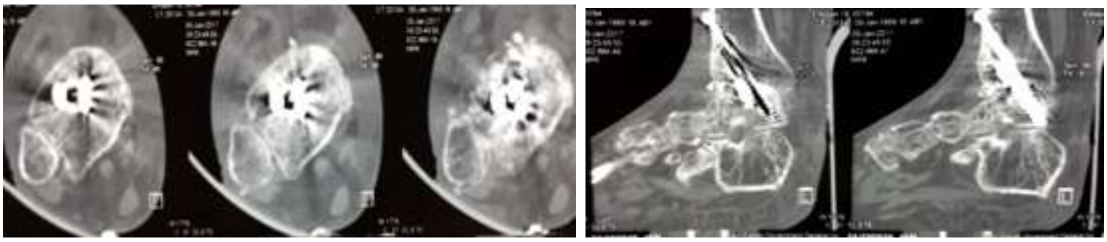

### *Immediate Post Operative X ray*

### *6 weeks follow up*


### *12 weeks follow up*

***3 months follow up***


***Post op CAT Scan***



***Post Operative CAT scan***

# CASE-3

Name : Mr.Srinivasan

Age / Sex : 64/M

IP No : 47641

Diagnosis : Post Traumatic Arthritis Right Ankle

Procedure : Ankle arthrodesis

***Pre operative Xray***

***Pre operative Scan***

*Immediate Post operative Xray*

## CASE-4

Name : Mrs.Noorjahan

Age/Sex : 45/F

IP No : 2794

Diagnosis : Bilateral charcot ankle joint

Procedure : Ankle arthrodesis right side

***Pre operative X ray***

***Immediate post operative Xray***

*6 weeks follow up*

*12 weeks follow up*

# OBSERVATION AND RESULTS

The observations and results from our study as follows

The Common Age Group who presents in this study belong to 46-60yrs (53%) followed by 31-45yrs (17%).

Ankle Arthritis predominant in male (76%)compared to female (24%). Patients in our study have arthritis predominant in right side (81%) compared to left side (19%).

The most common cause in our study is post traumatic arthritis (76%) followed by Charcot's Arthropathy (24%).

Time taken for fusion in most patients are 6 weeks (48%) followed by 8weeks (33%) followed by 10weeks (9.50%).

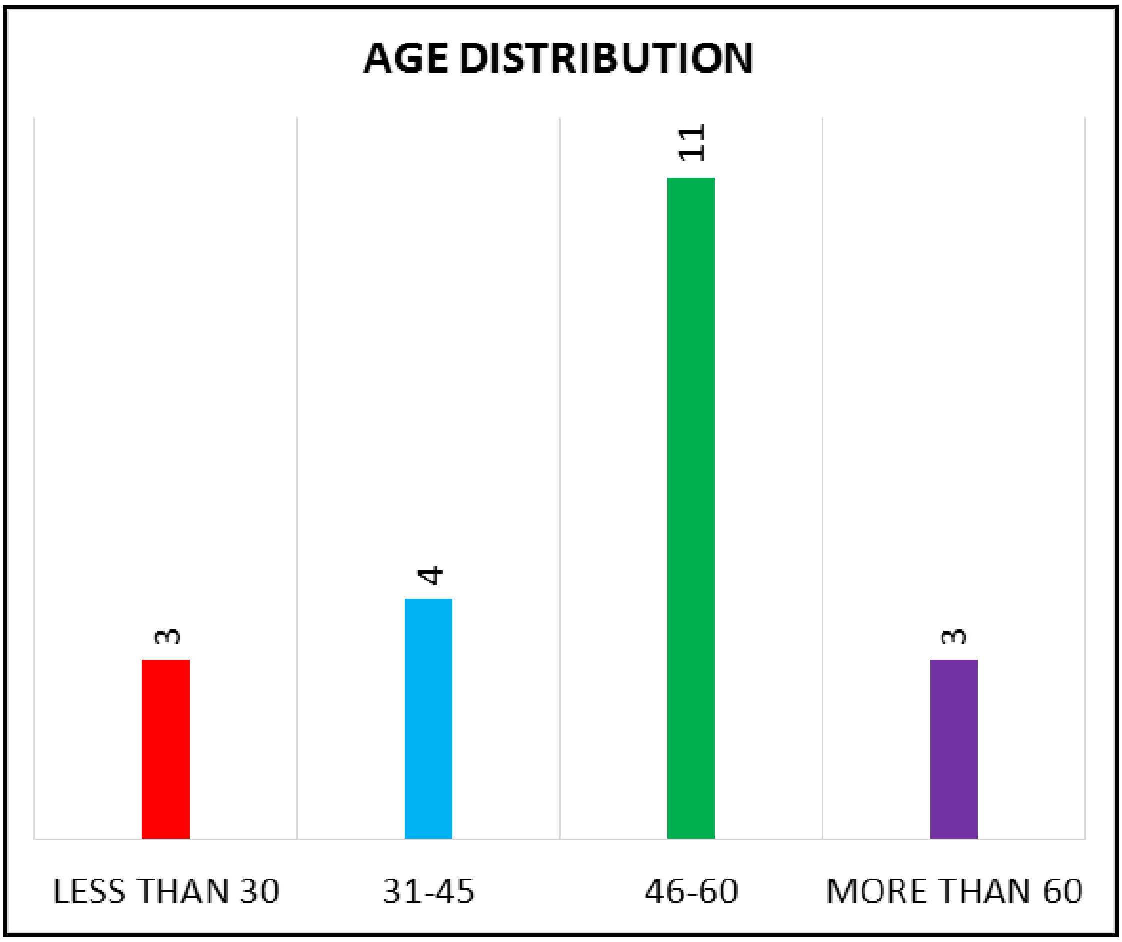
The outcome analysis is based on AOFAS score.AOFAS(American Orthopaedic Foot and Ankle Score)-outcome score shows 1 patient showed excellent result, 3patient showed good result,17 showed fair results.

Out of 21 patients,fracture united in 20 patients,malunited 1 in patients.

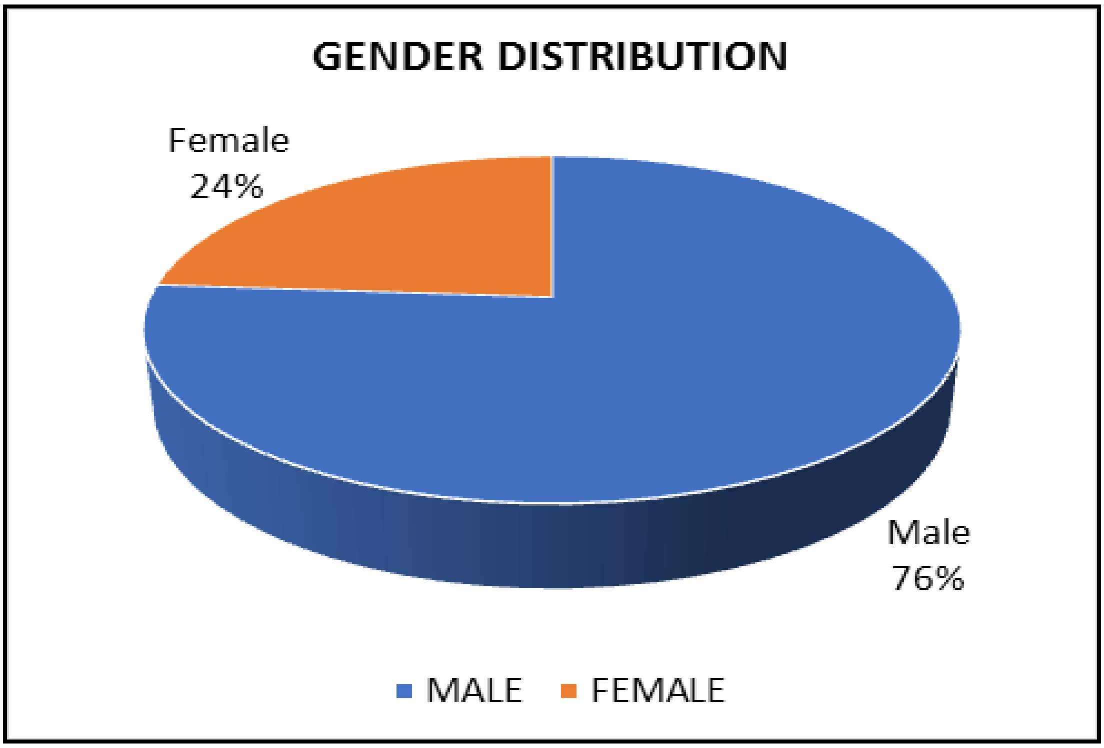
In our study method of fixation is internal (85%) compared to external (15%). The most common method of fixation is cancellous screw fixation (53%) followed by intramedullary nailing (26%).

**AGE DISTRIBUTION**

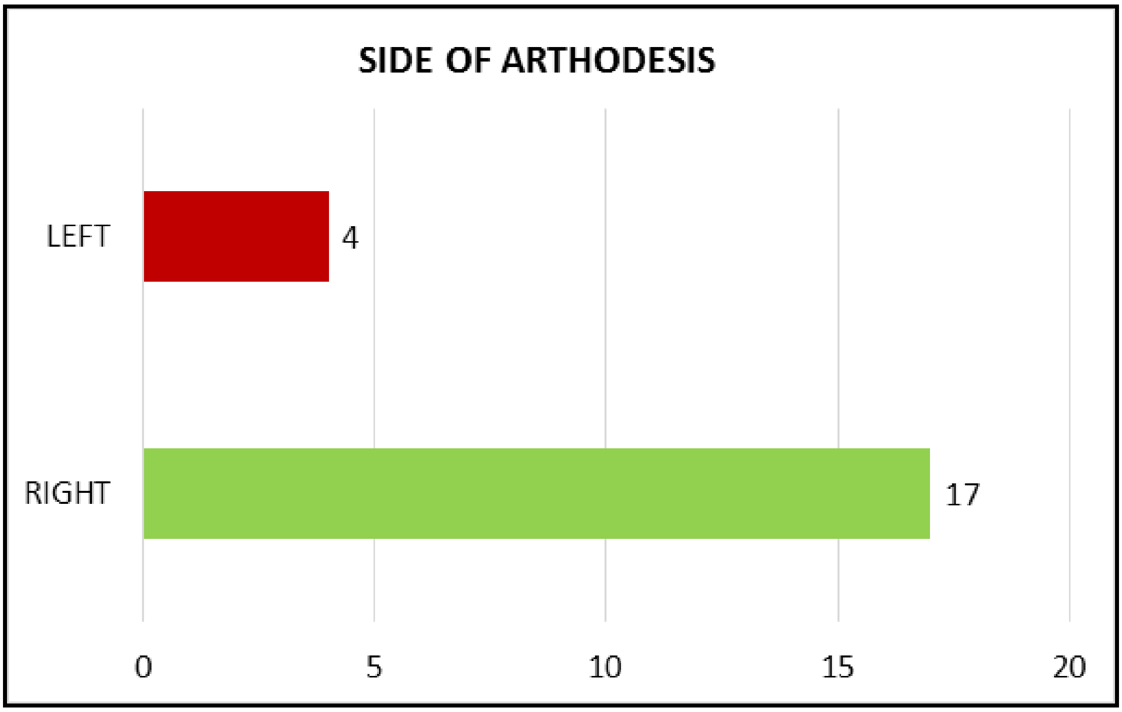
***RANGE: 28-65 YEARS***



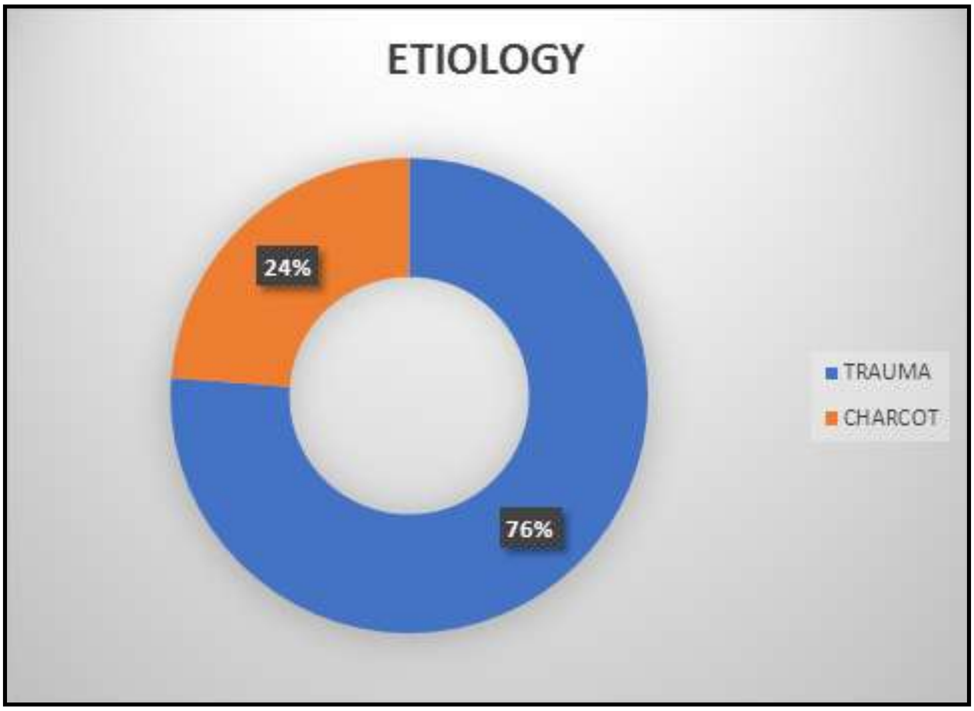
**GENDER DISTRIBUTION**



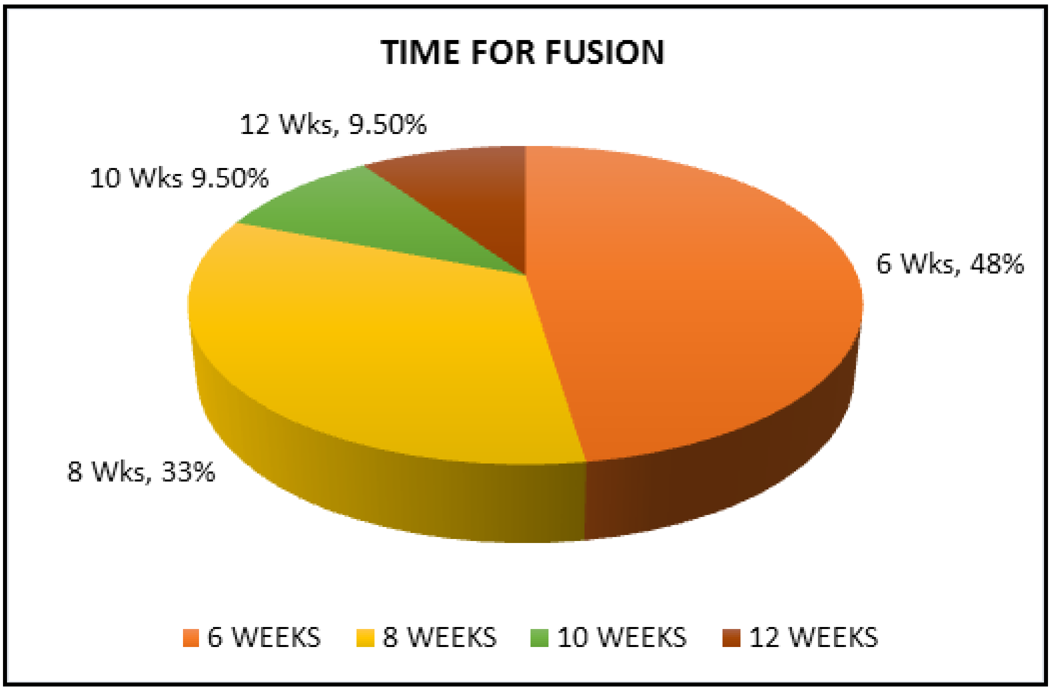

**SIDE OF ARTHRODESIS**



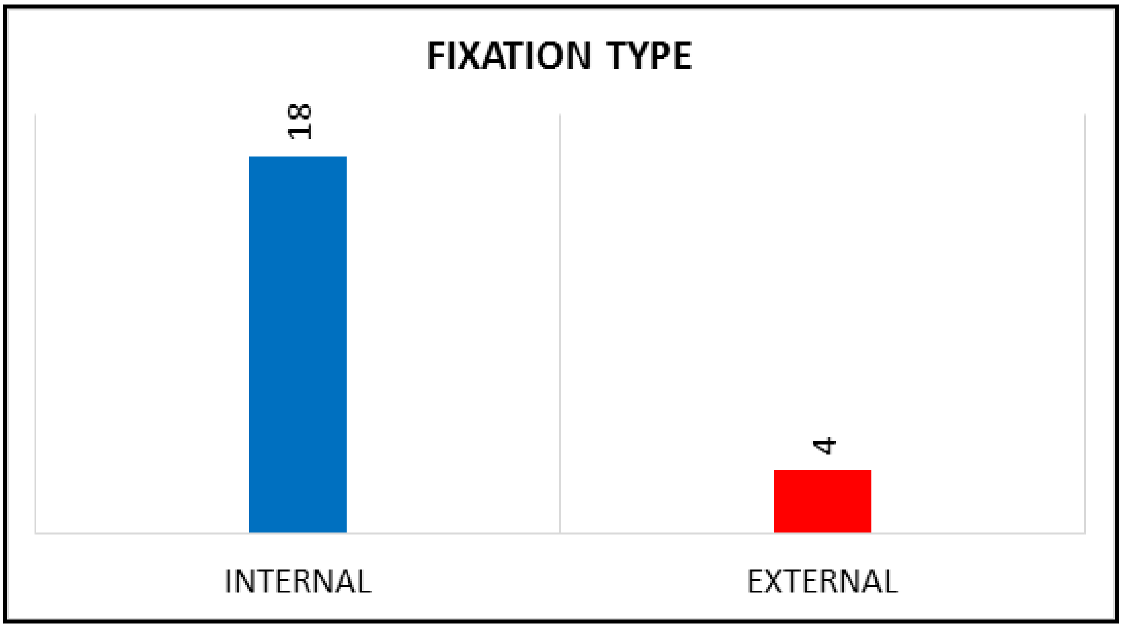
## ETIOLOGY FOR ARTHRITIS



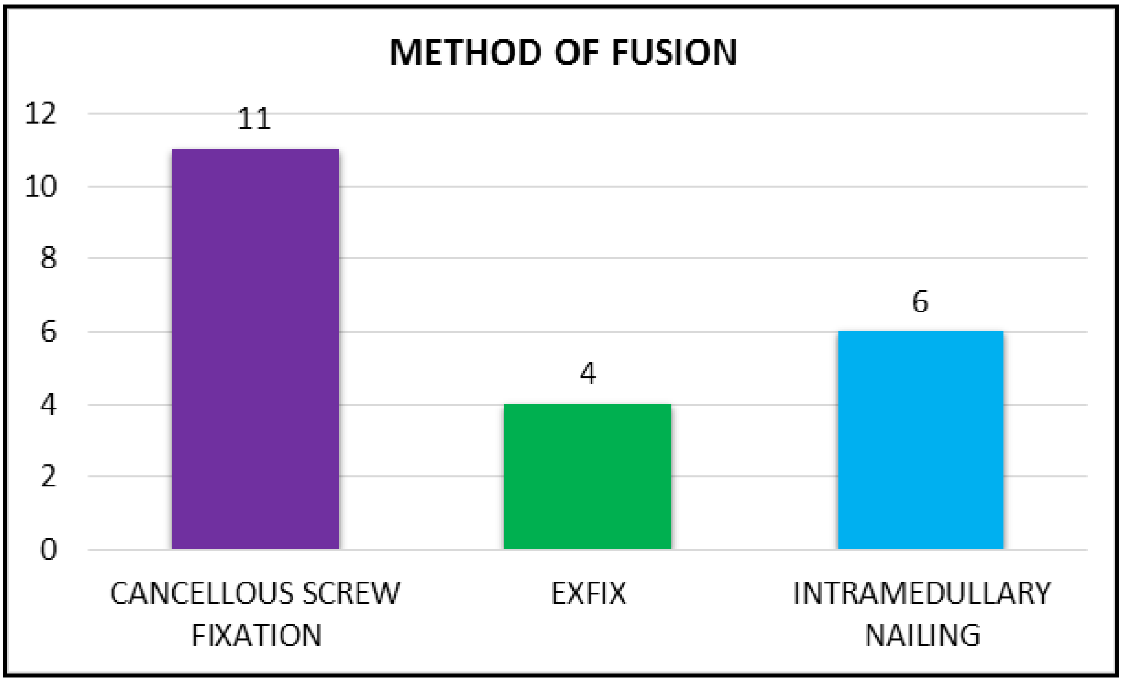

## TIME TAKEN FOR FUSION



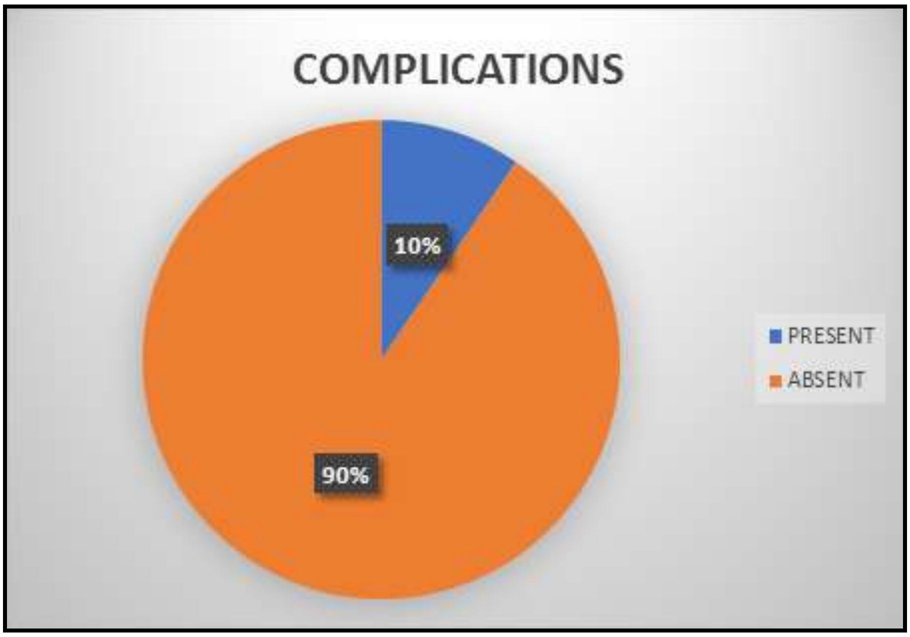
## METHOD OF FIXATION



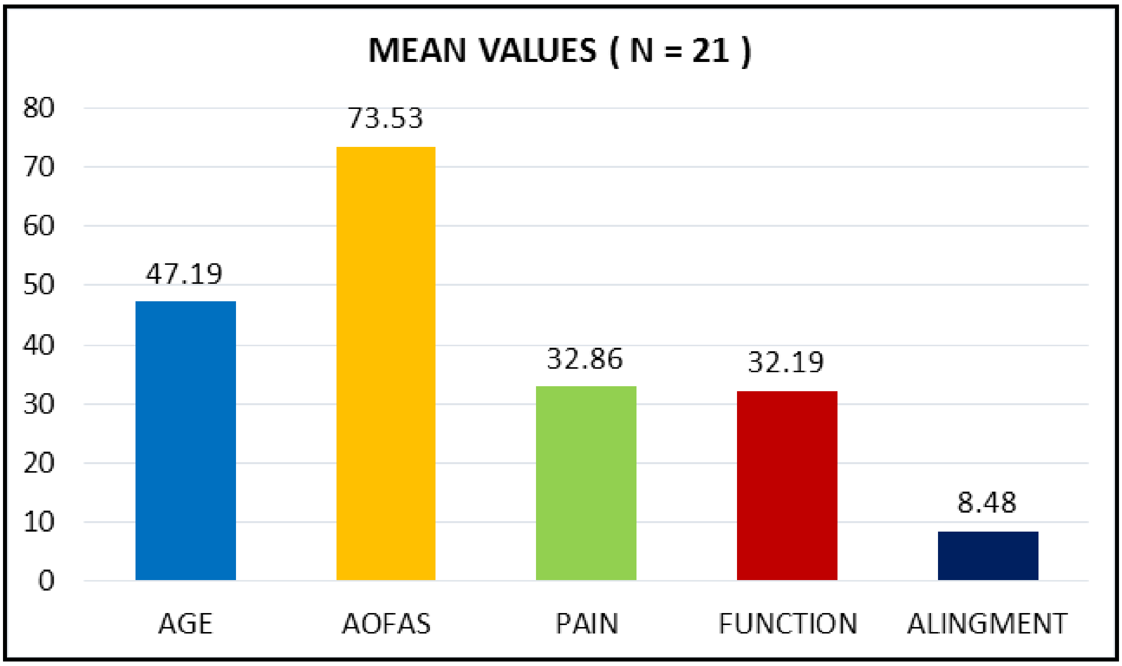

## METHOD OF FUSION



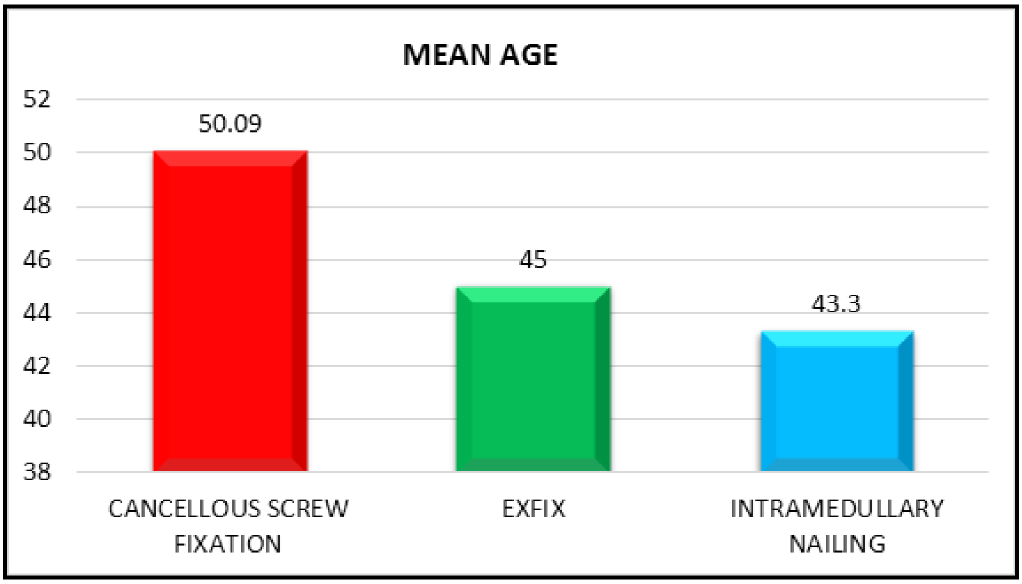
## COMPLICATIONS




## GENERAL CHARACTERISTICS

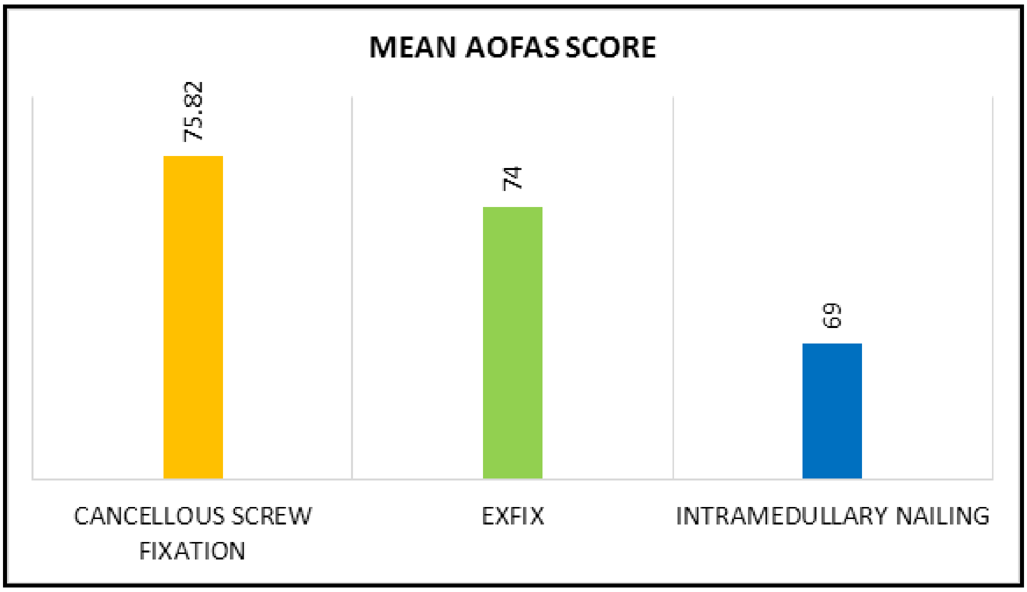


## AGE COMPARISON WITH ARTHRODESIS METHOD



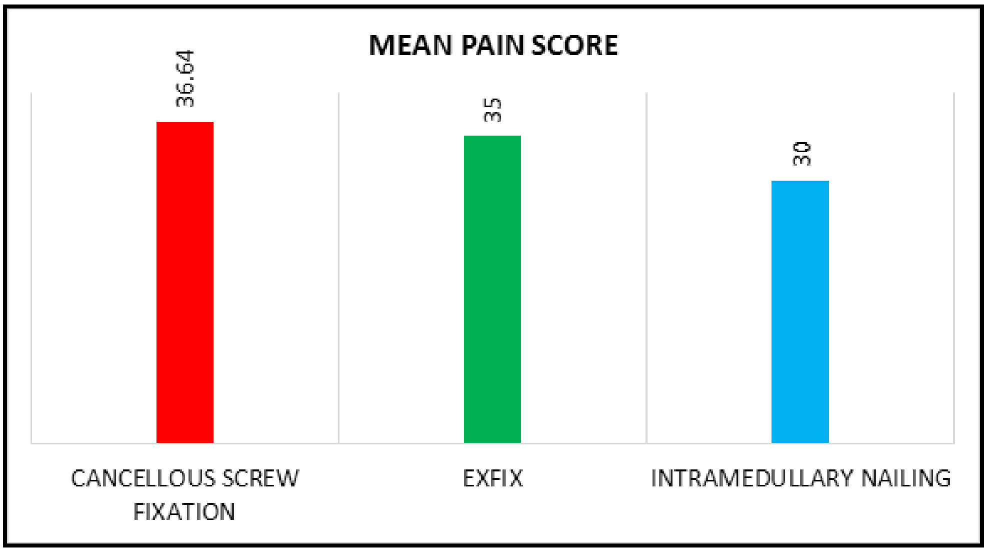

Though there is difference in mean age of patients in all three groups there is not statistical significance with P value of 0.465.

## AOFAS SCORE



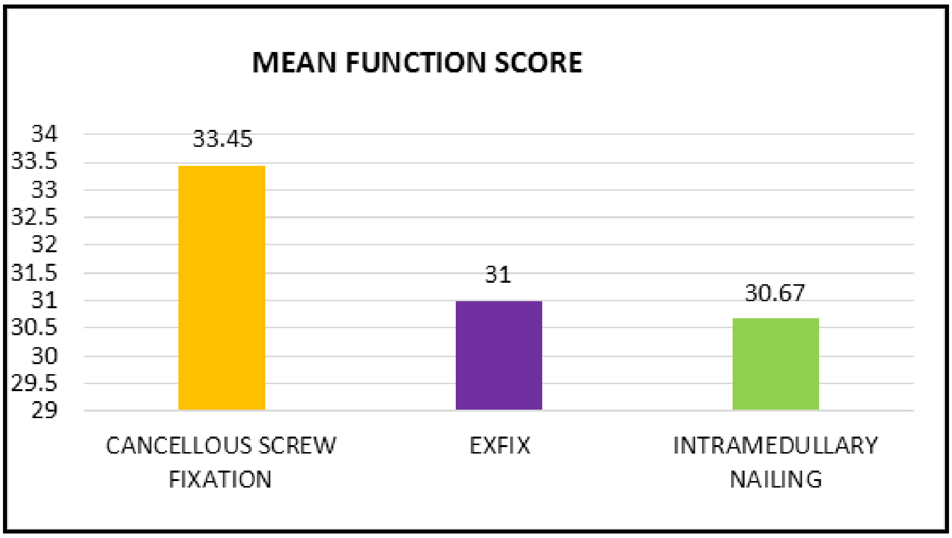

AOFAS score shows that cancellous screw fixation has better outcome when compared to other fixation with stastical significance of P value=0.046.

## AOFAS COMPONENT-PAIN SCORE



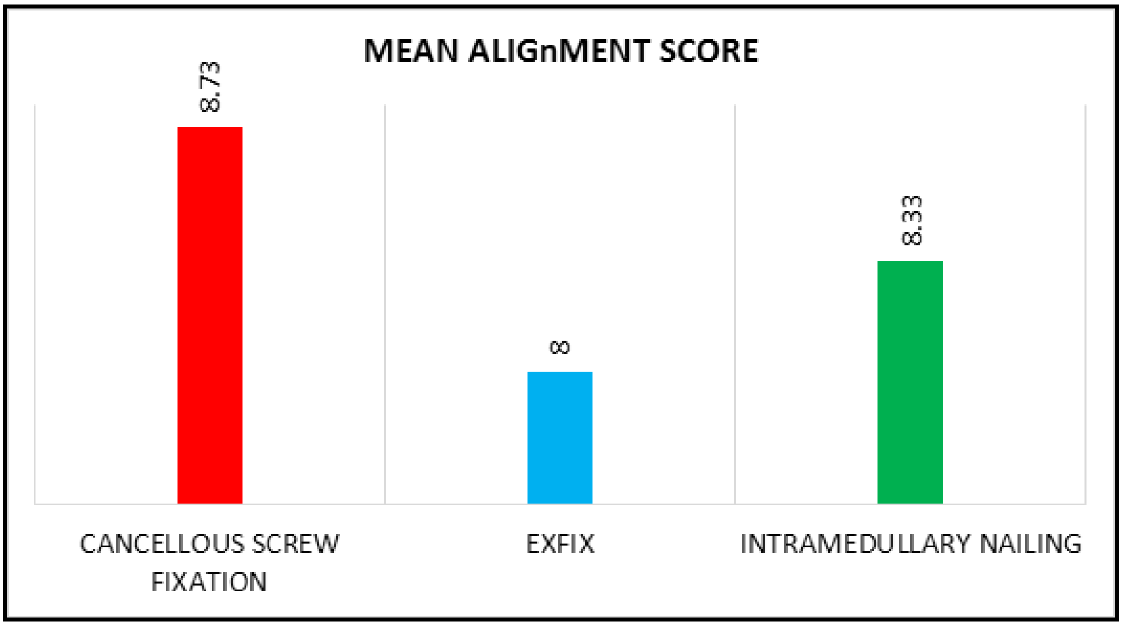

There is mean diffence between PAIN score between all three groups among which cancellous screw fixation has a better score .But this is not statistically significant with P value of 0.430.

## AOFAS COMPONENT-FUNCTION SCORE



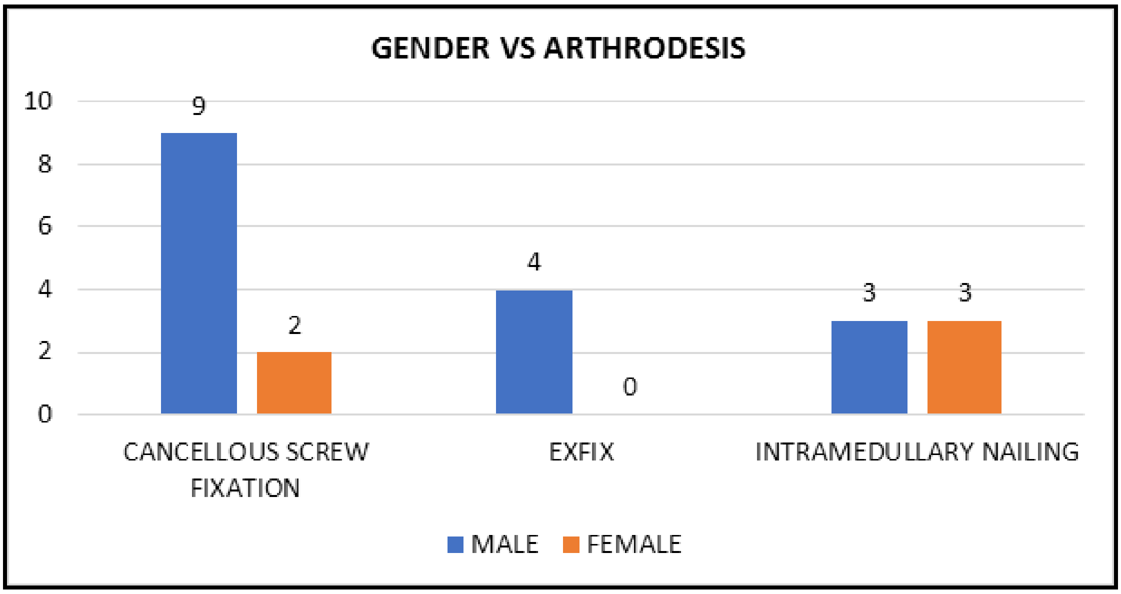

There is mean diffence between mean function score between all three groups among which cancellous screw fixation has a better score .This is also statistically significant with P value of 0.039.

## ALIGNMENT SCORE




There is mean difference between mean alignment score between all three groups among which cancellous screw fixation has a better score .But this is statistically not significant with P value of 0.34.

## GENDER INFLUENCE ON ARTHRODESIS METHOD

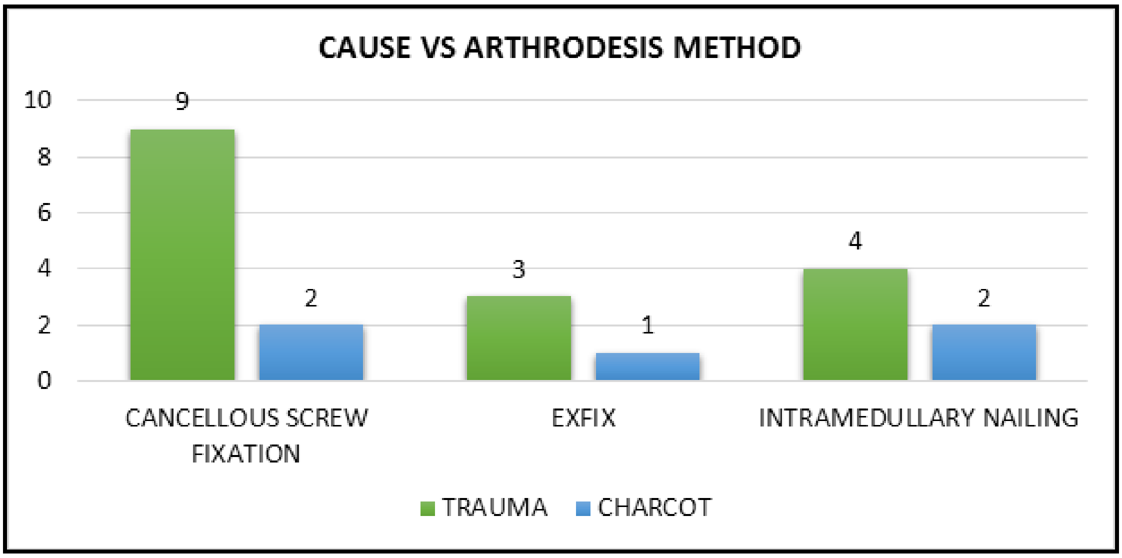


## SIDE VS TYPE OF ARTHRODESIS

| Arthrodesis method | Side of arthodesis | |
|---|---|---|
| | Right | Left |
| CANCELLOUS SCREW FIXATION | 10(58.8%) | 1(25%) |
| EXFIX | 3(17.6%) | 1(25%) |
| INTRAMEDULLARY NAILING | 4(23.6%) | 2(50%) |
| TOTAL | 17 | 4 |
| P VALUE - 0.451 | | |
| NON SIGNIFICANT | | |
| KRUSKAL WALLIS TEST | | |

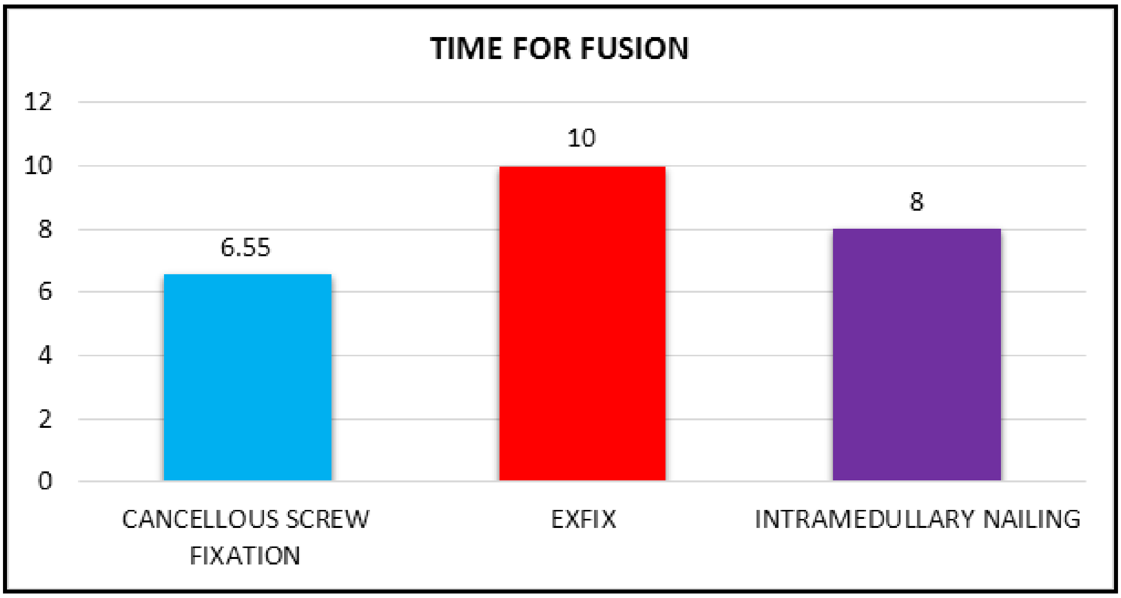
Though most patient has undergone surgery in their right leg, such influence is not statistically significant with P value of 0.451.

## CAUSE VS TYPE OF ARTHRODESIS




Best method of fixation for post traumatic arthritis is Cancellous screw fixation. Best method of fixation for charcot'arthropathy is Intramedullary Nailing.

## TIME FOR FUSION




Time taken for fusion is very minimal in cancellous screw fixation compared to other two procedures. This is also statistically significant with P value of 0.003.

# DISCUSSION

In our study of 21 patients, the most common indication for ankle arthrodesis is post traumatic arthritis. Lisa M Coester et al, in his study of long term results following ankle arthrodesis, the most common indication for ankle fusion is post traumatic arthritis. Similarly Mohammed et al, Aly et al, Zwipp et al and Coughlin et al, in their studies say that the most common indication for surgery is post traumatic arthritis. Nakul et al ,in his study of 11 patients did ankle arthrodesis for charcot's arthropathy.Ankle arthrodesis for endstage arthritis reduces pain and gives good patient satisfaction[87].However adequate information should be given to the patient preoperatively regarding potential hindfoot arthritis and need of second procedure in future[88]. Gait analysis of tibio-talo- calcaneal arthrodesis for associated subtalar arthritis and ankle arthrodesis(tibio- talar) show that compensatory hypermobility at small joints is responsible for the secondary arthritis[89,90,91].

The overall mean age of patients in our study is 47.19 years. This result is comparable with Kiene et al study, where the mean age was 45.4 years. Other studies like Coughlin et al had a mean age of 59.7 years, Zwipp et al 53 years and Nakul et al 56 years. Aly et al in 2009 showed in his study on arthrodesis by plate osteosynthesis in 29 patients, that the mean age was 26 years probably because charcots arthropathy was not included in his study.

The male to female ratio in our study is 3.2:1, which is slightly higher than other studies. Kiene et al reported a male to female ratio of 2.39:1 while Aly at al reported 2.625:1. In other studies like Nakul et al, Lisa et al, the male to female ratio is approximately 1:1. Mohammed et al showed that in his study the ratio of 2:1.

In our study, External Fixator was applied for 4 patients with mean age of  patients is 45years.There were no complications in patients treated with external fixator such as infection or nonunion, but patient treated with external fixator took longer duration for union with a mean duration of 10 weeks.The functional AOFAS outcome was good and the score was 74.Kiene et al, in his study of 95 patients with external fixation ,the mean age was 45.4 years.The mean duration of fusion was 12 weeks.The mean AOFAS score was good(69.3).Complications present in his study are pinsite infection,non union and need for secondary procedures.Nakul et al,in his study of 6 patients with external fixation,the mean age was 56 years.The fusion rate was 16.7%(only one achieved bony arthrodesis).Nonunion occurred in 4 out of 6 patiens.

Nakul et al had reported ankle arthrodesis by intramedullary nailing in patients with charcots arthropathy in which, the mean time to union is 16 weeks which is higher than our study, the mean time to union being 8 weeks. But both studies have a union rate of 100%. Also, in our study there were no complications in patients treated with intramedullary nail.

The mean union by cancellous screw fixation is 6.55 weeks in our study, which is better than other studies. Richard et al showed 12 weeks and Doughlas et al 9.2 weeks. But most studies have described that failure of union is least wth cancellous screw method and that this method gives better AOFAS score than other methods. Our study had AOFAS score of 75.82(good) in patients treated with screws. Zwipp et al has produced 85 score with this method and Doughlas et al has reported a score of 77, which is better than other methods of ankle arthrodesis.

Zwipp et al used standard screw technique of arthrodesis and showed that internal fixation methods in particular, with screws provide better AOFAS score(mean score84.7) than other methods of arthrodesis. Their study also revealed that screw fixation had the highest union rate(98.9%). This is comparable with our study, where the mean AOFAS score is 72.94 and the highest AOFAS score is by the screw fixation method- 75.82. Many other studies like Kennedy et al, Smith and Wood have also similar results with highest rate of bone union and least complications and a good AOFAS score in long term follow up studies.

There is sufficient evidence in literature to suggest that nonunion rates are higher in patients with charcot’s neuropathy, postinfectious arthrodesis and in those who smoke.[84,85,86]. In our study, 5 patients had charcot’s arthropathy, out of which, 1 patient was treated with external fixator while others with internal fixation methods. Mean duration to union in patients with charcot’s arthropathy was 8.4 weeks which is slightly higher than the mean union duration of 7.6 weeks.

Our study has no failure of fixation even though the methods of external fixation which has been reported to have high non union rates than internal fixation.Non union following internal fixation for ankle arthrodesis have been mentioned in literature and the numbers range from 0 to 7%. Kiene et al study gives a consolidated report of the literature review from 1985 to 2003, where in total 345 patients treated by various methods of internal fixation, 17 patients had non union which is 4% with the highest rate of non union in 3 studies of about 7.1%. Nakul et al showed in his study that the union rate by external fixator is only 16.79%.. As mentioned earlier the mean duration to union by external fixation is 11.3 weeks (10- 12 weeks) , longer than methods of internal fixation. This is comparable with the Kiene et al study, where the mean union is 12.3 weeks (8- 16 weeks).

In our study, 11 cases were treated with cancellous screws and complications were seen in two patients. The other treatment modalities were not encountered with any complications in the post operative period. But the cancellous screw fixation method seems to give better functional score than other methods of fixation. Also the duration to stable fusion is shortest with screw fixation.

# CONCLUSION

With the above results it can be seen that, cancellous screw fixation is the most common method of arthrodesis which provides best result in terms of function and union. Though intramedullary nailing is also equally effective, correct patient selection is needed and this method is suitable for treatment of charcot's arthropathy. External fixator though cumbersome for the patient and requires long time for bone union, is useful in compound fractures with bone loss.

There is no age difference between the genders, mean age at arthrodesis being 47 years. The range of AOFAS score is between 56 to 91, mean being 72.94. Again the AOFAS score is maximum with cancellous screw fixation. Thus the best method of ankle arthrodesis is by cannulated cancellous screw fixation, followed by intramedullary nailing. Ankle arthrodesis is a reliable method for post traumatic arthritis that provide good outcome to the patient and relief of pain.

# BIBLIOGRAPHY


1) American Orthopaedic Foot and Ankle Society Orthopaedic Foot and Ankle Outreach and Education 6300N River Road ,Suite 510.

2) The journal of bone & joint surgery jbjs.org volume 83-a number 2 february 2001 lisa m. Coester, md, charles l. Saltzman, md, john leupold, md, and william pontarelli, md . Long-Term Results Following Ankle Arthrodesis for Post-Traumatic Arthritis.

3) Ankle Arthrodesis: A Literature Review Patrick A. Deheer, dpma,*, Shirley M. Catoire, dpmb, Jessica Taulman, dpmc, Brandon Borer, DPM

4) American Orthopaedic Foot and Ankle Society Orthopaedic Foot and Ankle Outreach and Education 6300N River Road ,Suite 510.

5) Anterior Ankle Arthrodesis with Molded Plate Technique and Outcomes Mohammad Gharehdaghi, MD; Hasan Rahimi, MD; Alireza Mousavian, MD ABJS-2-203

6) Tibiotarsal compression arthrodesis using a lateral locking plate michael j. coughlin1, caio nery2, daniel baumfeld3, james jastifer4

7) The Journal of Foot & Ankle Surgery (2014) 1–4 A Biomechanical Comparison of Internal Fixation Techniques for Ankle Arthrodesis Craig Clifford, DPM, AACFAS 1, Scott Berg, DPM 2, Kevin mccann, DPM, AACFAS 3,Byron Hutchinson, DPM, FACFAS 4

8) Ankle Arthrodesis: A Literature Review Patrick A. Deheer, dpma,*, Shirley M. Catoire, dpmb, Jessica Taulman, dpmc, Brandon Borer, DPM

9) Ankle Arthrodesis: A Literature Review Patrick A. Deheer, dpma,*, Shirley M. Catoire, dpmb, Jessica Taulman, dpmc, Brandon Borer, DPM

10) Anterior Ankle Arthrodesis with Molded Plate Technique and Outcomes . Mohammad Gharehdaghi, MD; Hasan Rahimi, MD; Alireza Mousavian, MD ABJS-2-203

11) The principles of foot and ankle arthrodesis . Lee Parker Dishan Singh

12) Ankle Arthrodesis: A Literature Review Patrick A. Deheer, dpma,*, Shirley M. Catoire, dpmb, Jessica Taulman, dpmc, Brandon Borer, DPM

13) Ankle Arthrodesis: A Literature Review Patrick A. Deheer, dpma,*, Shirley M. Catoire, dpmb, Jessica Taulman, dpmc, Brandon Borer, DPM

14) The principles of foot and ankle arthrodesis. Lee Parker Dishan

15) Tibiotalar Arthrodesis.Eric M. Bluman, MD, phd, and Christopher P. Chiodo, MD

16) Tibiotalar Arthrodesis.Eric M. Bluman, MD, phd, and Christopher P. Chiodo, MD

17) Tibiotalar Arthrodesis. Eric M. Bluman, MD, phd, and Christopher P. Chiodo, MD

18) Gait and Posture 11 (2000) 54–61 Gait analysis after ankle arthrodesis. Wen-Lan Wu a, Fong-Chin Su a,*, Yuh-Min Cheng b, Pen-Ju Huang b,You Li Chou a, Cheng-Kuo Chou

19) Gait and Posture 11 (2000) 54–61. Gait analysis after ankle arthrodesis Wen-Lan Wu a, Fong-Chin Su a,*, Yuh-Min Cheng b, Pen-Ju Huang b,You-Li Chou a, Cheng-Kuo Chou

20) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

21) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

22) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

23) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

24) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

25) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

26) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

27) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

28) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

29) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

30) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

31) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

32) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

33) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

34) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

35) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

36) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

37) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

38) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

39) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

40) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

41) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

42) Rockwood & Green's Fractures in Adults, 8th Edition P2542-2546

43) Foot and Ankle Surgery 14 (2008) 1–10 Ankle arthrodesis Aneel Nihal M.D., FRCS (Orth.)A, Richard E. Gellman M.D.b,c, John M. Embil M.D., frcpcd,e, Elly Trepman M.D.e,f,g,

44) Foot and Ankle Surgery 14 (2008) 1–10 Ankle arthrodesis Aneel Nihal M.D., FRCS (Orth.)A, Richard E. Gellman M.D.b,c, John M. Embil M.D., frcpcd,e, Elly Trepman M.D.e,f,g,

45) Foot and Ankle Surgery 14 (2008) 1–10 Ankle arthrodesis Aneel Nihal M.D., FRCS (Orth.)A, Richard E. Gellman M.D.b,c, John M. Embil M.D., frcpcd,e, Elly Trepman M.D.e,f,g,

46) Campbell Operative Orthopaedics 12th edition P511-523

47) Campbell Operative Orthopaedics 12th edition P511-523

48) Campbell Operative Orthopaedics 12th edition P511-523

49) Campbell Operative Orthopaedics 12th edition P511-523

50) Campbell Operative Orthopaedics 12th edition P511-523

51) Campbell Operative Orthopaedics 12th edition P511-523

52) Campbell Operative Orthopaedics 12th edition P511-523

53) Campbell Operative Orthopaedics 12th edition P511-523

54) Campbell Operative Orthopaedics 12th edition P511-523

55) Campbell Operative Orthopaedics 12th edition P511-523

56) Campbell Operative Orthopaedics 12th edition P511-523

57) Campbell Operative Orthopaedics 12th edition P511-523

58) Campbell Operative Orthopaedics 12th edition P511-523

59) Campbell Operative Orthopaedics 12th edition P511-523

60) Campbell Operative Orthopaedics 12th edition P511-523

61) Campbell Operative Orthopaedics 12th edition P511-523

62) Campbell Operative Orthopaedics 12th edition P511-523

63) Foot and Ankle Surgery 14 (2008) 1–10 Ankle arthrodesis Aneel Nihal M.D., FRCS (Orth.)A, Richard E. Gellman M.D.b,c, John M. Embil M.D., frcpcd,e, Elly Trepman M.D.e,f,g,

64) Foot and Ankle Surgery 14 (2008) 1–10 Ankle arthrodesis Aneel Nihal M.D., FRCS (Orth.)A, Richard E. Gellman M.D.b,c, John M. Embil M.D., frcpcd,e, Elly Trepman M.D.e,f,g,

65) Foot and Ankle Surgery 14 (2008) 1–10 Ankle arthrodesis Aneel Nihal M.D., FRCS (Orth.)A, Richard E. Gellman M.D.b,c, John M. Embil M.D., frcpcd,e, Elly Trepman M.D.e,f,g,

66) Foot and Ankle Surgery 14 (2008) 1–10 Ankle arthrodesis Aneel Nihal M.D., FRCS (Orth.)A, Richard E. Gellman M.D.b,c, John M. Embil M.D., frcpcd,e, Elly Trepman M.D.e,f,g,

67) Ankle Arthrodesis: A Literature Review Patrick A. Deheer, dpma,*, Shirley M. Catoire, dpmb, Jessica Taulman, dpmc, Brandon Borer, DPM

68) Ankle Arthrodesis: A Literature Review Patrick A. Deheer, dpma,*, Shirley M. Catoire, dpmb, Jessica Taulman, dpmc, Brandon Borer, DPM

69) Charnley J. Compression arthrodesis of the ankle and shoulder. J Bone Joint Surg 1951; Vol 33 B / No 2 180 – 91

70) Buchner M, Sabo D. External or internal fixation for arthrodesis of the ankle – a comparative study of perioperative and long-term results. Unfallchirurg 2003; 106 472 – 77

71) Helm R. The results of ankle arthrodesis. J Bone Joint Surg 1990; Vol 72-B / No 1 141 – 43

72) Moeckel BH, Patterson BM, Inglis AE, Sculco TP. Ankle arthrodesis: A comparison of internal and external fixation. Clin Orthop Rel Res 1991; 268 78 – 83

73) Pilette S, Huk OL, Yahia L, Fowles JV. Comparative biomechanical evalution of the immediate stability of three fixators in arthrodesis of the ankle. Ann Chir 1993; 47 (9) 905 – 11

74) Scranton PE, Fu FH, Brown TD. Ankle arthrodesis: A comparative clinical and biomechanical evalution. Clin Orthop Rel Res 1980; 151 234 – 243

75) Thermann H, Hufner T, Roehler A, Tscherne H. Screw arthrodesis of the ankle joint. Technique and outcome. Orthopäde 1996; 25 166 – 76

76) Cierny, g., 3rd, w.g. Cook, and J.t. Mader, ankle arthrodesis in the presence of ongoing sepsis. Indications, methods, and results. Orthop clin north am, 1989. 20(4): p. 709-21

77) Berman, a.t., et al., compression arthrodesis of the ankle by triangular external fixation: an improved technique. Orthopedics, 1989. 12(10): p. 1327-30.

78) willms, R. And l. Gotzen, [Monolateral external compression arthrodesis of the upper ankle joint]. Unfallchirurg, 1990. 93(3): p. 115-9

79) Kennedy JG, Hodgkins CW, Brodsky A, Bohne WH. Outcomes after standardized screw fixation technique of ankle arthrodesis. Clin Orthop Relat Res. 2006;447:112–118

80) Morgan CD, Henke JA, Bailey RW, Kaufer H. Long-term results of tibiotalar arthrodesis. J Bone Joint Surg Am. 1985;67:546–550

81) Abdo RV, Wasilewski SA. Ankle arthrodesis: a long-term study. Foot Ankle. 1992;13:307–312

82) Buck P, Morrey BF, Chao EY. The optimum position of arthrodesis of the ankle. J Bone Joint Surg Am. 1987;69:1052–1062.

83) Mazur JM, Schwartz E, Simon SR. Ankle arthrodesis. Long-term follow-up with gait analysis. J Bone Joint Surg Am. 1979;61:964–975.

84) Fragomen AT, Borst E, Schachter L, Lyman S, Rozbruch SR. Complex ankle arthrodesis using the Ilizarov method yields high rate of fusion. Clin Orthop Relat Res. 2012;470:2864–2873.

85) Herscovici D, Sammarco GJ, Sammarco VJ, Scaduto JM. Pantalar arthrodesis for post-traumatic arthritis and diabetic neuroarthropathy of the ankle and hindfoot. Foot Ankle Int. 2011; 32:581–588

86) Myers TG, Lowery NJ, Frykberg RG, Wukich DK. Ankle and hindfoot fusions: comparison of outcomes in patients with and without diabetes. Foot Ankle Int. 2012;33:20–28.

87) Thomas T, Daniels TR, Parker K (2006) Gait analysis and functional outcomes following ankle arthrodesis for isolated ankle arthritis. J Bone Joint Surg 88A:526–535

88) Aly Mohamedean & Hatem G. Said & Mohammad El-Sharkawi & Wael El-Adly & Galal Z. Technique and short-term results of ankle arthrodesis using anterior plating. Said International Orthopaedics (SICOT) (2010) 34:833–837)

89) Beyaert C, Sirveaux F, Paysant J, Molé D, André JM: The effect of tibio-talar arthrodesis on foot kinematics and ground reaction force progression during walking. Gait Posture 2004, 20(1):84–91.

90) Thomas R, Daniels TR, Parker K: Gait analysis and functional outcomes following ankle arthrodesis for isolated ankle arthritis. J Bone Joint Surg Am2006,88(3):526–535.

91) Sealey RJ, Myerson MS, Molloy A, Gamba C, Jeng C, Kalesan B: Sagittal plane motion of the hindfoot following ankle arthrodesis: a prospective analysis. Foot Ankle Int 2009, 30(3):187–196.

92) IOTRA(institute of orthopaedics and traumatology research analysis).

# CASE STUDY-ANKLE ARTHRODESIS

1. Name:
2. Age/Sex:
3. Address:
4. Phone No:
5. Mode of Injury/Duration:
6. Associated Comorbidies:
7. Associated Foot Comorbidies:
8. Diagnosis:
9. Preop xray ankle AP/Lat/Mortise view:
10. Preop CT ankle:
11. P/D:
12. Postop xray:
13. Postop Functional Score:
14. Radiological Fusion:
15. Complication:
16. Rehabilitation Protocol:

## INSTITUTIONAL ETHICS COMMITTEE
## MADRAS MEDICAL COLLEGE, CHENNAI 600 003

EC Reg.No.ECR/270/Inst./TN/2013
Telephone No.044 25305301
Fax: 011 25363970

**CERTIFICATE OF APPROVAL**

To
**Dr. P.S. Vignesh**
**Post Graduate , MS (Orthopaedic Surgery)**
**Institute of Orthopaedics & Traumatology**
**Madras Medical College,**
**Chennai**

Dear ,

The Institutional Ethics Committee has considered your request and approved your study titled **"RETROSPECTIVE PROSPECTIVE AND COMPARATIVE ANALYSIS OF FUNCTIONAL OUTCOME FOLLOWING VARIOUS MODALITIES OF ANKLE FUSION " NO.18092016** .

The following members of Ethics Committee were present in the meeting hold on **06.09.2016** conducted at Madras Medical College, Chennai 3

| | |
|---|---|
| 1. Prof. C. Rajendran, MD. | Chairperson |
| 2. Prof. Dr. M.K. Muralidharan, M.S, M.Ch., MMC ,Ch-3 | Deputy Chairperson |
| 3. Prof. Sudha Seshayyan, MD., Vice Principal, MMC.Ch- 3. | Member Secretary |
| 4. Prof. B.Vasanthi,MD.,Prof of Pharmacology, MMC, | Member |
| 5. Prof. P.Raghumani.MS., Professor of Surgery, Inst. of surgery | Member |
| 6. Prof. R.Padmavathy,MD., Professor, Inst.of Pathology, MMC,Ch | Member |
| 7. Tmt.J.Rajalakshmi, Junior Administrative Officer,MMC,Ch | Layperson |
| 8. Thiru.S.Govindasamy., B.A.B.L., High Court, Chennai-1 | Lawyer |
| 9. Tmt.ArnoldSaulina, MA., MSW., | Social Scientist |

We approve the proposal to be conducted in its presented form.

The Institutional Ethics Committee expects to be informed about the progress of the study and SAE occurring in the course of the study, any changes in the protocol and patients information/informed consent and asks to be provided a copy of the final report.

23/9/16

Member Secretary – Ethics Committee

MEMBER SECRETARY
INSTITUTIONAL ETHICS COMMITTEE
MADRAS MEDICAL COLLEGE
CHENNAI-600 003

# ஒப்புதல் படிவம்

ஆராய்ச்சி மையம்: **இராஜீவ் காந்தி அரசு பொது மருத்துவமனை மற்றும் மருத்துவக் கல்லூரி, சென்னை.**

நோயாளியின் பெயர்: நோயாளியின் வயது:

பதிவு எண்:

நோயாளி கீழ்கண்டவற்றுள் கட்டங்களை (✓) செய்யவும்

1. மேற்குறிப்பிட்டுள்ள ஆராய்ச்சியின் நோக்கத்தையும் பயனையும் முழுவதுமாக புரிந்து கொண்டேன். மேலும் எனது அனைத்து சந்தேகங்களையும் கேட்டு அதற்கான விளக்கங்களையும் தெளிவுபடுத்திக் கொண்டேன்.
2. மேலும் இந்த ஆராய்ச்சிக்கு எனது சொந்த விருப்பத்தின் பேரில் பங்கேற்கிறேன் என்றும், மேலும் எந்த நேரத்திலும் எவ்வித முன்னறிவிப்புமின்றி இந்த ஆராய்ச்சியிலிருந்து விலக முழுமையான உரிமை உள்ளதையும், இதற்கு எவ்விட சட்ட பிணைப்பும் இல்லை என்பதையும் அறிவேன்.
3. ஆராய்ச்சியாளரோ, ஆராய்ச்சி உதவியாளரோ, ஆராய்ச்சி உபயத்தாரோ, ஆராய்ச்சி பேராசிரியரோ, ஒழுங்குநெறி செயற்குழு உறுப்பினர்களோ எப்போது வேண்டுமானாலும் எனது அனுமதியின்றி எனது உள்நோயாளி பதிவுகளை இந்த ஆராய்ச்சிக்காகவோ அல்லது எதிர்கால பிற ஆராய்ச்சிகளுக்காகவோ பயன்படுத்திக் கொள்ளலாம் என்றும், மேலும் இந்த நிபந்தனை நான் இவ்வாராய்ச்சியிலிருந்து விலகினாலும் தகும் என்றும் ஒப்புக் கொள்கிறேன். ஆயினும் எனது அடையாளம் சம்பந்தப்பட்ட எந்த பதிவுகளும் (சட்டப்பூர்வமான தேவைகள் தவிர) வெளியிடப்படமாட்டாது என்ற உறுதிமொழியின் பெயரில் இந்த ஆராய்ச்சியிலிருந்து கிடைக்கப்பெறும் முடிவுகளை வெளியிட மறுப்பு தெரிவிக்கமாட்டேன் என்று உறுதியளிக்கிறேன்
4. இந்த ஆராய்ச்சிக்கு நான் முழுமனதுடன் சம்மதிக்கிறேன் என்றும் மேலும் ஆராய்ச்சிக் குழுவினர் எனக்கு அளிக்கும் அறிவுரைகளை தவறாது பின்பற்றுவேன் என்றும் இந்த ஆராய்ச்சி காலம் முழுவதும் எனது உடல் நிலையில் ஏதேனும் மாற்றமோ அல்லது எதிர்பாராத பாதகமான விளைவோ ஏற்படுமாயின் உடனடியாக ஆராய்ச்சி குழுவினரை அணுகுவேன் என்றும் உறுதியளிக்கிறேன்.
5. இந்த ஆராய்ச்சிக்குத் தேவைப்படும் அனைத்து மருத்துவப் பரிசோதனைகளுக்கும் ஒத்துழைப்பு தருவேன் என்று உறுதியளிக்கின்றேன்.
6. இந்த ஆராய்ச்சிக்கு யாருடைய வற்புறுத்தலுமின்றி சொந்த விருப்பத்தின் பேரிலும் சுய அறிவுடனும் முழுமனதுடனும் சம்மதிக்கிறேன் என்று இதன் மூலம் ஒப்புக் கொள்கிறேன்.

நோயாளியின் கையொப்பம்/ ஆராய்ச்சியாளரின் கையொப்பம்

பெருவிரல் ரேகை

இடம்: தேதி:

# Urkund Analysis Result

| | |
|---|---|
| **Analysed Document:** | thesis1.pdf (D31421666) |
| **Submitted:** | 10/18/2017 9:32:00 AM |
| **Submitted By:** | vig8890@gmail.com |
| **Significance:** | 6 % |

## Sources included in the report:

thesis.docx (D31194183)
thesis final.docx (D31237764)
PLAGERISM - ANSAR.docx (D30524926)
https://www.louortho.com/documents/quill_second.pdf
https://link.springer.com/article/10.1007/s00068-010-0058-1
https://www.thefreelibrary.com/Total+ankle+replacement:+evolution+of+the+technology+and+future...-a0362607512

## Instances where selected sources appear:

26

## MASTER CHART

| case number | name | age | gender | side | cause | time to fusion(weeks) | fixation | methods | complications | results(AOFAS Score) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Rukkama | 42 | female | right | trauma | 6weeks | internal | Cancellous screw fixation | nil | 73 |
| 2 | Srinivasan | 64 | male | right | trauma | 6weeks | internal | cancellous screw fixation | nil | 83 |
| 3 | Rajendran | 48 | male | right | trauma | 6weeks | internal | cancellous screw fixation | nil | 76 |
| 4 | Rafi | 47 | male | left | trauma | 6weeks | internal | cancellous screw fixation | nil | 86 |
| 5 | Mohan raj | 53 | male | right | charcot | 8weeks | internal | cancellous screw fixation | nil | 68 |
| 6 | Noorjahan | 45 | female | right | trauma | 6weeks | internal | intramedullary nailing | nil | 68 |
| 7 | Rahim | 30 | male | right | trauma | 6weeks | internal | cancellous screw fixation | infection | 91 |
| 8 | Kasthuri | 48 | female | right | trauma | 6weeks | internal | cancellous screw fixation | nil | 78 |
| 9 | Vinayagamoorthy | 55 | male | right | charcot | 10weeks | external | exfix | nil | 86 |
| 10 | Sundaram | 65 | male | right | trauma | 6weeks | internal | exfix | nil | 76 |
| 11 | Vinitha | 50 | female | right | charcot | 8weeks | internal | intramedullary nailing | nil | 68 |
| 12 | Sugumar | 60 | male | right | charcot | 8weeks | internal | cancellous screw fixation | nil | 63 |
| 13 | Subbiah | 61 | male | right | trauma | 6weeks | internal | cancellous screw fixation | failed | 70 |
| 14 | Babu | 36 | male | left | trauma | 8weeks | internal | intramedullary nailing | nil | 56 |
| 15 | Kumaresan | 48 | male | right | trauma | 6weeks | internal | cancellous screw fixation | nil | 70 |
| 16 | Prabhu | 28 | male | right | trauma | 12weeks | external | exfix | nil | 68 |
| 17 | Selvaraj | 50 | male | right | trauma | 8weeks | internal | cancellous screw fixation | nil | 76 |
| 18 | Karthick | 32 | male | left | trauma | 12weeks | external | exfix | nil | 66 |
| 19 | Boominathan | 29 | male | left | trauma | 10weeks | internal | intramedullary nailing | nil | 68 |
| 20 | Subramani | 50 | male | right | charcot | 8weeks | internal | intramedullary nailing | nil | 68 |
| 21 | Shanthi | 50 | female | right | trauma | 8weeks | internal | intramedullary nailing | nil | 86 |