CLINICAL AND RADIOLOGICAL EVALUATION OF ANKLE MORBIDITY FOLLOWING LONG SEGMENT FIBULA GRAFT HARVESTING

By

DR. MOHD YUSOF IBRAHIM

M.D. (UKM)

Dissertation Submitted in Partial Fulfillment of The Requirements For The Degree of Master Of Medicine (Orthopedics)

UNIVERSITY SAINS MALAYSIA

2001

TABLE OF CONTENTS

Section C: CLINICAL AND RADIOLOGICAL EVALUATION OF THE ANKLE MORBIDITY FOLLOWING LONG SEGMENT FIBULAR GRAFT HARVESTING

List of tables **page**

List of figures **page**

List of Abbreviation

AP view	antero-posterior view
ASI	anterior syndesmotic interval
CT scan	Computed Tomography scan
HUSM	Hospital University Sains Malaysia
MRI	Magnetic Resonance Imaging
NWB	non-weight bearing
PSI	posterior syndesmotic interval
RDLF	residual distal length of fibula
RPLF	residual proximal length of fibula
SI	syndesmotic interval
TCS	tibiofibular clear space
TFO	tibiofibular overlap
WB	weight bearing

ACKNOWLEDGEMENT

Bismillahirrahmanirrahim...

I thank God for His mercy and help. Eventually I managed to finish this dissertation, even though at the initial stage, there were a lot of problems and obstacles in the way.

Acknowledgements to all contributors of my dissertation are beyond name mentioning. I am forever indebted to my research supervisors; Assoc. Prof. Dr. Zulmi Wan, a Consultant in Orthopedic and Musculoskletal Oncology as well as Head of Department of Orthopedic HUSM and Dr Abdul Sukari Halim, the Head Co-ordinator of Reconstructive Sciences Unit of HUSM. Both of them had contributed a lot in guiding me to materialize this study, which has always been a yesterday's dream. Thanks for the incessant encouragements and guidance that tremendously helped me to ensure this study was successfully proceeded

I would like also like to thank to Dr. Mahyuddin Mohammad, consultant Radiologist of HUSM, who was also involved in this study; thank you for the radiological assessment and services. Not forgetting, Pn. Rohani, a radiographer for her willingness in helping me perform the CT scan ankle on every patient at a needed time.

My sincere thanks to my other teachers, Assoc. Prof. A.S. Devnani, Dr. Nordin Simbak, Dr. Abdul Halim, Dr. Iskandar, Dr. Aidura, Dr. Faisham and Dr. Razak for their ideas and support which had motivated me not only in completing this *dissertation, but more importantly for the four years programme of post-graduate studies in Orthopedic. Not to forget my former teachers Dr. Ruslan Razak (now in Pantai Hospital, Ipoh), Dr. Ibrahim Mokhti (now in Penawar Hospital, Johor Bharu), Dr. Zulkifli Abd. Rashid (now in Southern Specialist Hospital, Melaka) and Dr. Marwan Hassan (now in Palestine)*

To my wife, Dr. Mariana Daud, and my sons, Khairul Fikri and Khairul Fahmi thank you very much for everything. This world is a whole lot nicer and meaningful with all of you around. Without your love, support and encouragement I would have not been able to get through this project as well as my post-graduate training. May Allah bless all of you.

ABSTRAK

Tajuk:
KAJIAN KLINIKAL DAN RADIOLOGI KE ATAS MORBIDITI SENDI PERGELANGAN KAKI SELEPAS PENGAMBILAN GRAFT SEGMEN PANJANG TULANG FIBULA

Pengenalan

Fibula graft adalah satu teknik untuk mengembalikan keutuhan tulang rangka akibat kecacatan tulang. Walaupun teknik ini amat berguna, namun banyak laporan berkaitan masalah di kawasan di mana tulang ini diambil (kawasan penderma) terutamanya berkaitan sendi pergelangan kaki.

Objektif

Untuk mengenal pasti simptom-simptom, tanda-tanda klinikal dan perubahan-perubahan radiologi dan kaitannya dengan ketidakstabilan sendi pergelangan kaki selepas pegambilan segmen panjang tulang fibula.

Cara kajian

Ini adalah kajian kohort keatas pesakit-pesakit yang telah menjalani pengambilan graft segmen panjang tulang fibula sekurang-kurangnya 15 sm. Seramai sembilan pesakit berumur 12 hingga 64 tahun terlibat dalam kajian ini. Sembilan pasang kaki telah diperiksa dengan kaki sebelah berlawanan (kontralateral) yang normal sebagai kontrol. Kajian keatas morbiditi sendi pergelangan kaki adalah secara temuramah langsung dan pemeriksaan klinikal. Kajian objektif keatas simptom-simptom subjektif berkaitan morbiditi sendi pergelangan kaki adalah berdasarkan sistem permarkahan kaki Maryland

(Maryland Foot Score). Kajian radiologi termasuklah pengambilan X-ray secara pandangan sidesmosis sendi pergelangan kaki untuk kedua-dua keadaan, semasa berdiri dan semasa berbaring. Kajian keatas kedudukkan hujung malleolus luar berbanding dengan hujung malleolus dalam dijalankan. Darjah kecondongan baki tulang fibula sendi kaki diukur. Image CT scan secara melintang di kedudukan 9 mm diatas plafond tulang tibia dikaji dan pengukuran jarak sindesmosis depan dan belakang dijalankan. Purata kedua-dua jarak ini diambil sebagai jarak sindesmosis sendi pergelangan kaki tersebut manakala perbezaan kedua-duanya mengambarkan rotasi tulang fibula dikedudukan sindesmosis. Perbandingan dengan kaki sebelah normal dilakukan. Analisis statistik menggunakan ujian T-test berpasangan dijalankan untuk menganalisis hasil keputusan-keputusan pengukuran kaki sebelah penderma graft tulang fibula berbanding dengan sebelah yang normal.

Keputusan

Analisis keatas simptoms-simptom subjektif menghasilkan markah diantara 78 hingga 99% berdasarkan analisis menggunakan sistem permarkahan kaki Marryland (Maryland Foot score scoring system). Darjah purata pergerakan fleksi plantar (loaded plantar flexion) untuk sendi buku lalai penderma ialah 46.33° manakala sebelah kaki yang normal ialah 48.11°. Darjah purata pergerakan fleksi dorsi (loaded dorsi flexion) untuk sendi pergelangan kaki penderma ialah 27.78° manakala sebelah kaki yang normal ialah 30.89° . Perubahan osteoporosis keatas baki tulang fibula distal sebelah kaki penderma terjadi sebanyak 89 % daripada keseluruhan subjek kajian. Disebelah sendi pergelangan kaki yang normal, hujung malleolus luar adalah berkedudukan lebih bawah berbanding hujung malleolus dalam dengan purata 9.22 mm semasa berbaring dan jarak bertambah kepada 11.33 mm semasa berdiri. Disebelah sendi pergelangan kaki penderma, hujung malleolus luar juga adalah lebih bawah daripada hujung malleolus dalam dengan purata hanya 7.33 mm semasa berbaring dan jarak ini menjadi lebih pendek semasa berdiri iaitu kepada 6.56 mm. Darjah kecondongan tulang fibula sebelah kaki yang normal yang diukur melalui filem X-ray pada kedudukan sindesmosis ialah 90.33° semasa berbaring dan bertambah kepada 91.67° semasa berdiri manakala purata darjah kecondongan baki tulang fibula distal sebelah kaki penderma ialah 90.11° semasa berbaring dan menjadi semasa kurang kepada 88.22° semasa berdiri. Jarak sindesmosis belakang kedua-dua sendi pergelangan kaki normal dan penderma adalah lebih besar daripada jarak sindesmosis depan. Purata jarak sindesmosis tibial-fibula di kedudukan 9 mm diatas plafond tibia ialah 2.939 mm manakala sebelah kaki sebelah penderma ialah 3.500mm. Purata perbezaan antara jarak sindesmosis hadapan dan belakang ialah 1.700 mm di sebelah kaki normal dan 2.022 mm di sebelah kaki penderma.

<u>**Kesimpulan**</u>

Walaupun perubahan-perubahan radiologi ke atas baki tulang fibula hujung dan sendi pergelangan kaki adalah signifikan, tetapi analisis symptom-simptom yang subjektif ke atas morbiditi sendi pergelangan kaki memberikan keputusan yang bagus atau memberansangkan (excellent). Markah analisis keatas simptom-simptom subjektif adalah menurun apabila baki tulang fibula hujung adalah kurang dari[pada 5.5 cm. Meninggalkan tulang fibula hujung dengan baki sekurang-kurangnya 7 cm adalah dicadangkan untuk mengurangkan simptom-simptom ketakstabilan sendi pergelangan kaki.

ABSTRACT

Title:
CLINICAL AND RADIOLOGICAL EVALUATION OF THE ANKLE MORBIDITY FOLLOWING LONG SEGMENT FIBULAR GRAFT HARVESTING

Introduction

Fibular graft is a useful technique to restore skeletal integrity of bony defects. Despite the benefits of this procedure, there are some reported problems associated with donor site, particularly with regards to ankle stability.

Objective

To determine the clinical signs and symptoms, as well as radiographic findings and their correlation with ankle stability following a long segment fibular graft resection

Methodology

A cohort study was performed on patients who had undergone long segment fibular graft resection of minimum 15 cm in length. A total of nine patients ranging from 12 to 64 years old were included in the study and the assessment performed after a minimum of 4 months following the operation. Nine pairs of legs were evaluated with contralateral normal legs as control. The assessment for ankle morbidity was based on interviews and physical examination. The objective assessment for subjective symptoms of ankle morbidity was done based on Maryland Foot scoring system. Radiological assessments included plain radiograph in syndesmotic views, on both non-weight bearing supine position and weight bearing standing position. The distance of the tip of lateral

malleolus in relation to the tip of medial malleolus was assessed. The tilting angle of the residual distal fibula was measured. The axial CT scan slice done at the level of 9 mm above the tibial plafond was assessed to measure the anterior and posterior syndesmotic interval. The average of this two intervals was used as the syndesmotic interval of the ankle, whereas the difference between the two was used to determine the rotation of the fibula. The comparison was made with the contralateral normal ankle. Statistical analysis using student-t test was performed to assess the results of the donors' ankle as compared to the normal ankle.

Results

Subjective assessments revealed score ranging from 78 to 99% according to Maryland Foot scoring system. The average plantar flexion of the donors' ankles was 46.33°, compared to the normal ankles of 48.11°. The average range of loaded dorsiflexion of the donors' ankles was 27.78° compared to 30.89° of the normal ankles. Osteoporosis of distal fibula of the donors' side was present in 89 %. In normal ankles, the tip of lateral malleolus were distal than tip of medial malleolus with the average of 9.22 mm during non-weight bearing, and increased to 11.33 mm with weight bearing. In donors' ankles, the tip of lateral malleolus were also distal than tip of medial malleolus but with the average of 7.33 mm during non-weight bearing, and further decreased to 6.56 mm on weight bearing. The mean tilting angle of distal fibula of normal legs on syndesmotic view of plain radiograph was 90.33° with non-weight bearing, and increased to 91.67° with weight bearing. However the mean tilting angle for distal fibula of donors' legs on syndesmotic view of plain radiograph was 90.11°

with non-weight bearing but decreased further to 88.22° with weight bearing. Both normal and donors' ankles had posterior syndesmotic interval greater than anterior interval. The average width of tibiofibular interval at 9 mm above the tibial plafond of normal ankles was 2.939 mm, whereas for the donors' ankles was 3.500 mm. The average difference of anterior and posterior interval in the normal ankles was 1.700 mm and 2.022 mm for the donors' ankles.

Conclusion

Despite the significant radiological changes of the residual distal fibula and the ankle, the subjective assessment of the ankle morbidity yielded good or excellent results. The residual distal fibula of 5.5 cm or less was ascociated with a low score of less than 85%. Leaving a minimum of 7 cm length of the residual distal fibula is advisable to minimize symptoms of ankle instability.

1.0 Introduction

The vascularized autogenous fibular graft is a useful tool and represent the state-of-the art technique to restore skeletal integrity for bony defects existed congenitally, following trauma or tumor excision. There are only a limited number of centers having the capability in performing this procedure. Hospital University Sains Malaysia Kubang Kerian, Kelantan is one of those. This is a teaching hospital and a tertiary referral center for musculoskeletal tumors and major maxillofacial reconstructive surgery.

Despite the well-documented benefits of this procedure, there are problems associated with this technique. Ankle instability is one of the major concerns following the resection of fibular graft. There were many studies, which have tried to relate the incidence of this complication with the residual length of distal fibula. Ankle instability following a resection of long segment fibular graft was related to the extremely short residual distal fibula length, often less than 6-8 cm. However, to my knowledge there was no explanation given to the causes of instability. However, a constant observation in short residual fibular length following fibula harvesting was a proximal migration of fibula. Thus, the purpose of this study is to objectively measure the effects on functional daily activity to the patient and radiographic changes onto the ankle joint particularly distal tibiofibular syndesmosis and residual distal fibula following a long segment fibular graft harvesting

2.0 RELEVANT ANATOMY AND MOVEMENT OF THE ANKLE

The ankle is a complex joint consisting of functional articulations between the tibia and fibula, tibia and talus, and the fibula and talus. Each articulation is supported by a group of ligaments. The tibia and fibula form a mortise. This provides a constrained articulation for the talus or tenon. Both the articular surface of the distal tibia (tibial plafond) and the mortise are wider superiorly and anteriorly to accommodate the wedge-shaped talus. The shape of the joint alone provides some intrinsic stability, especially in weight bearing (Fig. 2.0.1). (Mc Cullough 1980)

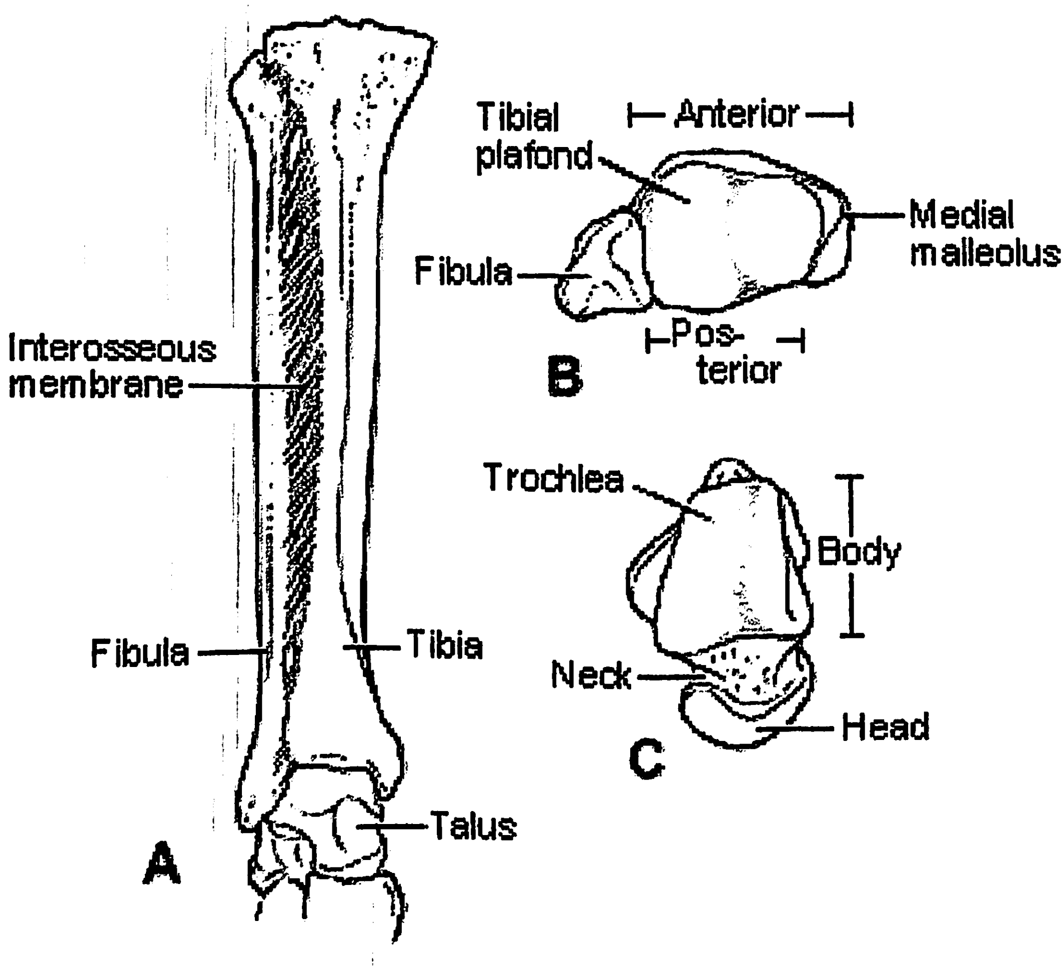

Fig. 2.1: Anatomy of the ankle; (A) Anteroposterior view (B), View of the tibial side of the joint illustrating the quadrilateral shape of the articular surface and the posterolateral position of the fibula, (C) the corresponding surface of the talus.

2.1 Bone

Stability of the ankle joint is due to a combination of the bony architecture, the joint capsule, and the ligaments. The medial malleolus is an extension of the distal tibia. The inner surface is covered with articular cartilage and articulates with the medial facet of the talus. The distal, inner surface of the malleolus is divided by a longitudinal groove into a large, anterior colliculus and a smaller, posterior colliculus. Each has an attachment site for a portion of the deltoid ligament. There is also a groove on the posterior surface malleolus where the posterior tibial tendon passes and where of the tendon sheath is attached to.

The fibula provides lateral support for the ankle. Just above the ankle joint, the fibula sits in a groove formed by a broad anterior tubercle and a smaller posterior tubercle of the tibia. There is no articular surface between the distal tibia and fibula, even though there is a small amount of motion between these two bones. The medial border of the fibula is covered by an articular cartilage from the level of the tibia plafond to a point approximately halfway down its remaining length. The distal end is tapered and has a posterior groove for the peroneal tendon.

The talus has a curved head, an intermediate neck portion, and a large trapezoidal body. It articulates with the navicular, calcaneus, tibia, and fibula. The body of the talus is almost entirely covered by articular cartilage. The superior surface is convex from front to back and slightly concave from side to side. The dome of the talus is trapezoidal, and its anterior surface is an average of 2.5 mm (a range of 0 to 6 mm) wider than the posterior surface. The articular surfaces of the malleolus are also wider anteriorly to support the talus. The medial and lateral articular facets of the talus are continuous with its superior articular surface. The lateral facet is larger than the corresponding facet on the fibula. The majority of the talar neck has no articular surface. The multiple articular facets and lack of muscular attachments are evidence of the intercalary role of the talus in connecting the leg to the foot.

2.2 Ligaments

Three distinct groups of ligaments support the ankle joint: the syndesmosis, medial collateral, and lateral collateral ligaments.

2.2.1 Deltoid ligament.

The deltoid ligament provides the medial ligamentous support of the ankle. This strong, dense, fan-shaped structure arises from the medial malleolus and consists of a superficial and deep layer (Fig. 2.2.).

The superficial deltoid ligament originates primarily from the anterior colliculus of the medial malleolus. It extends in three bands to the navicular and along the plantar calcaneonavicular (spring) ligament, to the sustentaculum tali of the calcaneus, and to the medial tubercle of the talus. The tibionavicular portion suspends the spring ligament and prevents inward displacement of the head of the talus, while the tibiocalcaneal portion prevents valgus displacement. The superficial deltoid is also partially covered by tendon sheaths and crural fascia.

The deep deltoid ligament originates from the posterior border of the anterior colliculus, the intercollicular groove, and the posterior colliculus. It is oriented transversely and inserts into the entire nonarticular surface of the medial talus. This ligament extends the function of the medial malleolus and prevents lateral displacement of the talus.

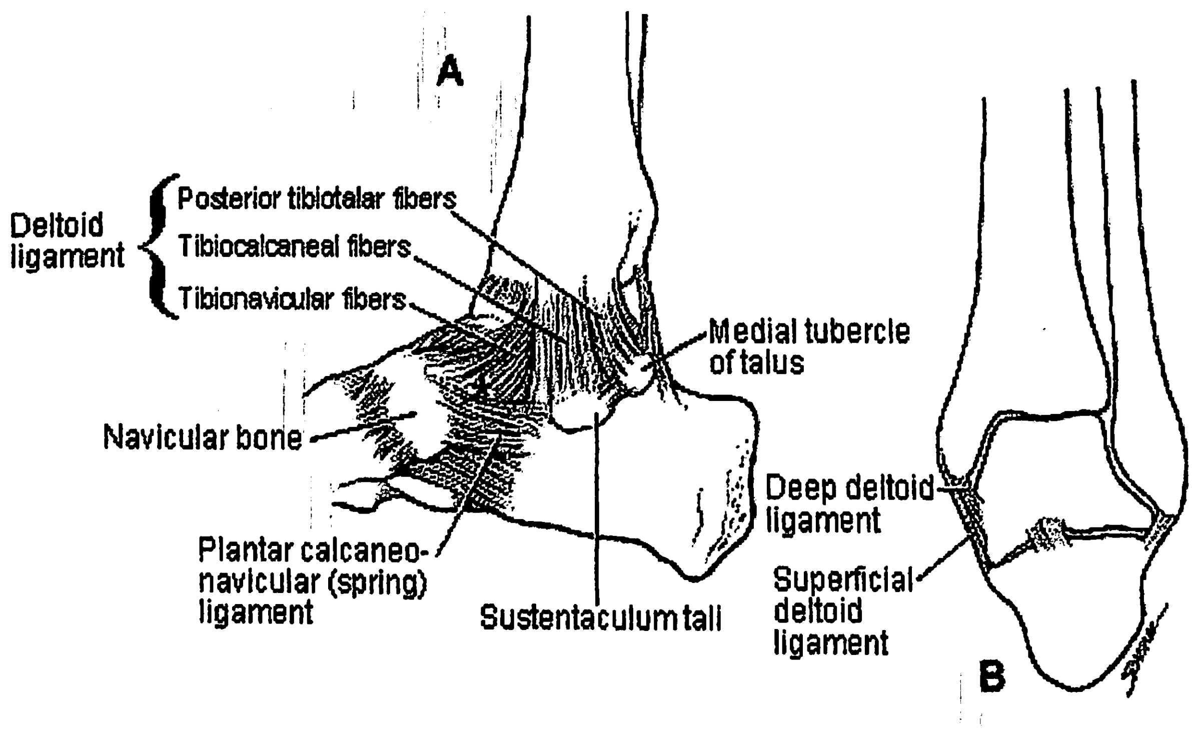

Fig. 2.2. Medial aspect of the ankle joint, showing the ligaments.

2.2.2 Lateral ankle ligaments

The fibular collateral ligament is made up of three separate structures (Fig. 2.3). They are not as strong as the medial ligaments as the fibula also provides lateral support for the ankle. The anterior talofibular ligament is the weakest of these ligaments. It connects the anterior fibula to the neck of the talus and prevents anterior subluxation of the talus when the ankle is in plantar flexion. The midportion of this ligament is confluent with the capsule of the ankle. This area overlies a ridge formed by the anterior border of the lateral articular facet of the talus. This ridge may injure the ligament when the ankle is in a plantar flexed position.

The **anterior talofibular ligament** runs anteriorly to the neck of the talus. Burks et al. (1994) studied the anatomy of the lateral ankle ligaments in a cadaver dissection involving 39 specimens. He noted that the anterior talofibular ligament had an average length of 24.8 mm and directed at an average of 44.8° medially from the fibula to the talus. The center of the ligament bulk was located at an average of 10.1 mm proximal to the tip of fibula. This was measured along the long axis of the fibula. Its insertion was at an average of 18.1 mm proximal to the subtalar joint of the talus.

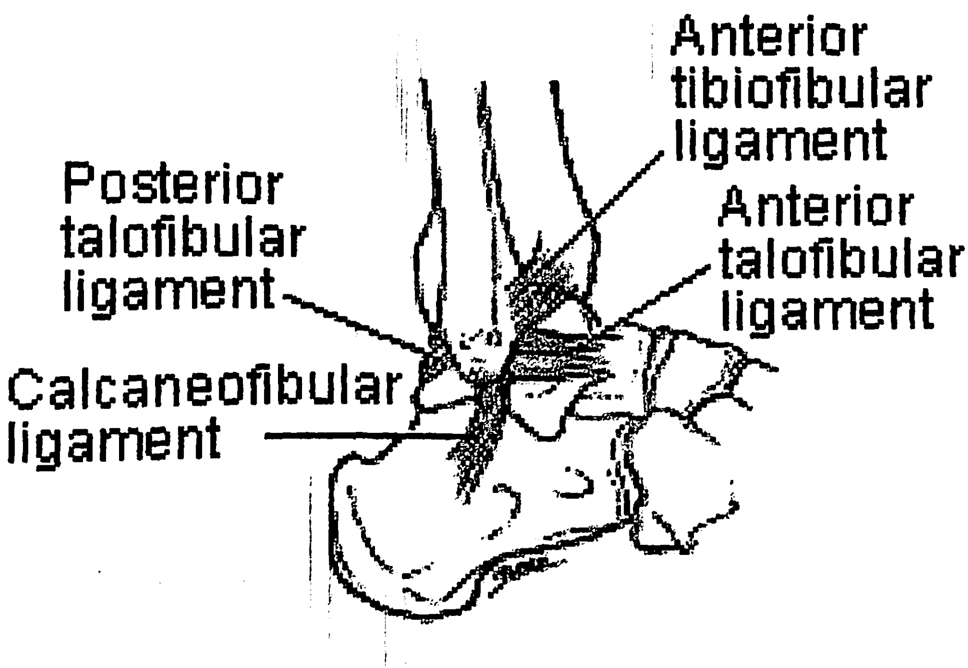

fig. 2.3: Lateral collateral ligaments with adjacent tibiofibular ligament

The **calcaneofibular ligament** runs vertically downward from the distal fibula to a small tubercle on the posterior and lateral aspect of the calcaneus. This ligament is not associated with either the ankle capsule or the peroneal tendon sheath. It is lax in the normal standing position, owing to the relative valgus orientation of the calcaneus. It acts primarily to stabilize the subtalar joint and limit inversion. Burks et al. (1994) noted that the calcaneofibular ligament had an average measurement of 5.3 mm wide, 35.8 mm long , and formed an angle of 133° with the fibula when the foot was in plantigrade.

The **posterior talofibular ligament** is deep-seated and arises from the nonarticular surface of the posteromedial fibula. It runs medially in a more horizontal plane to attach to an eminence on the lateral tubercle of the body of the talus lateral to the groove for the flexor hallucis longus tendon. It is the strongest of the lateral ligaments and prevents posterior and rotatory subluxation of the talus.

2.2.3 Syndesmotic ligament

The ligaments of the syndesmosis form a complex articulation that maintains the fibula closely approximated in the fibular notch. Interosseous membrane runs between the tibia and fibula at the level of the proximal tibiofibular joint. On the other hand the interosseous ligament is an inferior extension of interosseus membrane, and is a key transverse stabilizer of tibiofibular articulation.

The syndesmotic ligament complex maintains the integrity between the distal tibia and the fibula and resists the axial, rotational, and translation forces that attempt to separate these two bones. It is made up of four ligaments: (see fig. 2.4)

(1) the anterior tibiofibular ligament,

(2) the posterior tibiofibular ligament,

(3) the transverse tibiofibular ligament, and

(4) the interosseus ligament

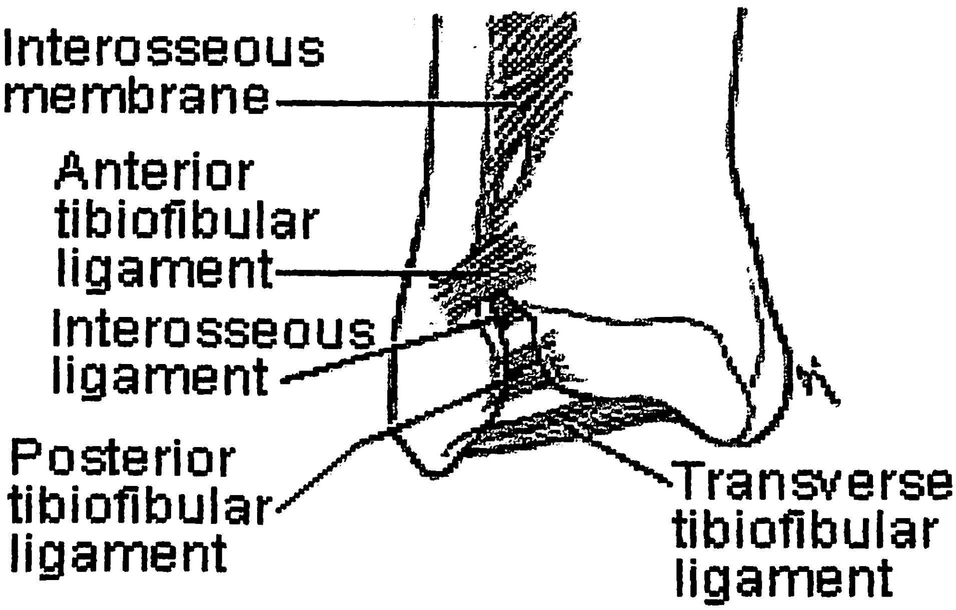

fig. 2.4: The syndesmotic ligament of the ankle.

The **anterior tibiofibular** ligament originates from the anterior tubercle and anterolateral surface of the tibia and runs obliquely to the anterior fibula. The **posterior tibiofibular** ligament originates from the posterolateral tubercle of the tibia and inserts onto the posterior fibula. It is stronger and thicker than its anterior counterpart. Owing to this difference, torsional or translational forces usually cause an avulsion fracture of the posterior tibia tubercle and rupture of the weak Anterior talofibular ligament, while leaving the posterior ligament intact, while the weaker anterior tibiofibular ligament usually ruptures.

The **transverse tibiofibular ligament** is often considered part of the posterior tibiofibular ligament complex and acts to deepen the posterior aspect of the ankle joint.

The **interosseous ligament** is an extension of the interosseous membrane and is the key transverse stabilizer of the tibiofibular articulation. The interosseous membrane runs between the tibia and fibula to the level of the proximal tibiofibular joint. It stabilizes the fibula, provides additional attachment sites for muscles, and may have some load-bearing functions. (Vulkicevic et al. 1980). The interosseous ligament is triangular with a proximal apex and a broad distal base. It is thinner in its midportion because of a perforating synovial pouch from the ankle joint.

2.3 Subtalar joints.

The subtalar joint is divided into two separate compartments with separate synovial cavities. The talocalcaneal interosseous ligament is the structure that divides the subtalar area into the posterior and anterior subtalar joints. This ligament binds the talus and calcaneus together, adding stability to the subtalar area.

2.4 Structures crossing the ankle

Ankle joint is crossed by thirteen tendons, two major arteries and veins, and five nerves (Fig. 2.5). The tendons are divided into four groups. The Achilles and plantaris tendons lie posteriorly in the midline and are not intimately associated with the ankle joint. The tibialis posterior, flexor digitorum longus, and flexor hallucis longus muscles are innervated by the tibial nerve. Their tendons pass posterior to the medial malleolus, held in position by the flexor retinaculum. The tibialis anterior, extensor digitorum longus, extensor hallucis longus, and peroneus tertius muscles are innervated by the deep peroneal nerve. Their tendons pass anterior to the ankle joint and are held in position by the thick, broad extensor retinaculum. The peroneus longus and brevis muscles are innervated by the superficial peroneal nerve, and their tendons are held in position behind the fibula by the peroneal retinaculum and peroneal tendon sheath.

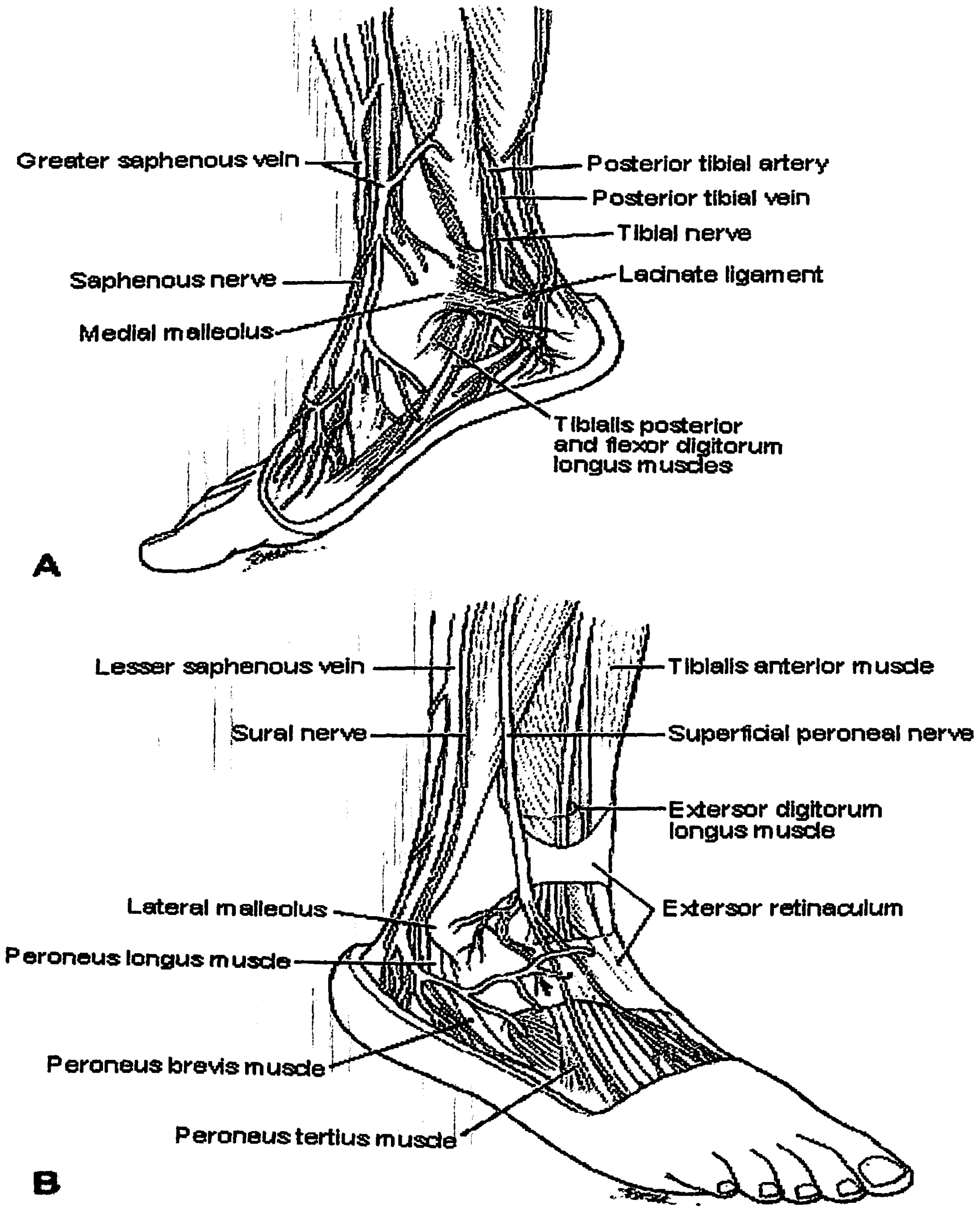

fig. 2.5: Superficial antomy of the ankle (A) Medial and (B) Lateral view

The anterior neurovascular bundle (anterior tibial artery and deep peroneal nerve) crosses the ankle beneath the extensor retinaculum. It is also passes between the tibialis anterior and the extensor hallucis longus tendons. The posterior neurovascular bundle (posterior tibial artery and tibial nerve) passes behind the medial malleolus within the flexor retinaculum. It lies between the flexor digitorum longus and flexor hallucis longus tendons. Three superficial sensory nerves cross the ankle. The saphenous nerve passes anterior to the medial malleolus, along with the long saphenous vein. It innervates the medial part of the foot. The superficial peroneal nerve is located just lateral to the anterior midline and supplies the skin of the dorsum of the foot. The sural nerve passes posterior to the fibula, along with the short saphenous vein, and supplies the non–weight-bearing lateral skin.

2.5 MOVEMENTS OF THE FOOT

2.5.1 Dorsiflexion and Plantar Flexion

Vertical movements of the foot involve motion in the tibiotalar joint and in the talocalcaneonavicular joint. Having no muscle attachments, talus cannot move alone. It has to follow the motions of the calcaneus and the navicular. Dorsiflexion of the tibiotalar joint is accompanied by pronation of the foot. Upward movement of the foot requires simultaneous relaxation of the triceps and the tibialis posterior. This permits a downward migration of the posterior tuberosity of the calcaneus as the anterior end of the calcaneus everts while the navicular moves laterally on the talus.

Plantarflexion is a combination of equinus, inversion, and adduction. In plantar flexion, the foot supinates because the tibialis posterior pulls the navicular medially. Via its attachment to the sustentaculum, tibialis posterior also inverts and pulls the anterior end of the calcaneus downward. At the same time, the triceps surae pulls the posterior tuberosity of the calcaneus upward. The triceps and the tibialis posterior are the only extrinsic muscles that which insert on the calcaneus. As they both plantar flex and invert the heel, equinus, varus, and adduction take place simultaneously and not as separate isolated movements of the foot.

Full dorsiflexion and plantar flexion are not possible without motion in the talocalcanconavicular complex.

2.5.2 Horizontal Motion

Movements at the talonavicular and the anterior and posterior subtalar joints elicit horizontal motions . The anterior end of the calcaneus and the navicular move together around the talar head. Majority of horizontal motion takes place at the talonavicular and the anterior subtalar joints. Less movement occurs in the posterior subtalar joint. The calcaneocuboid joint has a very limited gliding mobility as the cuboid moves with the calcaneus. For normal subtalar motion, the navicular has to be mobile and free to rotate around the talar head. The heel cannot be everted or inverted without simultaneous motion between the navicular and the head of the talus. Movement in the subtalar joint is limited when the talonavicular is transfixed. "when displacement of the navicular is prevented, little movement can be obtained in the subtalar joint.

Restriction of either the talonavicular or subtalar motion affects the mobility of the other. Neither functions independently of the other. In horizontal motion, both joints move simultaneously.

2.5.3 Inversion

When the normal foot is adducted and inverted (supination), the navicular rotates medially around the head of the talus, moving proximally and slightly downward and closer to the medial malleolus. In turn this will diminish the interval between the navicular and the sustentaculum. At the same time, as the navicular moves medially, the calcaneus inverts and lies under the talus. The tibialis posterior tendon by its insertion on the navicular, the spring ligament, and the sustentaculum tali of the calcaneus, is the active force that pulls the navicular and the anterior end of the calcaneus medially. This medial migration of the navicular and calcaneus diminishes the size of the acetabulum for the head of the talus, and opens the sinus tarsi laterally.

2.5.4 Eversion

When the foot is abducted and everted (pronation), movement of the socket is the opposite of inversion. The calcaneus everts and the navicular moves laterally with the calcaneus in relation to the talus. Thus the capacity of the socket is greater as more of the talar head is covered by the acetabulum, and the sinus tarsi is closed.

3.0 Fibular graft

3.1.0 Anatomy of the Fibula

The anatomy of the fibula and its vasculature has been described in details by Yun et.al. (1994) and McKee (1984). Fibula is not the main weight bearing bone of the leg. Only Its upper three quarters serve to give attachments to the adjacent muscles. Therefore, removal of this segment of the shaft has no significant effect on the ankle stability and renders it as being a suitable donor for both conventional and microvascular bone transplantations.

3.1.2 Morphologic and functional characteristics of fibula

Fibula is the most slender of the long bones in the skeleton. It is almost perfectly cylindrical in the greater part of its extent and situated at the lateral side of the leg. It is 34 cm in length and 3 cm longer in male than in females. The fibula head is expanded, and has a flattened articular surface directed upward and medially for articulation with a corresponding facet on the lateral condyle of tibia. It also bears a surface. Superomedially, for the attachment of the ligament of fibular head. The articular cavity of tibiofibular joint does not communicate with the knee joint.

The neck of fibula can be palpated just distal to the head. It serves the passage of the common peroneal nerve which may be felt and rolled with a finger on its lateral surface. The cross section of the long slender shaft of fibula varies considerably along its length. It is described as having four borders and four surfaces. The surfaces are named according to an established anatomy texts (**clinically oriented anatomy; second edition**): the anterior surface; the medial surface; the lateral surface; and the posterior surface. On the other hand the four borders are the interosseus border between the anterior and medial surfaces; the medial crest between the medial and the posterior surface; the posterior border between lateral and posterior surfaces; and the anterior border between anterior and lateral surfaces (figure 3.1)

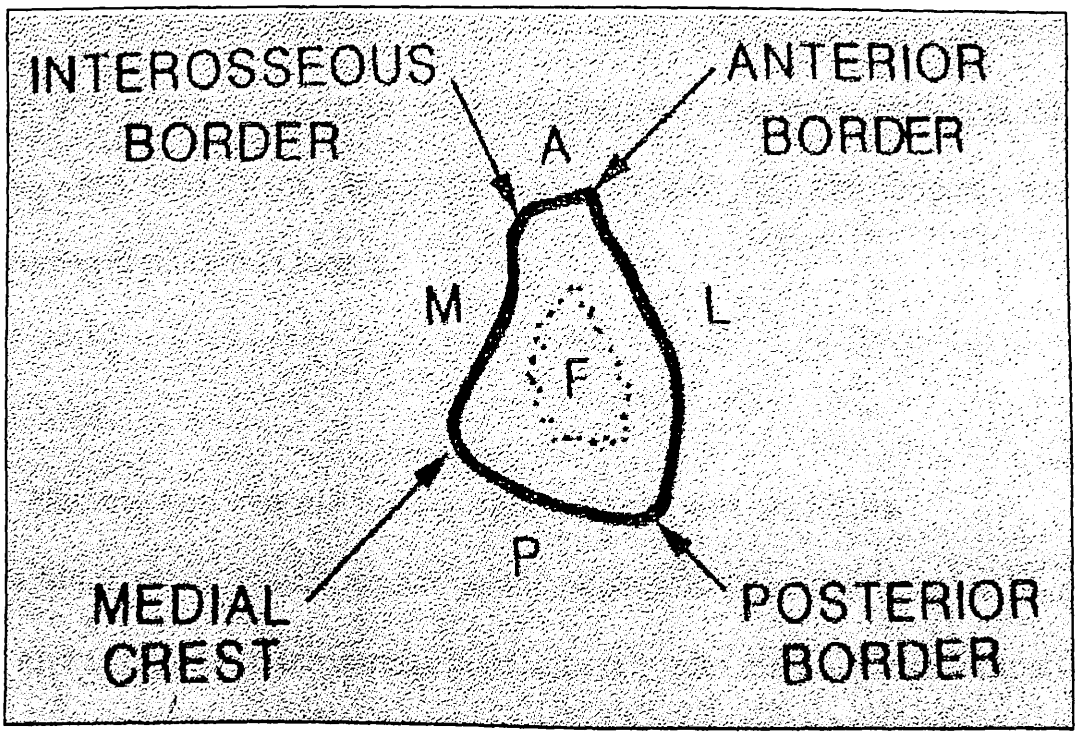

Fig 3.1.: Crossectional diagram of the right fibula, with the appropriate terminology for the surfaces and borders, showing the anterior (A), posterior (P), medial (M), and lateral (L) surfaces.

Superiorly the anterior border begins in front of the head. It runs vertically downward to the lower segment of the bone. Then it bifurcates to embrace a triangular surface immediately above the lateral malleolus. The lateral surface is directed lateral ward in the upper two thirds of its course, of which the upper half is extremely narrow and flat and the lower half grooved longitudinally. In the lower third, the lateral surface is directed backward where it is smooth and broader and continuous with the lateral malleolus. The posterior surface is the space included between the posterior and the medial borders. In its upper part, It is directed backward for the attachment of the soleus; while its lower part gradually turns medial ward for the attachment of the flexor hallucis longus. The medial surface is the interval included between the middle and the anteromedial borders. It is grooved for the attachment of tibialis posterior. The anterior surface is the space between the anteromedial and the anterior borders. It is smooth and broad in the upper part and narrow in the lower part. It is directed medial ward and gives attachment to extensor hallucis longus, extensor digitorum and peroneus tertius.

3.1.3 Muscle and crural / interosseus attachment on fibula

The anterior crural intermuscular septa originates from the anterior border of fibula and separates the extensor compartment from the peroneal compartment, The interosseous membrane originates from the medial border of fibula and separates the extensor compartment from deep posterior compartment. The medial crest gives attachment to four transverse crural intermuscular septum, which is the landmark for the course of peroneal vessels near fibula. The posterior crural intermuscular septum separates the lateral compartment from posterior compartment.

The four surfaces of fibula together with respective adjacent border are corresponding to the origin of three groups of muscle compartment: anterior border has origin of extensor muscles, the lateral surface has origin of the paroneal muscles, posterior and medial surfaces have origin of posterior muscles compartment fig. 3.2 and fig 3.3(a-c)

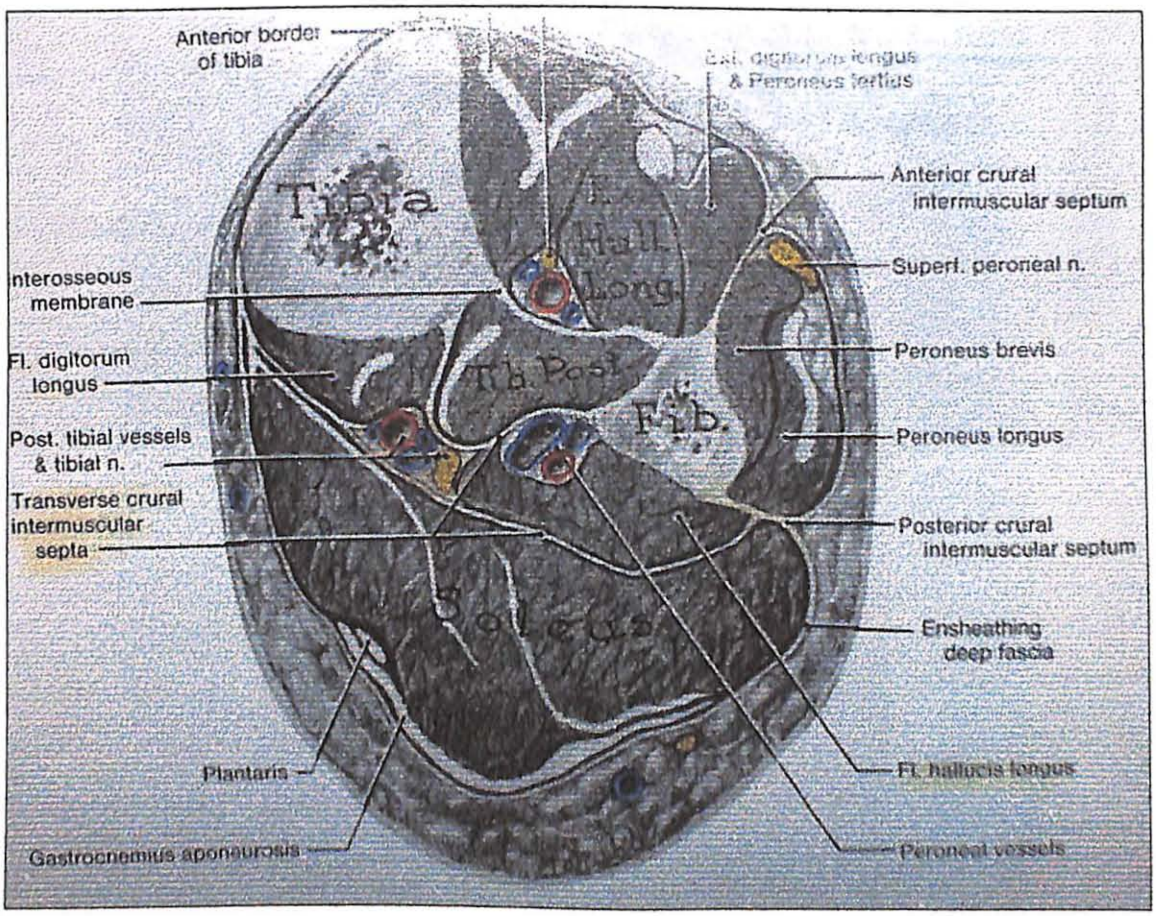

fig. 3.2 Drawing of the cross section of the right leg showing the relashionship of the three crural compartments with the tibial and fibula.

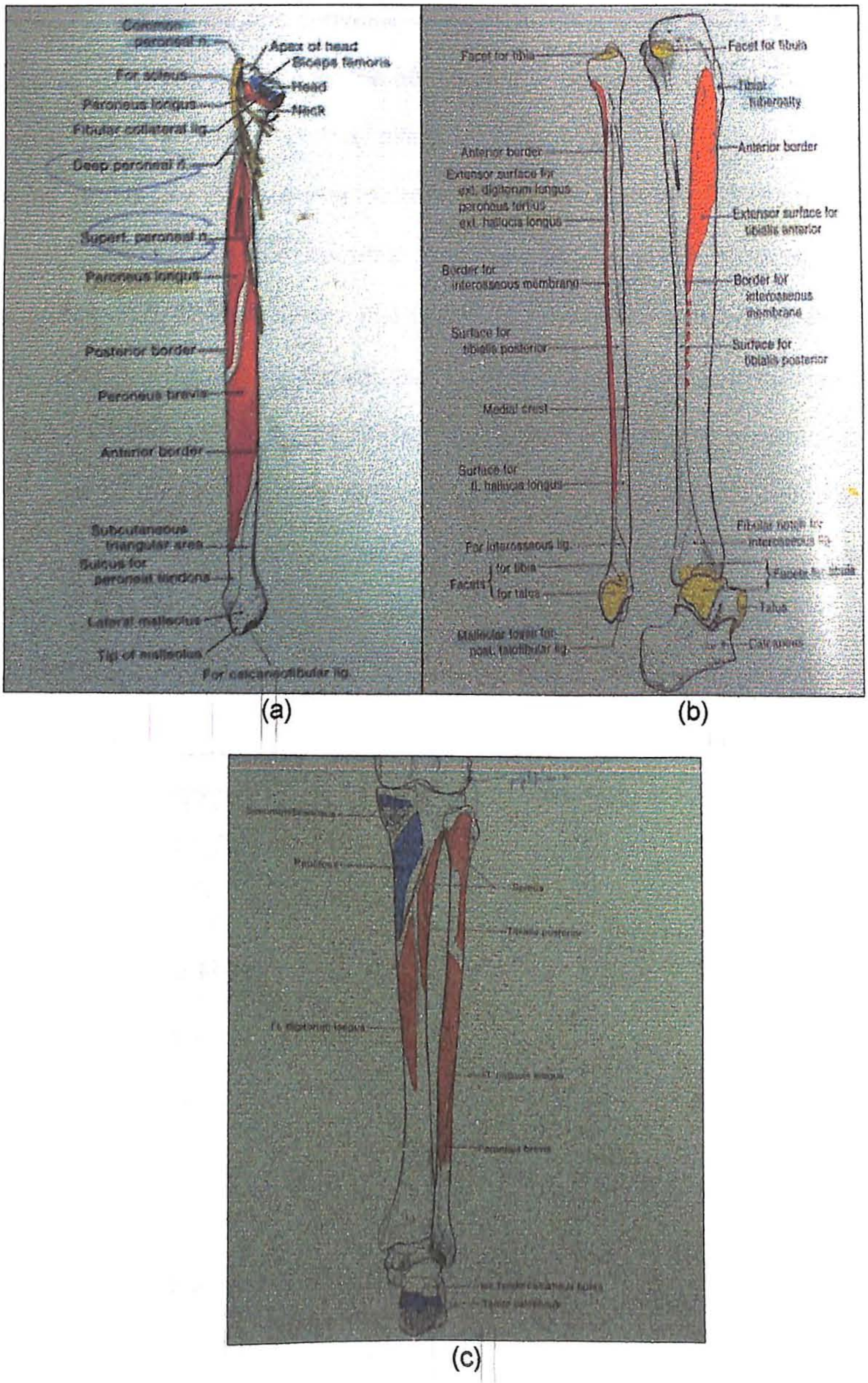

Fig 3.3 Drawings of the leg bones showing the attachment of muscles and ligaments. (a) lateral surface of fibula (b) tibia and fibula, opposed aspects (c) posterior aspects of the tibia and fibula.

Although it is simple and convenient to regard the shaft of fibula as having four borders and four surfaces for the attachment of muscles and understanding the physiologic functions of the different groups of muscles, it should be emphasized that there are some morphologic differences of fibula in different individuals. For example, in some cases, the cross section of fibula is almost oval in shape, while in others, it is triangular. The lower extremity is also called the lateral malleolus. Its medial surface is triangular, which articulates with a corresponding surface on the lateral side of talus. The lateral surface is convex and subcutaneous. The anterior border gives attachment to tibiofibular ligament, anterior lateral malleolar ligament and calcaneofibular ligament. The posterior border is broad and transmits the peroneus longus and brevis. The lateral malleolus plays an important role in maintaining ankle stability as it constitutes the lateral wall of glenoid cavity of the ankle joint and its anterior and posterior borders afford attachments for the ligaments mentioned above.

3.1.4. Extrinsic Muscles of Foot related to the fibula

Flexor Hallucis Longus.

This muscle arises from the lower two-thirds of the posterior surface of the fibula and the interosseous membrane. From its lateral origin, it runs obliquely downward and medially to form a tendon just above the ankle joint. The tendon of the flexor hallucis longus lies in a groove on the posterior surface of the tibia and the talus. It continues under the sustentaculum tali of the calcaneus and then passes under the navicular. It goes forward in the sole of the foot to insert to the terminal phalanx of the big toe.

Poroneus Longus and Peroneus Brevis.

Both of these muscles arise from the lateral surface of the fibula. Their tendons pass behind the lateral malleolus-, the brevis attach to the base of the fifth metatarsal, whereas the peroneus longus tendon run deep across the sole of the foot to attach to the base of the first metatarsal and the adjacent cuneiform. The peroneals pronate and plantar flex the foot.

Flexor Digitorum Longus.

The flexor digitorum longus arises from the posterior surface of the tibia. Its tendon, which begins higher than that of the flexor hallucis longus, passes behind the medial malleolus below the posterior tibial tendon in a separate tunnel. It lies superficial to the deltoid ligament and runs into the sole of the foot under the navicular, where it crosses the hallucis longus. Distally, it is joined by the quadratus plantae (flexor accessorius), and divides into four tendons which insert on the terminal phalanges. The tendon of flexor digatarum longus is separated from tendon of flexor hallucis longus by a well defined tendon sheaths which enclosed them separately.

Extensor digatarum longus

This muscles arise from lateral condyle of the tibial, superior three-forths of anterior surface of fibula, and interosseus membrane. It inserted on the distal phalanges of lateral four toes.

Extensor halucis longus

Extensor halucis longus this thin muscles origin from middle half of the anterior surfca of fibula and interosseus membrane. It tendons passes deep to the superior and inferior extensor retinaculum and inseted on the dorsal aspects of base of distal phalanx of great toe.

Tibialis posterior muscle

This large muscle, the deepest one in the posterior crural compartment lies in between and the same plane as the tibial and fibula. Tibialis posterior muscle originated from interosseous membrane, lateral part of the posterior surface of the tibia and superior two-thirds of the medial surface of the fibula.

3.1.5 Nutrient foramen

A study by McKee et al. (1984) on 305 fibulae showed that the most frequent findings was a single nutrient foramina (86.4%) followed by two foramina (7.7%). It was surprising that about 5.6% of fibula in McKee series had no visible nutrient foramina and this was quite similar. This was similar with the findings by Restrepo et al. (1980), which reported that four of 100 fibulae lacked of nutrient foramina. McKee et al. also showed that most nutrient foramina was mostly located near the midpoint of the fibular shaft, with the middle-third of the shaft included 96% of the foramina. This finding was in agreement with that of Taylor (1975). The diameter of the foramen in McKee series was between 0.5 mm - 0.71 mm in 65.4% and between 0.71 mm - 1.10 mm in the 34.6% of the sample. In relation to the cross sectional surface of the fibula, McKee et al.

found that the majority of the nutrient foramina were in the posterior surface (67.5%), medial crest in 18.1% and medial surface in 12.9%

3.1.6 Blood supply

Similar to other long bones, fibula is supplied by nutrient artery, epiphyseal arteries and periosteal arteries. Blood supply to the fibula comes is mainly from the peroneal artery (figure 3.4). It nourishes the bone by sending branches, i.e. the nutrient artery and the arcuate arteries, to the marrow cavity, the periosteum and the cortex of the bone. The peroneal artery arises from the posterior tibial artery, and 2.9 cm on the average below the mid-point of the lower border of popliteus muscle. Its average outer diameter is 4.0 mm. The artery proceeds laterally downward, keeping on initial distance from the fibula. As it proceeds downwards the nearer it approaches the bone. Hence, the upper segment of the artery can be exposed by cutting the posterolateral intermuscular septum between the peroneus longus and soleus muscles along the lateral border of fibula and pulling the soleus muscle aside. The lower segment of the artery, that is the lower three-fourths, is covered by flexor hallucis longus. Sometimes, the muscle arises so high and is developed so well that the whole length of peroneal vessel is covered by it. In such case, it is necessary to incise the muscle along its medial border so as to expose the vessel. The peroneal artery can be divided into four types (figure 3.5)

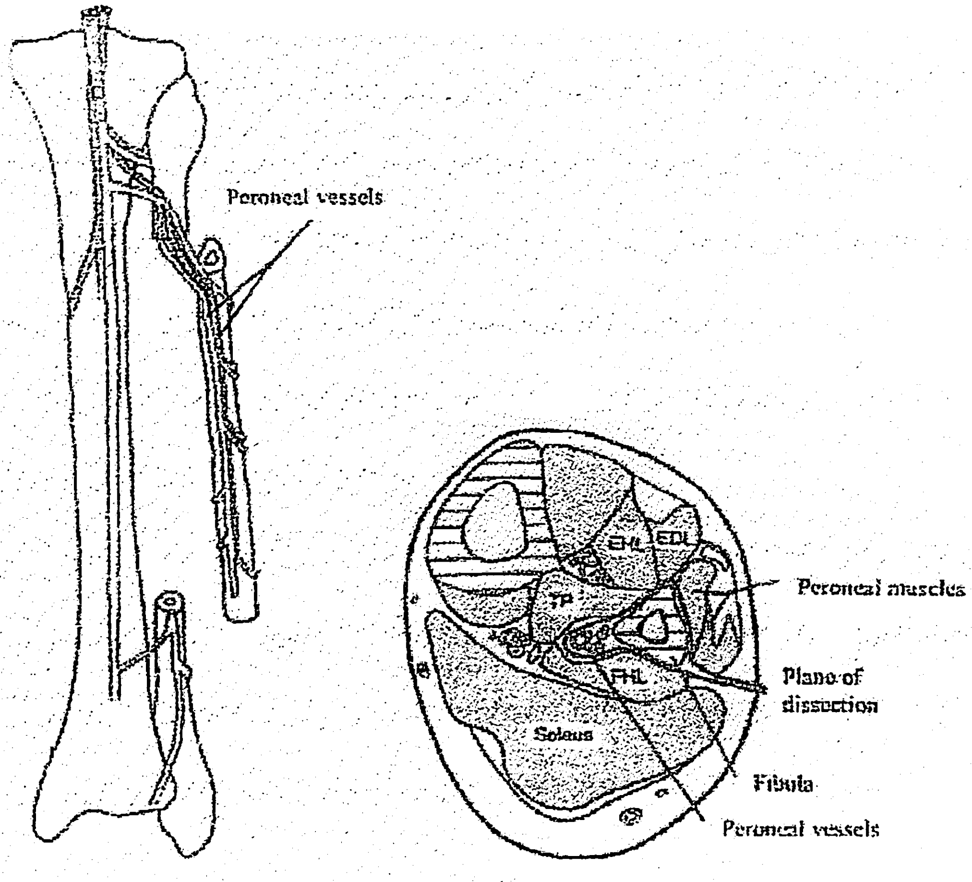

Figure 3.4: *Free vascularized fibular graft isolated on peroneal vessels (Rouholamin,1994)*

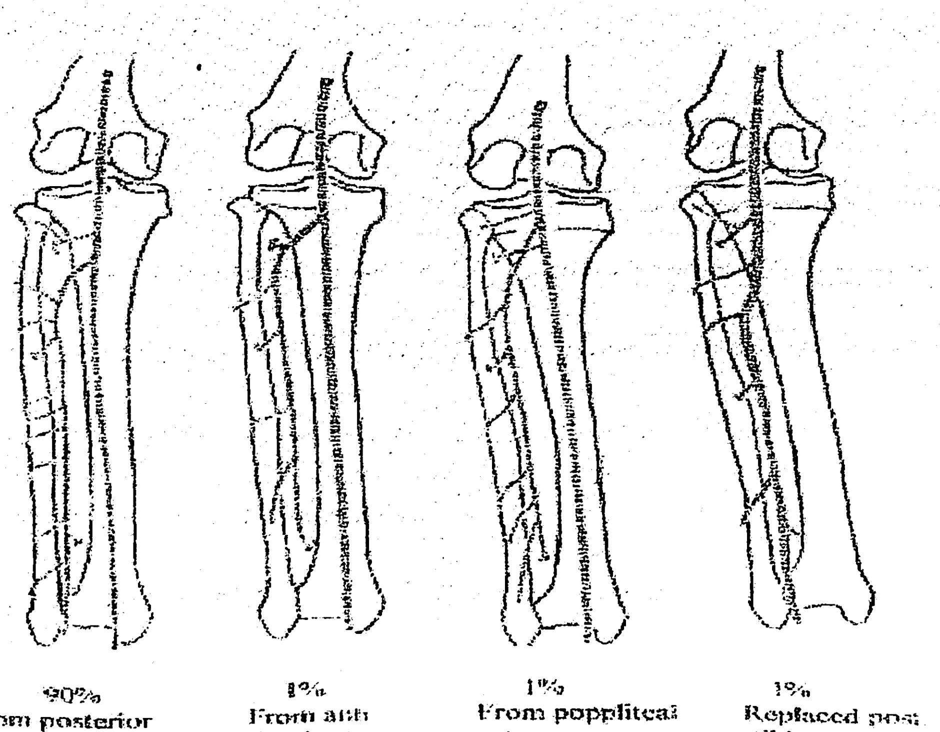

Fig 3.5: Diagram showing the origins of peroneal artery (Yun & Qi, 1994)