ERGONOMICS OF FREE FIBULA FLAP IN MANDIBLE RECONSTRUCTION

Dissertation submitted to partial fulfilment of the requirements for the degree of

M.Ch. (Plastic & Reconstructive Surgery) – Branch III

THE TAMILNADU DR. M.G.R. MEDICAL UNIVERSITY

CHENNAI

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CERTIFICATE

This is to certify that the dissertation entitled "**ERGONOMICS OF FREE FIBULA FLAP IN MANDIBLE RECONSTRUCTION**" is a bonafide work done **DR. K. SENDHIL NATHAN**, *post graduate (2011-2014) in the Department of Plastic, Reconstructive & Faciomaxillary Surgery, Madras Medical College & Rajiv Gandhi Government General Hospital, Chennai – 03*, in partial fulfillment of the University rules and regulations for award of **Master of Chirurgiae**, ***Plastic & Reconstructive Surgery (branch III)*** degree under my guidance and supervision during the academic year 2011-2014.

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DECLARATION

I solemnly declare that this dissertation "**ERGONOMICS OF FREE FIBULA FLAP IN MANDIBLE RECONSTRUCTION**" was done by me in the Department of Plastic, Reconstructive & Faciomaxillary Surgery, Madras Medical College & Rajiv Gandhi Government General Hospital, Chennai-03 between 2011 and 2013.

This dissertation is submitted to **THE TAMILNADU DR.M.G.R. MEDICAL UNIVERSITY, GUINDY, CHENNAI-32** in partial fulfilment of the university requirements for the award of degree of **M.Ch. PLASTIC & RECONTRUCTIVE SURGERY**.

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CONTENTS

INTRODUCTION

INTRODUCTION

Composite defects in the oro-mandibular region commonly resulting from trauma and cancer surgeries pose a great challenge for the reconstructive surgeon. It envisages the surgeon's planning abilities and abstractive thinking about the defect that has to be reconstructed.

Seeing that Mandibular defects occur more commonly secondary to wide local excision for carcinoma in the oro-mandibular region, they produce significant morbidity by affecting both the function and aesthetics of the face. Also most carcinoma patients may already have had a course of radiotherapy or might need radiotherapy post-surgically. This imposes further burden on any of the flaps designed to cover the cancer post-excisional defect.

Though various local and loco-regional options, like, pectoralis major myocutaneous flap, lattismus dorsi flap, forehead flap, bilobed forehead flap (Narayanan's flap) are available for covering the defect, they fail to produce optimal functional and aesthetic results and add to the morbidity of the patient. Hence vascualrized free fibula osteomyocutaneous flaps, with better functional and aesthetic outcome have become the mainstay of treatment for defects in the oro-mandibular region.

Having decided on the use of vasculaised free fibula osteomyocutaneous flap for the reconstruction, the surgeon has to plan the flap taking into accounts multitudes of factors like positioning of the skin paddle, the site to harvest the

flap, the muscles to include in the flap to obliterate the dead space, length of the pedicle needed for a tensionless anastamosis, length of the bone needed to replace the mandible lost in surgery, the number and sites of osteotomies needed to get the desired curvature and the positioning of the pedicle in the graft for anastomosis without kinks in the vessels.

Previous radiotherapy and post-radiational vascular diseases impose further challenges in choosing a healthy recipient vessel in the neck for anastamosis.

Reconstruction of the mandible not only brings back the contour of the chin, it also acts as base for fixing prosthetic dentition and thus aids in various functions like chewing, deglutition, breathing and speech.

Applying the knowledge gleaned from cadaveric dissection in our clinical scenarios had produced improved results in terms of aesthetics and function. This study of ours tries to streamline the various steps of the harvest, transfer and anastamosis of the vascularised free fibula osteomyocutaneous flaps by studying the various parameters in cadavers and applying that knowledge in clinical scenarios to measure the outcome qualitatively and quantitatively.

AIM OF THE STUDY

AIMS/OBJECTIVES

Primary Objectives:

To do cadaveric dissections with the objectives of,

- To find the location of perforator with good size, diameter and length to serve as the single best perforator for chimeric free fibula osseocutaneous/ osseomyocutaneous flap for reconstruction of mandible
- To find the safe site for ostectomy and application of contoured plates and screws

Secondary Objective:

Application of the cadaveric study findings in reconstructive surgeries of oro-mandibular defects and assessing the outcome, and

- To find the best position of pedicle in the graft without any kinking
- To ascertain whether the eccentric location of the perforator with respect to the skin paddle helps in positioning and three dimensional manipulation in reconstruction of composite oro-mandibular defects

SURGICAL ANATOMY

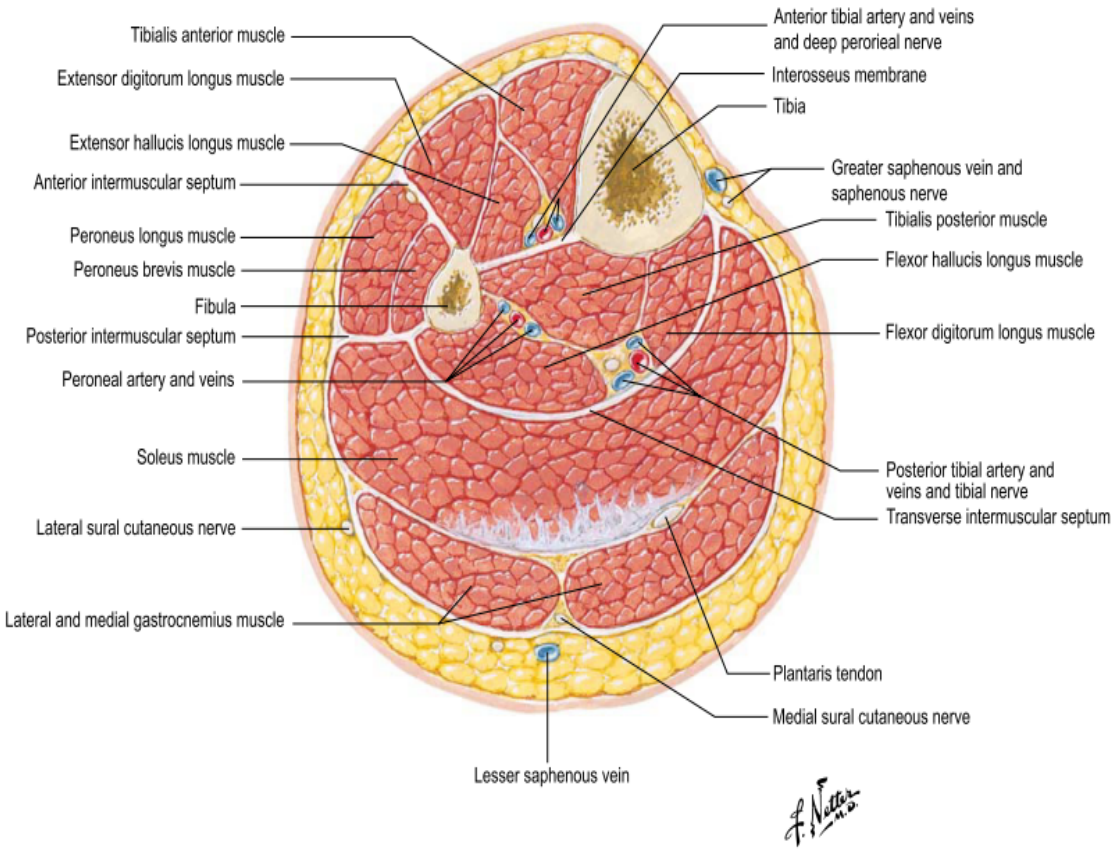
SURGICAL ANATOMY

Compartments of the leg:

The lower leg framework is composed of two long bones – Tibia and fibula. They are arranged parallel to each other and are attached along most of their length by a strong fibrous membrane called the interosseus membrane. Tibia and fibula with the connecting interosseus membrane divide the leg into anterior and posterior compartments. Two fibrous septa – anterolateral and posterolateral divide the anterior compartment into anterior and peroneal (lateral) compartments. Both of them pass from the fibula to the deep fascia. The anterolateral septum occurs between the extensor digitorum longus and the peroneus longus muscles. The posterolateral septum lies between the peroneus longus/brevis and the soleus muscles.

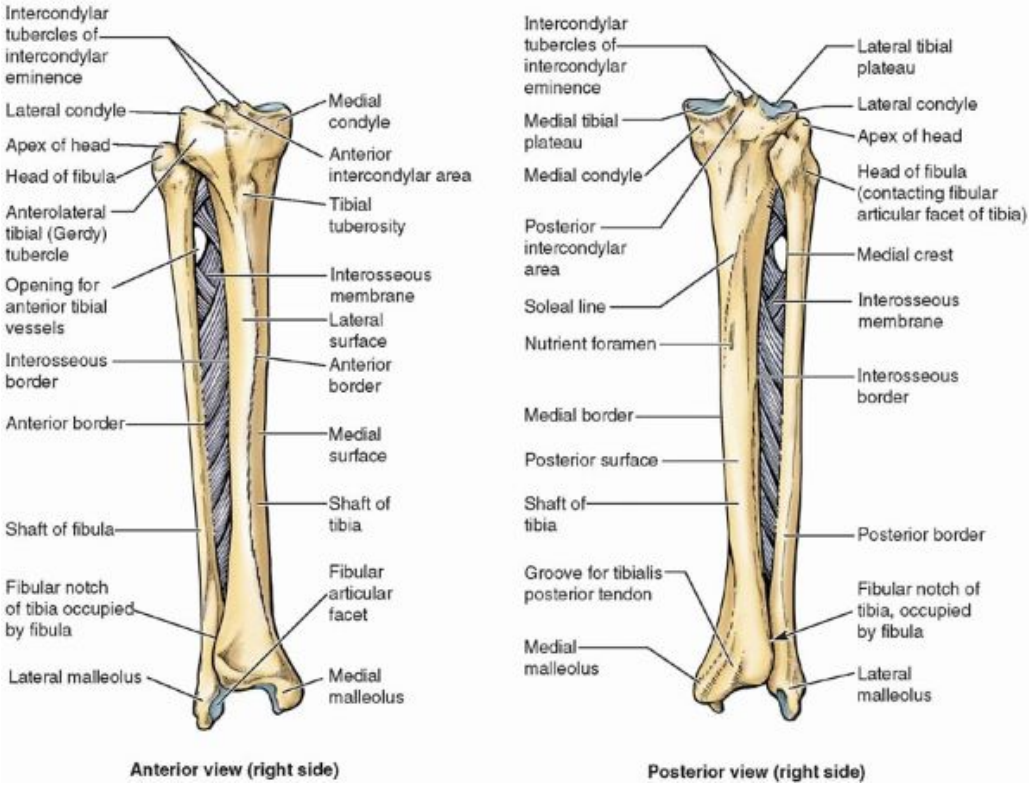
The anterior compartment is made up of 4 muscles – extensor digitorum longus, extensor hallucis longus, tibialis anterior and the peroneus tertius. All of these muscles are innervated by the deep peroneal nerve and supplied by anterior tibial vessels.

The lateral compartment contains only 2 muscles – peroneus longus and peroneus brevis. These muscles are innervated by the superficial peroneal nerve and supplied by vessels from the peroneal artery.



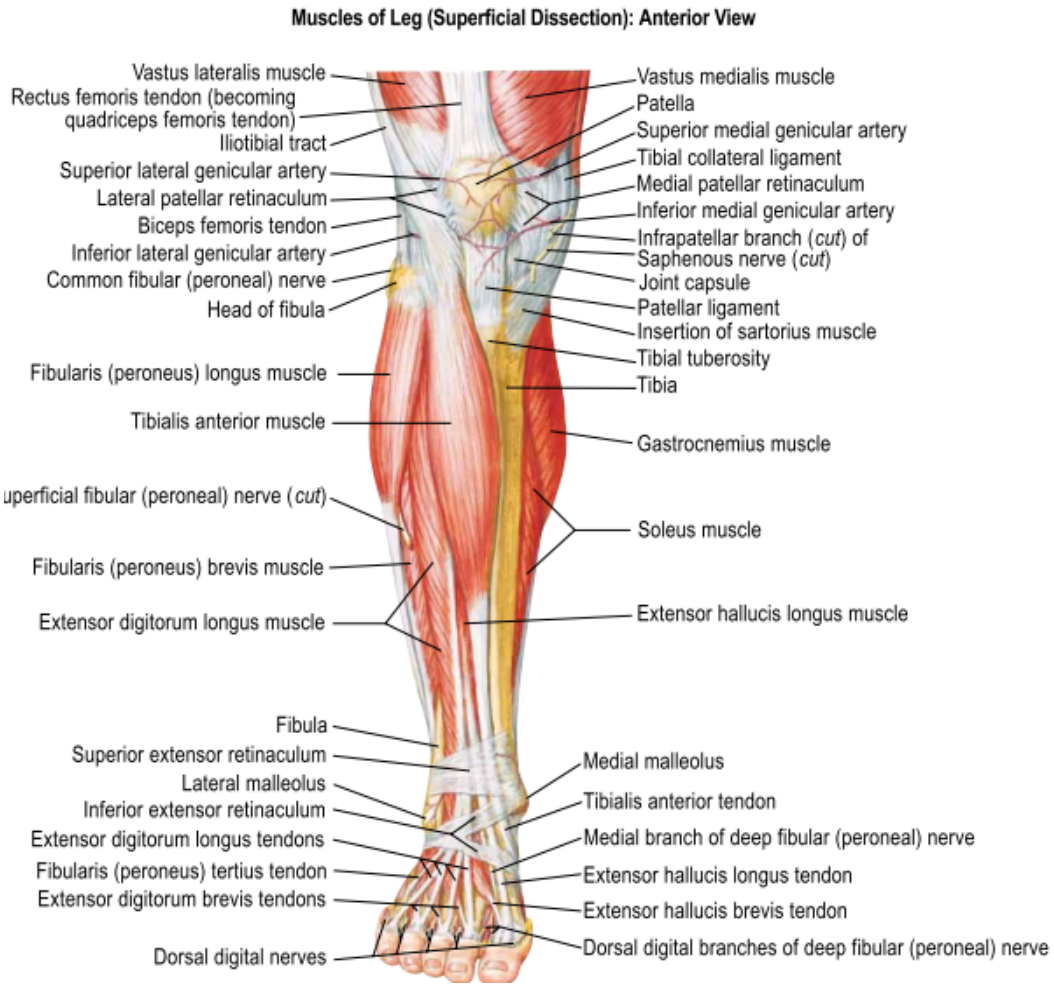
The posterior compartment is further divided into superficial and deep compartments by a transverse intermuscular septum. Gastrocnemius, soleus and plantaris are found in the superficial compartment. The deep compartment contains popliteus, flexor hallucis longus, flexor digitorum longus and the tibialis posterior. This compartment is innervated by tibial nerve and supplied by popliteal and posterior tibial arteries.

Fibula:



The fibula (Latin clasp/pin) does not participate in the formation of the knee joint. It forms a mortice of the ankle joint. It articulates with the tibia at the upper end by a small plane synovial joint enclosed by a capsule and forms a syndesmosis with the tibia at the lower end. The fibula is connected with the tibia throughout the length by the interosseus membrane.

It has got 3 borders – anterior, posterior and medial/interosseus borders. It has 3 surfaces – medial, lateral and posterior. The fibula itself is non-weight bearing but gives complete or partial origins to the following muscles:

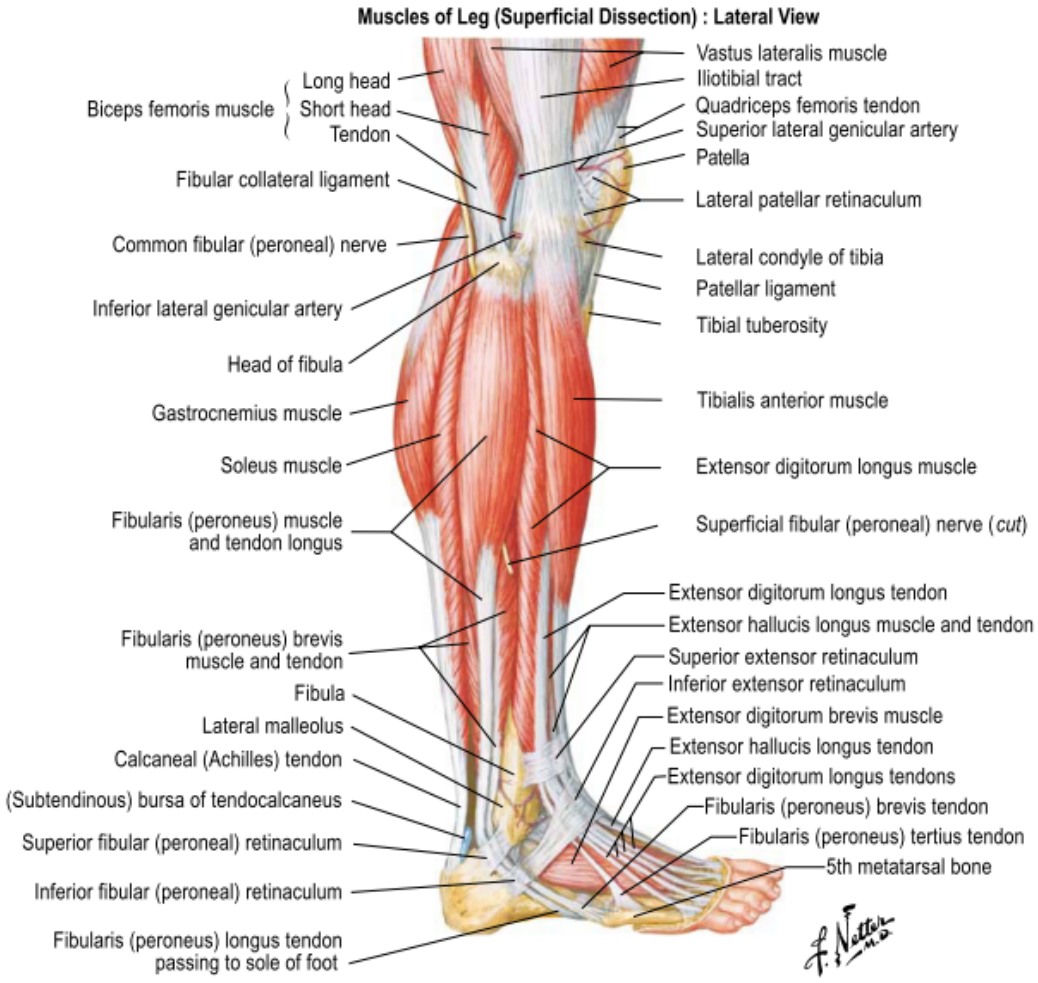


Medial surface: extensor digitorum longus, peroneus tertius and extensor hallucis longus.

Posterior surface: Soleus, flexor hallucis longus and tibialis posterior

Lateral surface: peroneus longus and peroneus brevis

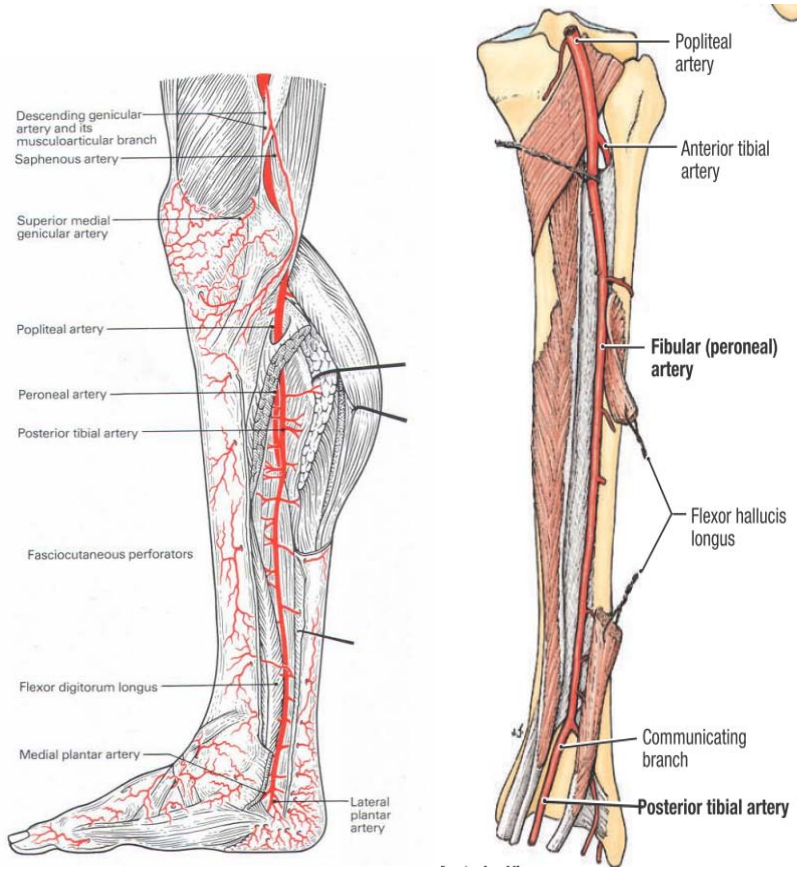
The fibula is supplied by a nutrient artery from the peroneal artery. This enters the bone on the posterior surface and is directed upwards.



Arterial Anatomy:

The femoral artery as it emerges from the hiatus magnus, continues as the popliteal artery. The popliteal artery branches into anterior and posterior tibial arteries at the lower border of the popliteus muscle.

The posterior tibial artery travels in the deep in the posterior compartment. More distally it is more superficial and travels parallel to the medial border of the tendoachilles. It is accompanied by two venae commitantes and tibial nerve.



The peroneal artery is a branch of the posterior tibial artery 2 cm distal to the inferior border of the popliteus muscle. It first descends between the tibialis posterior muscle and its fascia. Later it shifts laterally and travels anterior to flexor hallucis longus muscle. Throughout its course it runs downward along the posterior surface of the fibula. It provides 4-6 segmental branches, which provides nourishment to the bone, periosteum and the muscles. These branches then pierce through the posterolateral intermuscular septum to enter the peroneal (lateral) compartment and supply the skin over the lateral compartment. The peroneal artery also gives off a nutrient artery to the fibula. It arises about 10 cms from the peroneal artery origin. It enters the fibula through

the nutrient foramen located about 15 cms proximal to the styloid process of fibula, posterior to the intermuscular septum. The nutrient artery is about 1-2 cms and 1mm diameter. Within the fibula, the nutrient artery divides into ascending and descending branches, the descending branch is usually longer. In 5% of the population there is no nutrient vessel.

In 1% of the people, the peroneal artery originates from the anterior tibial artery. It is absent in 0.1% of the population. In 8% of population, the anterior and posterior tibial arteries are hypoplastic and the peroneal artery becomes the main supply of the foot. It is then called as the peroneal arteria magna.

Venous Anatomy:

The venous system of the leg is divided into deep and superficial sets. The superficial veins are the great and small saphenous veins and are located superficial to the deep fascia. The deep veins accompany the arteries as venae commitantes. Though both sets are provided with valves, they are more robust in the deep system.

Nerve Innervation:

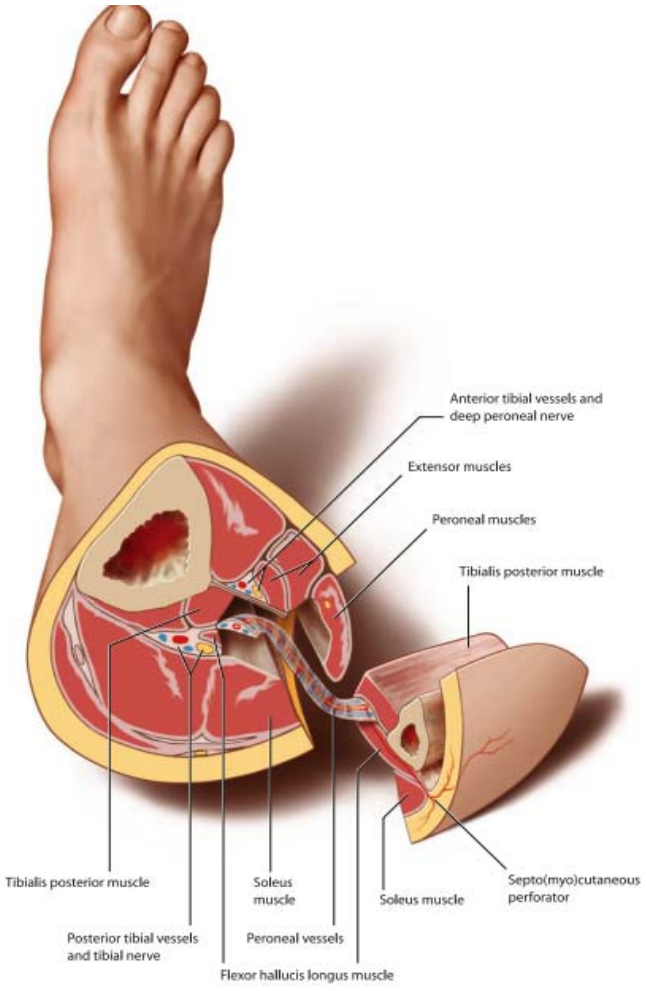
The sciatic nerve (L_4, L_5, S_1, S_2 and S_3) divides at the superior angle of the popliteal fossa into tibial nerve (ventral divisions of the anterior primary rami of L_4, L_5, S_1, S_2 and S_3) and common peroneal nerves (dorsal divisions of the anterior primary rami of L_4, L_5, S_1 and S_2).

The peroneal nerve winds around the posterolateral surface of the neck of fibula and enters the lateral compartment of the leg. It then pierces the peroneus longus before dividing into superficial and deep branches. The superficial peroneal nerve run deep to peroneus longus proximally and becomes superficial more distally and ends up as medial and intermediate dorsal cutaneous nerves. The superficial peroneal nerves supplies muscles of the lateral compartment, and the dorsum of the foot (except the first web space). The deep peroneal nerve runs in the anterior compartment and supplies the muscles of the anterior compartment and the first web space.

Choice of fibula for vascularized free flap:

- Reliable blood supply
- A good length of solid and sizeable bone stock can be harvested
- A relatively expendable bone, removal of which does not cause instability of the knee joint.
- The ability to take as a composite free flap – bone, muscle, fascia and skin

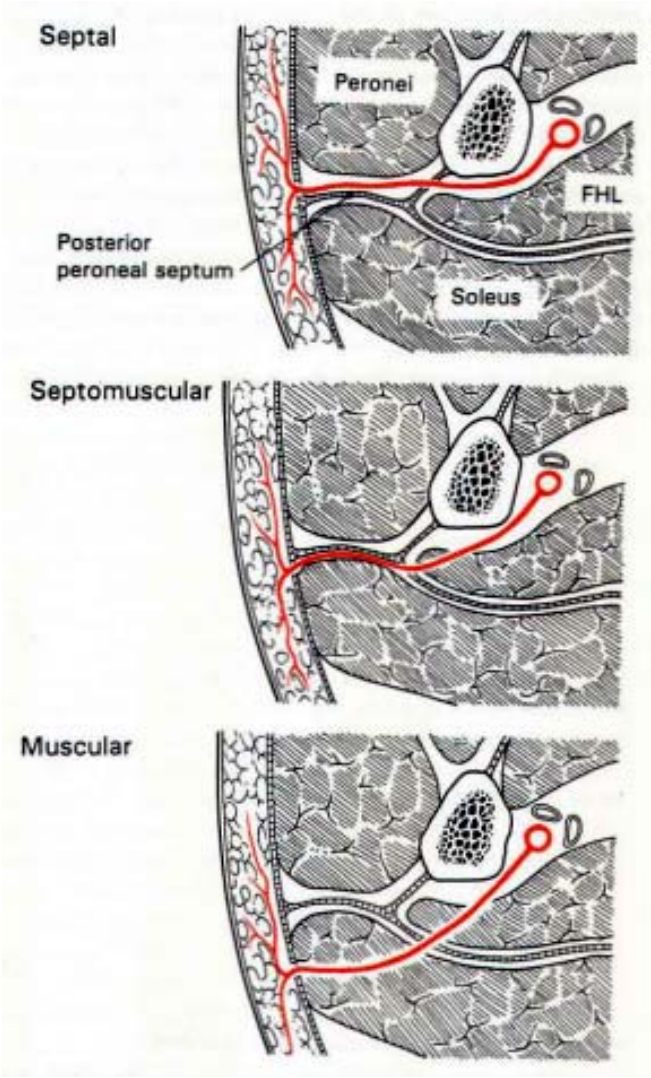
Flap Anatomy:



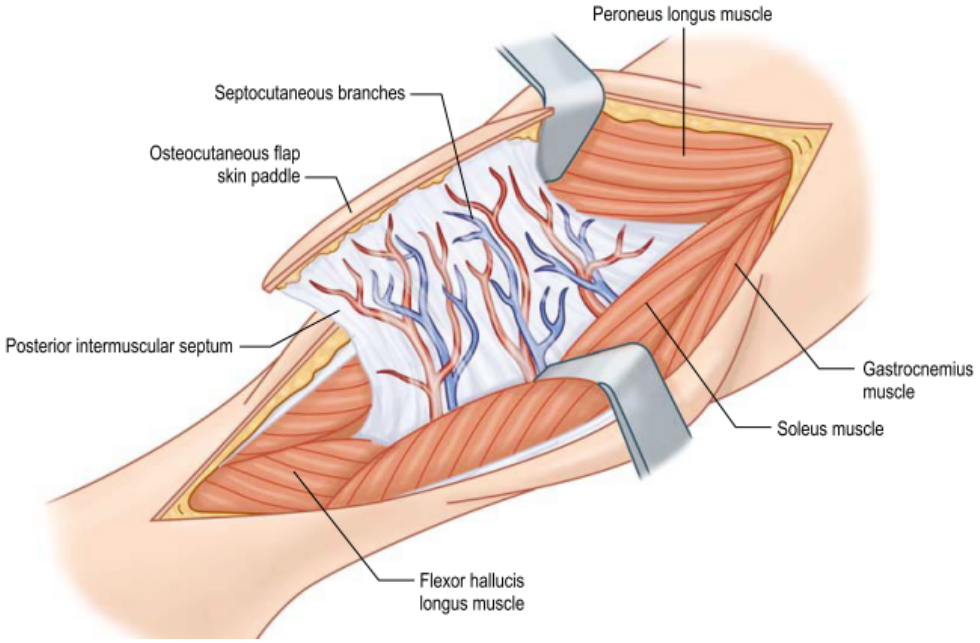
Arterial Supply of the free fibula Flap:

Peroneal Artery is the main vascular supply of the flap. It measures 1.5-2.5mm in external diameter. The length of the pedicle is variable and depends on the amount of the proximal being dissected.

The dominant blood supply is from the peroneal artery. The length varies from 2 to 4 cm and diameter from 1.0 to 2.5 mm.



The peroneal artery gives many branches along its length. One of the branches is the nutrient artery given about 15 cm proximal to the styloid process of fibula. It enters the nutrient foramen about mid-fibula point. After a short intracortical distance, it divides into anterior and posterior branches. The ascending branch is often shorter than the descending branch. Very rarely there may be 2 nutrient areteries.



The fibula flap also has minor pedicles in the form of periosteal and muscular branches of the peroneal artery. They are segmental and found between 4 and 27 cm from the fibular head. Their length is about 0.8 to 1.7 cm and external diameter is about 0.8 to 1.6 cm. They are mainly musculoperiosteal and musculocutaneus (flexor hallucis longus and soleus). The maximum amount of these periosteal vessels is found in the middle third of the leg.

Venous drainage:

The flap is mainly drained by the two venae commitantes accompanying the peroneal artery. The length ranges from 2 to 4 cm. The external diameter of the vessel ranges from 2 to 4 mm. There is no definite secondary drainage for this flap. Sometimes a superficial vein draining the skin paddle is used. If skin paddle is designed distally, the short saphenous vein may be used.

Flap innervations:

This flap is not advised as for functional muscle transfer, but if needed lateral sural sensory nerve can be used to create a sensate flap. But it is not commonly done.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Classification of Mandibular Defects:

Chalian (1985)[8] has arranged mandibular defects in a classification system as follows

Class I Resection of the ipsilateral condyle

Class II Resection of the ipsilateral condyle and ascending ramus

Class III Resection of the ipsilateral condyle and body to midsymphysis

Class IV Resection of the ipsilateral condyle to the contralateral body

Class V Total mandibulectomy

Class VI Resection of the midsypmphysis

Class VII Segmental resection of the body

Class VIII Marginal or coronal resection of the body.

Boyd JB, Gullane PJ, Rotstein LE, et al. (1993)[19] classified mandibular defects as follows:

H - lateral defects of any length up to the midline that include the condyle

L - lateral defects that exclude the condyle

C - defects involve the central segment containing the four incisors and two canines.

The three lowercase letters in this classification system describe the associated soft tissue components:

o - no skin or mucosal component

s - skin

m - mucosa

sm - skin plus mucosa

Loss of the central segment poses problems with restoration of stomal competence, restoring the lip height for cosmesis and restoration of an anterior gingivolabial sulcus for fitting prosthetics for dental rehabilitation

Urken ML, Weinberg H, Vickery C, et al. (1991)[17] Reported of 71 cases of oro-mandibular reconstruction using microvascular composite free flaps and a new classification scheme for bony, soft tissue and neurologic defects.

C - Condyle

R - Ramus

B - Body

S - Total Symphysis

SH - Hemisymphysis

P - Palate

Surgical Anatomy:

Carriquiry C, Aparecida Costa M, Vasconez LO. (1985)[10] found in their dissection that almost all the perforators have two venae comitantes accompanying them. The peroneal artery supplies the skin of the lateral leg, the fibula, and the peroneal muscles. They also found that there were about 7 musculocutaneous and septocutaneous perforators with an external diameter of

4.8mm. They also found that these perforators are found predominantly in the middle ⅓rd of the lower leg, at approximately 13-18 cm proximal to lateral malleolus. The musculocutaneous perforators were found to pierce through soleus and/or peroneus longus muscles. The septocutaneous perforators emerge between flexor hallucis longus and peroneus brevis.

Yoshimura M, Shimada T, Hosokawa M. (1990)[16] in their stuidy of the vasculature of the peroneal tissue found that of the peroneal perforators, 71% were musculocutaneous and 29% were septocutaneous

Beppu M, Hanel DP, Johnston GH, et al. (1992)[18] in their clinical studies found that 38% of the peroneal perforators were musculocutaneous and 62% were septocutaneous.

Wu WC, Chang YP, So YC, et al. (1993)[20] found from their clinical experience that the perforators are mostly septocutaneous, but musculocutaneous perforators were also found in the medial, posterior, and lateral aspects of the soleus.

Heitmann C, Khan FN, Levin LS. (2003)[34] found in their studies of the vasculature of the peroneal artery that 34% of the peroneal perforators are musculocutaneous and 66% are septocutaneous.

Geddes CR, Tang M, Yang D, et al. (2006)[37] found in their studies that the skin of knee and leg forms 34% of the lower extremity integument, and is vascular supply was through about 20-43 perforators, with a diameter of 0.5-0.9 mm.

They found five vascular territories, arranged as a series of four longitudinal rows in the intermuscular septum of the lower leg

Scheverien, M. and Saint-Cyr, M. (2008)[40] found in their studies that the perforators of the lower leg were clustered in three distinct levels.

- First group of perforators were 4-9 cm proximal to intermalleolar line.
- second group of perforators were 13-18 cm proximal to intermalleolar line
- Third group of perforators were 21-25 cm proximal to intermalleolar line.
- The peroneal perforators were found exiting between the flexor hallucis longus muscle and the peroneus brevis muscle.
- The perforators with the largest diameter are in the proximal two-thirds,

Diego Ribuffo et al (2010)[43] did a Clinical study of peroneal artery perforators with CT-angiography and concluded that the vascular anatomy of peroneal artery perforators is highly variable and hence pre-operative imaging can be used to demonstrate cases where there is aberrant or non-preferred anatomy, or to select the limb of choice for harvest.

Their study was conducted using 82 limbs in which about 171 cutaneous perforators of the peroneal artery >0.8 mm were identified. Of these,

- 59.6% of the perforators were septocutaneous, running in the posterolateral intermuscular septum all along their course. They were found more in the lower third of fibula.

- 29.2% of the perforators were musculocutaneous, passing either through the soleus or the extensor hallucis longus, or both. They were found more in the upper third of the fibula.
- 11.1% of the perforators were septomusculocutaneous, passing throught the muscle proximally but more distally emerging from the posterolateral intermuscular septum to course superficially.
- The external diameter of the perforators was from 0.8 mm to 3.2 mm.
- The length of perforators were from 8.32 to 13.71 cm (mean 9.95 cm)

It was notable that every extremity had at least one septocutaneous perforator

Purushothaman R, Balakrishnan TM, Alalasundaram KV (2013)[45] found in their studies 3-5 constanst septocutaneous perforators. The most proximal was about 3 cm from tip of lateral malleolus and the most distal was found at the level of lateral malleolus tip. All were Septofasciocutaneous perforators directed downwards and laterally.

Management of Mandibular Conditions:

Bataineh AB, al Qudah M. (1998)[27] discussed the treatment of mandibular odontogenic keratocysts and found mandibular resection of the involved segment produced complete cure.

Zhao YF, Wei JX, Wang SP. (2002)[30] in their follow-up studies on 255 chinese patients, for treatment of odontogenic cysts found that simple marsupialisation

or curettage produces greater recurrence rates and concluded complete excision is the only treatement for cure.

Nakamura N, Mitsuyasu T, Mitsuyasu Y, Taketomi T, Higuchi Y, Ohishi M. (2002)[32] showed by their studies showed that only enucleation produced more recurrence rates, hence resection of the affected jaw is the only effective treatment for prevention of recurrences.

Van Rensburg LJ, Paquette M, Morkel JA, Nortje CJ. (2003)[33] came to the conclusion, in cases of ameloblastoma, enucleation alone is not adequate treatment due to large recurrence rates and it should combined with peripheral ostectomy to improve results.

Methods of Mandibular Reconstruction:

Ariyan S. (1979)[4] advocated the usage of PMMC as a versatile flap for reconstruction in the head and neck region.

Pogrel MA, Podlesh S, Anthony JP, Alexander J. J (1997)[24] did a comparison study of vascularised and nonvascularized bone grafts for reconstruction of mandibular defects and concluded that vascularized bone grafts had better long term results.

Klotch (1974-1986) studied a series of 60 patients, and described the effectiveness of reconstruction plates for the purpose of bridging the mandibular defect produced after resection to provide stabilization of the remaining mandibular segments.

Hidalgo DA (1989)[14] in his seminal article advocated the usage of vascularized fibula for reconstruction of the mandible.

Eppley BL (1996)[22] did a presentation on vascular methods of mandible reconstruction. He also compared the usage of metal plates, pectoralis major muscle flaps and other alloplastic materials.

Ribeiro RF, Tallents RH, Katzberg RW, Murphy WC, Moss ME, Magalhaes AC, Tava-no O. (1997)[25] concluded from their clinical studies that the magnitude of the reconstruction is dictated by the size of the defect.

Ferrari R, Leonard MS. (1998)[28] showed by their article that non-vascularized autogenous bone grafts can also be harvested from the patient's fibula, rib, ilium, calvarium or tibia.

Chepeha DB, Annich G, Pynnonen MA, Beck J, Wolf GT, Teknos TN, et al. (2004)[35] did a comparative study between the effectiveness of Pectolaris major myocutaneous flap and revascularized free tissue transfer and concluded that revascularized free tissue transfer is the best of the two options.

Koh KS, Eom JS, Kirk I, et al.(2006)[38] showed that Pectoralis major musculocutaneous flap can be used successfully in the oropharyngeal reconstruction

Reconstruction of Mandibular defects by microvascular Technique:

Taylor GI, Miller GD, Ham FJ (1975)[1] was the first persons to advocate the usage of free vascularized bone graft for reconstuction of bony defects.

Conley J. (1976)[3] showed that composite pedicled rib flap can be used for reconstruction of the oro-mandibular region.

Harashina T, Fujino T, Aoyagi F. (1976)[2] presented the reconstruction of the oral cavity with a free flap

O'Brien BM, Morrison WA, MacLeod AM, et al. (1979)[5] showed the usage of groin flap with iliac crest bone and the dorsalis pedis flap with second metatarsal for microvascular osteocutaneous transfer.

Cuono CB, Ariyan S. (1980)[6] concluded that any composite mandibular defect can reconstucted immediately with a regional osteomusculocutaneous flap

Green MF, Gibson JR, Bryson JR, et al. (1981)[7] showed that single stage reconstuction of mandibular defects can be done using a split sternum pectoralis major osteo-musculocutaneous transfer.

Robertson GA. (1986)[11] advocated the usage of sternum in osteomyocutaneous reconstruction of major mandibular defects

Evans HB, Lampe HB. (1987)[13] advocated the usage of free radial forearm flap in head and neck reconstruction.

Jewer, D.D., et al., (1989)[15] studied the usage of iliac crest free flap for Orofacial and mandibular reconstruction

Kroll SS, Evans GR, Goldberg D, Wang BG, Reece GP, Miller MJ, et al. (1997)[26] did a comparative study of resource cast and reconstruction with free and pectoralis major flaps. The study concluded that free fibula osteocutaneous

flaps have better functional and aesthetic outcome and have better patient acceptance.

Osseocutaneous Free Fibula Reconstruction:

Hidalgo D.A. (1989)[14] in his landmark paper first reported the successful usage of free fibula osseous flap for mandibular reconstruction. With this paper he revolutionized the surgical treatment of mandibular reconstruction with good reconstructive and aesthetic results, which can also be harvested without significant donor site morbidity.

Jones NF, Monstrey S, Gambier BA (1996)[23] showed by anatomical and surgical confirmation the consistant reliability of the fibular osteocutaneous flap in mandibular reconstruction

Cordeiro PG, Disa JJ, Hidalgo DA et al (1999)[29] showed by his follow-up study of 150 consecutive patients over 10-year that reconstruction of the mandible with osseous free flaps produced better functional and aesthetic results.

Hidalgo DA, Pusic AL. (2002)[31] did a 10 year follow-up study of his cases of free flap mandibular reconstruction and showed that the results were consistant even in long term follow-up and firmly established the usage of vascularized free fibula flap in mandible reconstruction.

Cheng MH, Saint-Cyr M, Ali RS, et al. (2009)[42] shared his clinical experience in the usage of osteomyocutaneous peroneal peforator based composite flap for

reconstruction of composite mandibular defects. He also used soleus muscle with the free fibula septocutaneous flap as chimeric flap based on separate musculocutaneous perforators. This study contributed significantly allowing for better 3 dimensional reconstruction of complex mandibular and maxillary defects. This also produced a single stage surgery with better functional and aesthetic outcomes than previous reconstructive options.

Surgical Planning:

DeSanto LW, Beahrs OH, Holt JJ, O'Falon WM. (1985)[9] showed after extensive clinical studies that any head and neck cancer should be treated vigorously with tumor resection, immediate reconstruction and postoperative radiotherapy.

Yagi S, Kamei, Y., Torii, S. (2006)[39] highlighted the importance of respecting the geometry of the fibula osteomyocutaneous flap to obtain good outcomes in mandibular reconstruction.

Wei FC, Chen HC, Chuang CC, et al. (1986)[20] defined and mapped the septocutaneous perforators of the peroneal artery thereby developing a new concept and technique of elevation of the fibular osteoseptocutaneous flap. This also expanded the usage of the fibula flap to complex composite tissue defect reconstruction, especially in head and neck reconstruction.

Chang SY, Huang JJ, Tsao CK, et al. (2010)[44] found by clinical experience that it is better to shorten the ischemia time to less than 5 hours for fibula

osteocutaneous flaps in order to reduce the partial flap loss and other complication rates.

Complications:

Anthony JP, Rawnsley JD, Benhaim P, Ritter EF, Sadowsky SH, Singer MI. (1995)[21] studied the donor leg morbidity and function disturbances after free fibula flap for mandible reconstruction. The study concluded that post operative donor site morbidity was the least in free fibula flap compared to other vascularised free bone flaps.

Peled M, El-Naaj IA, Lipin Y, Ardekian L. J (2005)[36] compiled his experiences in use of free fibula flap for funtional mandibular reconstruction. In his study he encountered various complications like poor wound healing, temporary foot drop, complete/partial flap loss and oro-cutaneous fistula. He showed a success rate of 84%.

MATERIALS AND METHOD

MATERIALS AND METHODS

Cadaver Studies:

A total of 21 legs were dissected and the peroneal perforator system studied by mercurochrome injection studies.

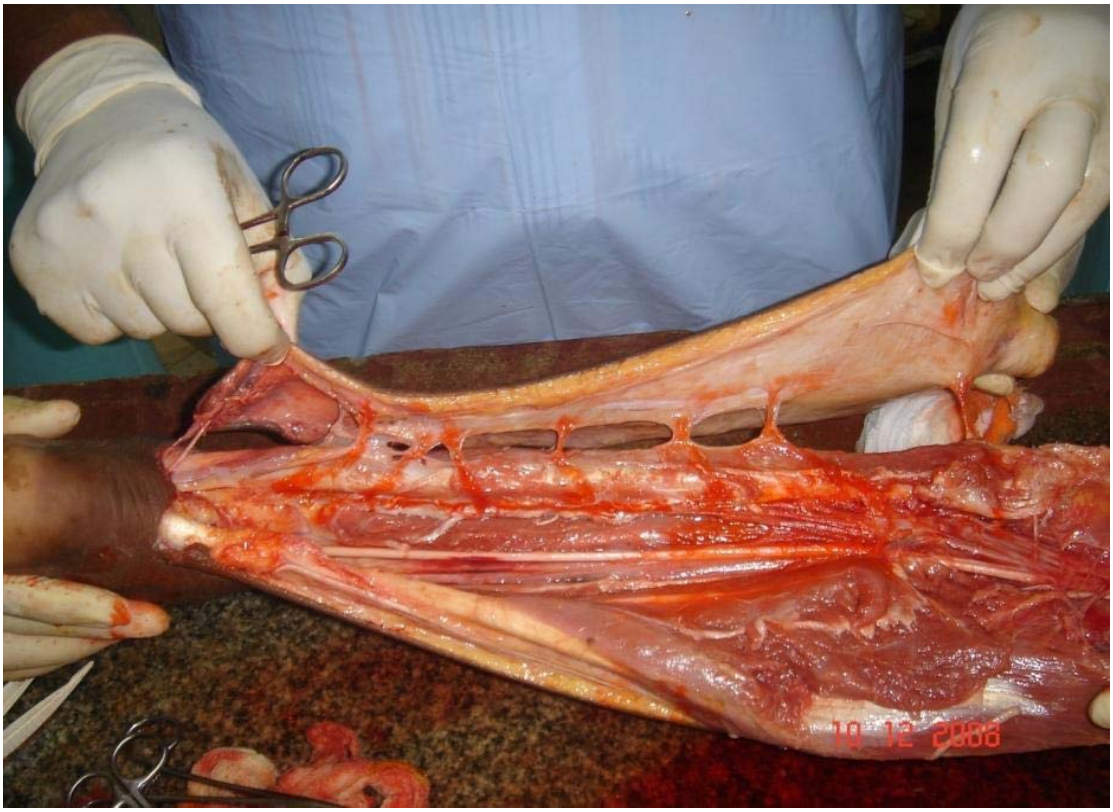
Procedure for Cadaver Dissection:

Incision was made on the medial aspect of the popliteal fossa and brought down along the anteromedial border of tibia. The soleus muscle attachement to the soleal line is exposed. The Sartorius, Semimembranosus and gracilis attachements to the upper medial aspect of tibia excised and released. Then soleus muscle was detached from the soleal line exposing the posterior tibial vessels and tibial nerve lateral to the flexor digitorum longus. The posterior tibial artery traced to its site of branching into peroneal artery. A syringe containing mercurochrome was injected pushing it distally into the peroneal artery.

Simultaneously, we exposed the distal end of the peroneal artery behind the lateral malleolus, where it branches into ramus perforans and lateral calcaneal artery, lateral to flexor hallucis longus, medial and superior to tibiofibular syndesmosis. The injection continued till the dye is seen entering into the distal parts of the peroneal artery. In fair skinned cadavers, it even caused mild discolouration in perferosomes of the peroneal vessel.

DISTRIBUTION OF PERFORATORS

INK INJECTION STUDY



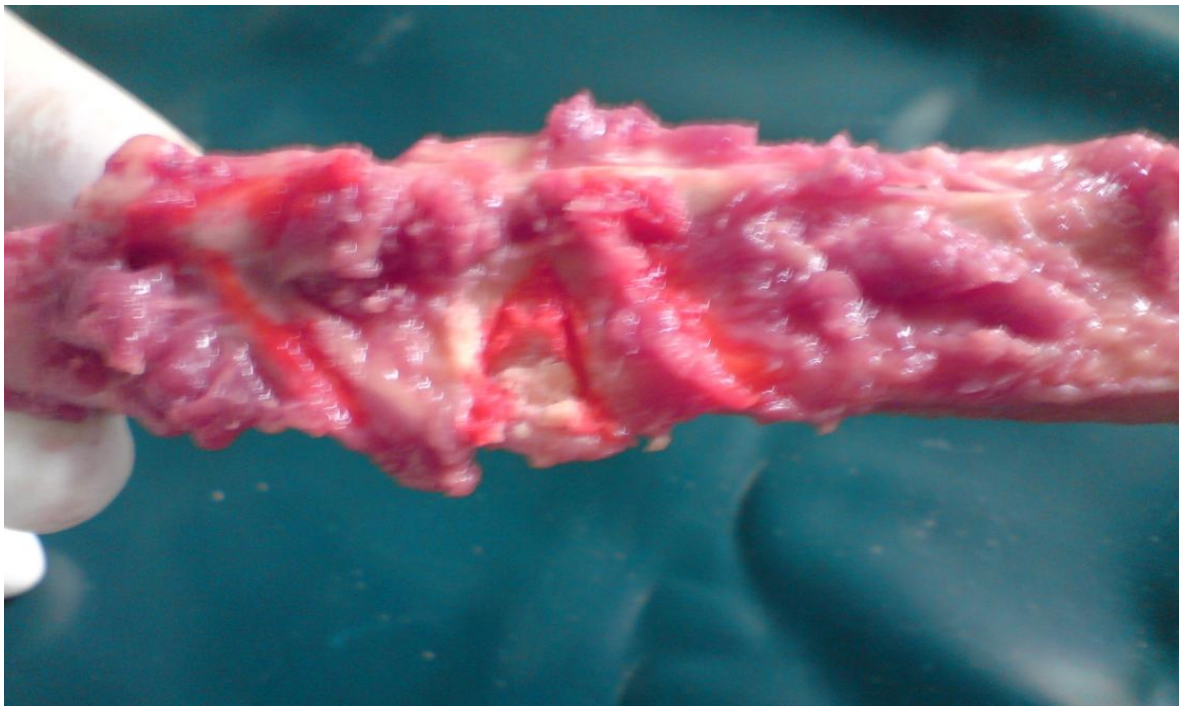
The posterolateral septum was marked on the surface by line extending from the head of fibula to the lateral malleolus. Then 2 incisions were made 2.5 cm anterior and posterior to the posterolateral septum. The dissection was started from posterior incision and carried towards postero-lateral septum. The peroneus longus was stripped anteo-laterally, soleus and flexor hallucis longus posteriorly and medially. Dissection was carried towards the source vessel – the proneal artery. The stained perforators were then studied from the source vessel peroneal artery to the skin paddle.

We used scales and ordinary calipers to measure the location of the perforators from bony points and the position, size and length of the perforators. The size of the perforator was measured at its origin from the source vessel.
The course of the perforators and the course of the mucoperiosteal vessels which are stained with mercurochrome was studied. Most of the mucoperiosteal vessels were found to be directed laterally. The safe window for ostectomy was studied in relation to the mucoperiosteal and nutrient arteries of the fibula, which arises from peroneal artery was also studied. The safe window was marked and measured in relation to proximal and distal ends.

After making ostectomy cuts using power instruments, the kinking of vessels and the position of the pedicle were determined by fixing the ostectomy fragments in the function of mandibular angles.

CADAVER DISSECTION: OSTECTOMY WINDOWS

CADAVER DISSECTION: WEDGE OSTECTOMY CUTS GIVEN



Clinical Case Studies:

These were conducted in our department, with the cases from Surgical Oncology, ENT, Dental Surgery and Trauma cases in our own department over a period of 30 months from August 2011 to March 2013 after obtaining approval from institutional ethics committee.

Inclusion Criteria:

- For reconstructive surgeries:
    - Patients with composite oro-mandibular defect
    - Patients with loss due to trauma or surgery
    - Patients relatively strong enough to withstand long duration of surgery
    - All patients post radiotherapy or chemotherapy are also included
    - patients who give consent for the use of fibula for mandible reconstruction

Exclusion Criteria:

- Patients with pulmonary or cardiac complications
- Patients who are emaciated and cannot withstand the long duration of surgery
- Patients who by pre-operative counseling we believe are not motivated enough to come for regular follow-up

- Patients with co-morbid conditions like, diabetes mellitus, connective tissue disorders, peripheral vascular diseases, less than 3 months of abstinence from smoking or tobacco usage in any form

Pre-Operative Investigations:

- Careful medical history to mainly look for any possibility of unreliability of the peroneal vasculature like – Deep vein thrombosis, previous trauma to the legs, arteritis, peripheral vascular diseases, atherosclerosis, etc.,
- History of co-morbid conditions which might affect the early recovery of the patient like diabetes mellitus, hypertension
- Assessment or range of motion for knee and ankle joint to look for any stiffness or laxity which might indicate any previous trauma or co-morbid conditions.
- Foot Allen's test was performed, palpating dorsalis pedis artery and posterior tibial artery.
- The perforators in the legs were identified with hand Doppler (8 Hz) and marked with permanent markers on the day of the surgery. The recipient site was also examined to locate possible vessels for anastamosis.
- Facial photography was taken for all patients in front and both profiles.
- Oro-mandibular region was examined for mouth opening, facial asymmetry, speech disturbances

- The dimensions of the tumour/defect was assessed. Apparent and real defects marked and the approximate amount of bone and soft tissue loss post-excision was calculated and provisional surgical plans were made.
- The following radiological investigations were done:
    - OPG (Orthopantomogram)
    - PNS x-ray
    - CT facial bones (with 3D reconstruction) and neck regions (to look for nodal involvement)
    - X-ray – both legs with knee and ankle joints
    - In cases of suspected vascular pathology, duplex USG of both the arterial and venous systems in both legs were done.

Clinical Study:

A total of 21 patients were taken up for mandibular reconstruction. Their CT facial bones and neck regions were studied and treatment plan formalized with the surgical team (Surgical Oncologists/ENT surgeons/Dental Surgeons). The three dimensional post-excisional defect was found by using dental compound for creating the models of both maxilla and mandible and aligning them to get normal occlusion. The amount of mandible to be resected was found out and the best site for ostectomies found pre-operatively and a surgical plan charted out.

MOCK MANDIBLE SURGERY PLANNING SESSION


13/03/2011

All the patients had two teams operating on them. The wide local excision with/without modified radical neck dissection was carried out by surgical oncologists/ENT surgeons/Dental surgeons while our team was involved in the harvest of the vascularized free fibula graft. The fibular ostectomy was done as bench surgery in accordance with the mandible defect.

Once the wide local excision was completed, the mandible defect and soft tissue defect confirmed. The pre-fabricated mandible with the skin paddle was taken to the recipient site and vascularized free fibula was fixed to the recipient site using stainless steel miniplates and screws.

Operating microscopes with 10x magnification was used for microvascular anastamosis.

Flap monitoring:

The flap was monitored in the post-operative period by assessing the following parameters:

- Flap colour – pallor indicates arterial block, darker colour indicates venous block, while pink colour indicates optimal flow
- Capillary bleed
- Flap temperature
- Assessment of distal blood flow using hand doppler

Post-op Protocol:

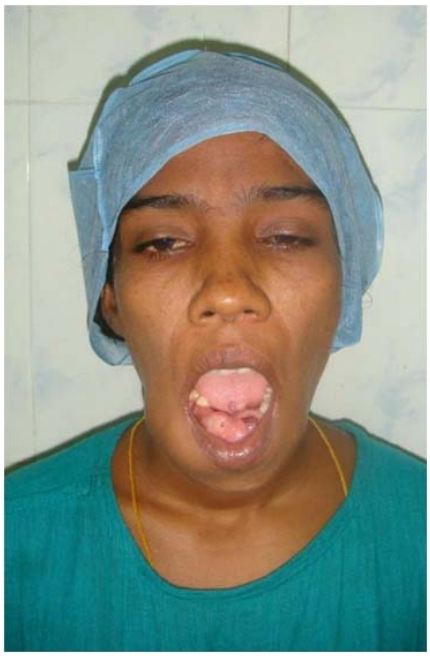
- Keeping the head of the patient immobilized by keeping two small pillows on either side of the head.
- Inj. Lomodex (LMW Dextran 40) 20/hr for 24-48 hrs. in the immediate post-op period.
- Ryle's Tube feeding started on 2nd day starting with clear liquid followed by high viscous fluids (kanji, coconut water, etc.,)
- Ryle's Tube removed on the 10th day if there is no complication
- Patient was ambulated after 48 hrs. with partial weight bearing on the harvested leg.
- Inj. Heparin 10000 units BD was not routinely used and is reserved only following re-exploration for venous thrombosis.

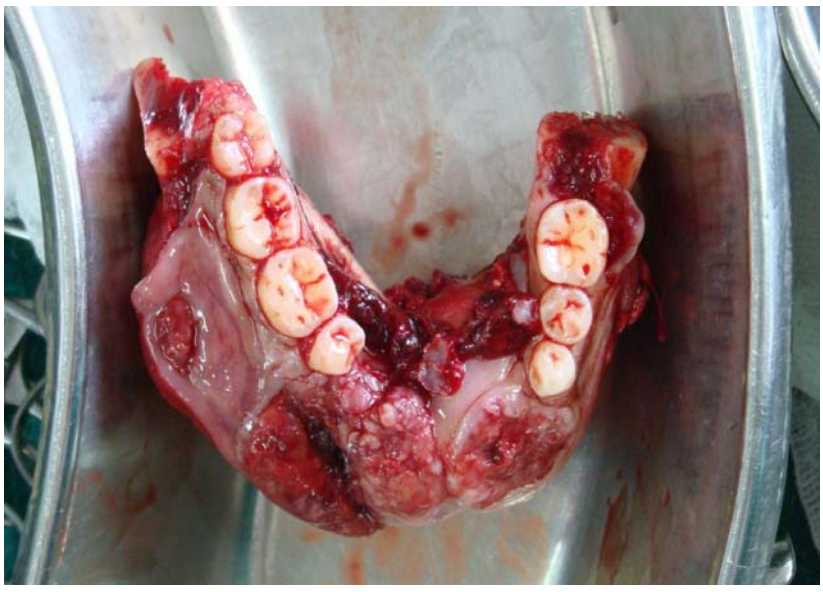
Follow-up:

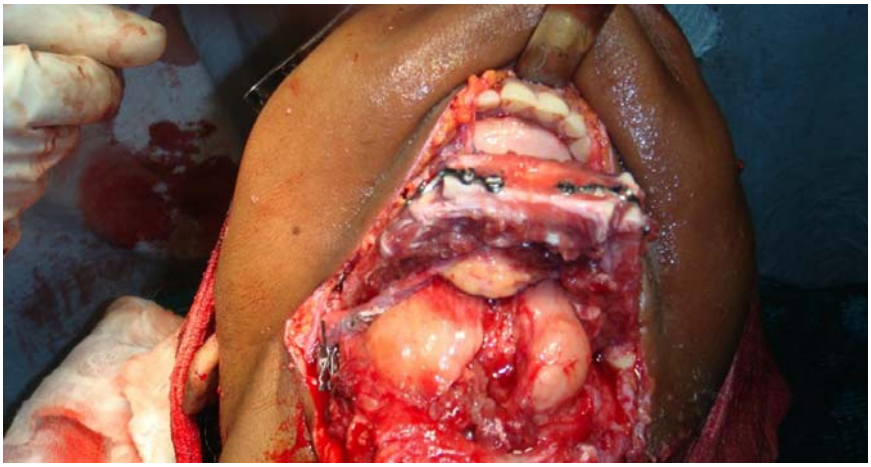
OPG was taken before discharge to confirm the proper alignment of the fibular graft to the cut ends of the mandible. After discharge, the patients were asked to come for review once in every week for the first month, twice a month for the next six months. During each visit photos were taken in frontal and profile views. Patients were asked to fill charts to subjectively assess the aesthetic and functional outcomes to record the satisfaction level of the patients.

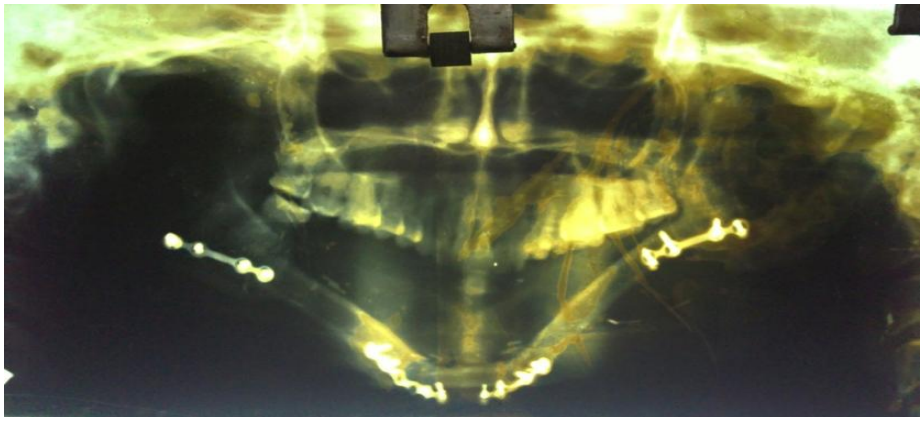
RTA WITH SEGMENTAL MANDIBLE LOSS

AMELOBLASTOMA MANDIBLE

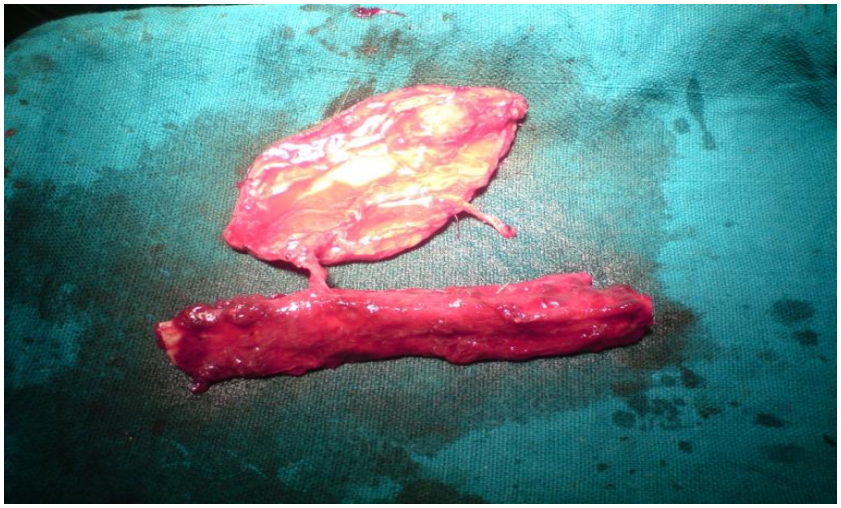




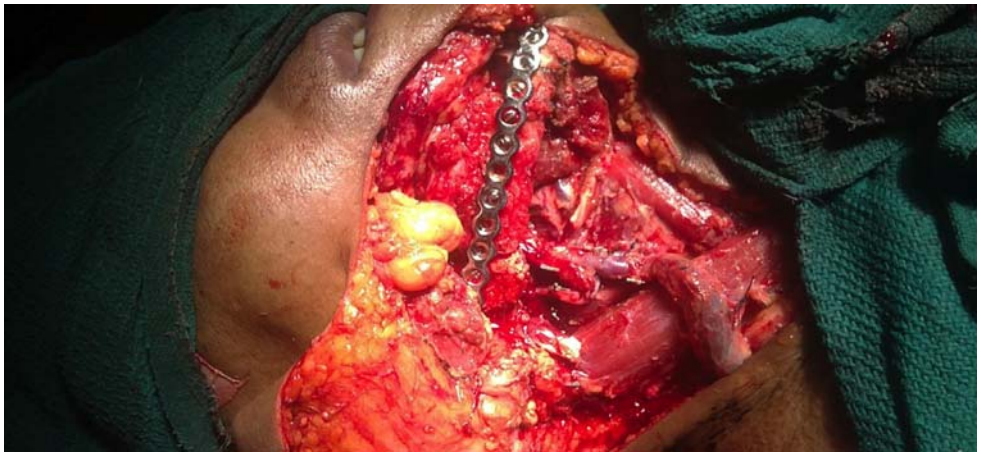


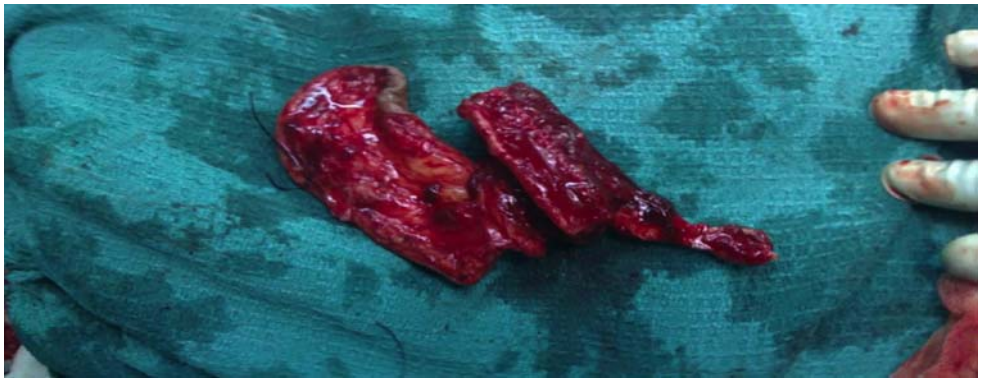


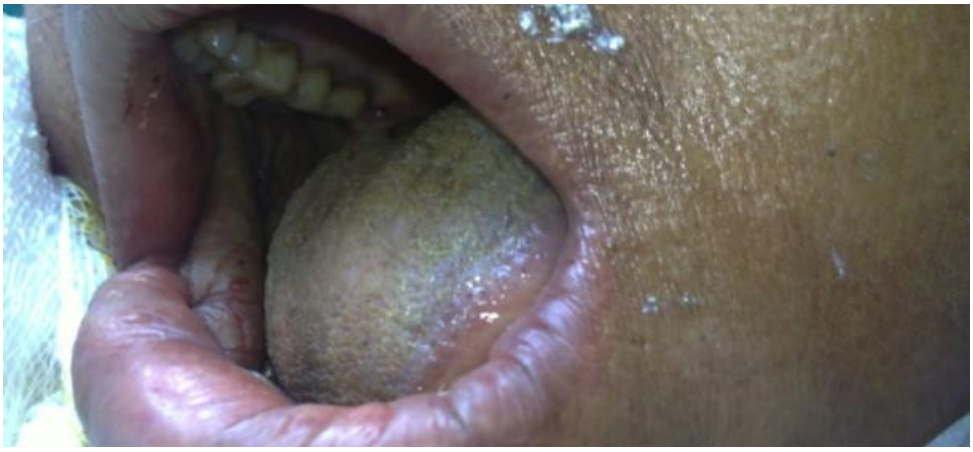
CA. LOWER LIP



CARCINOMA CHEEK AND ALVEOLUS







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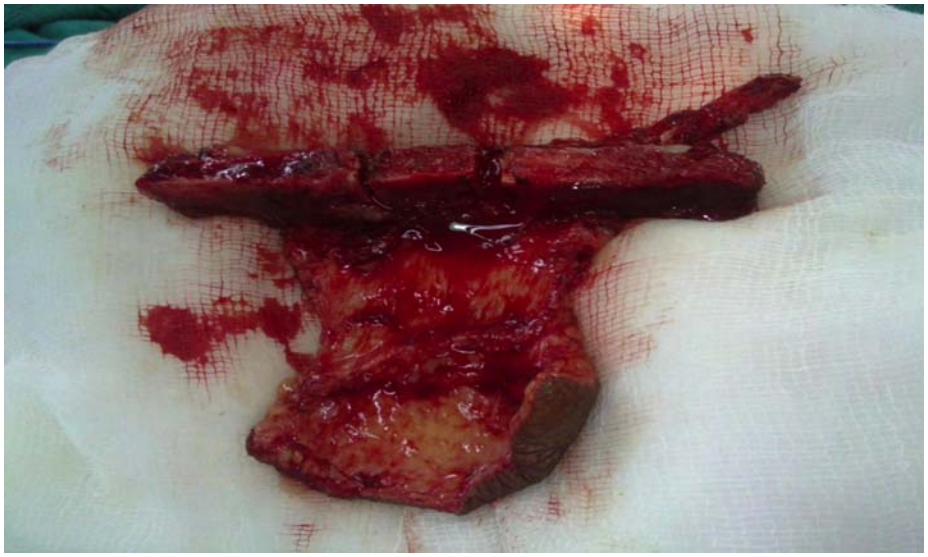
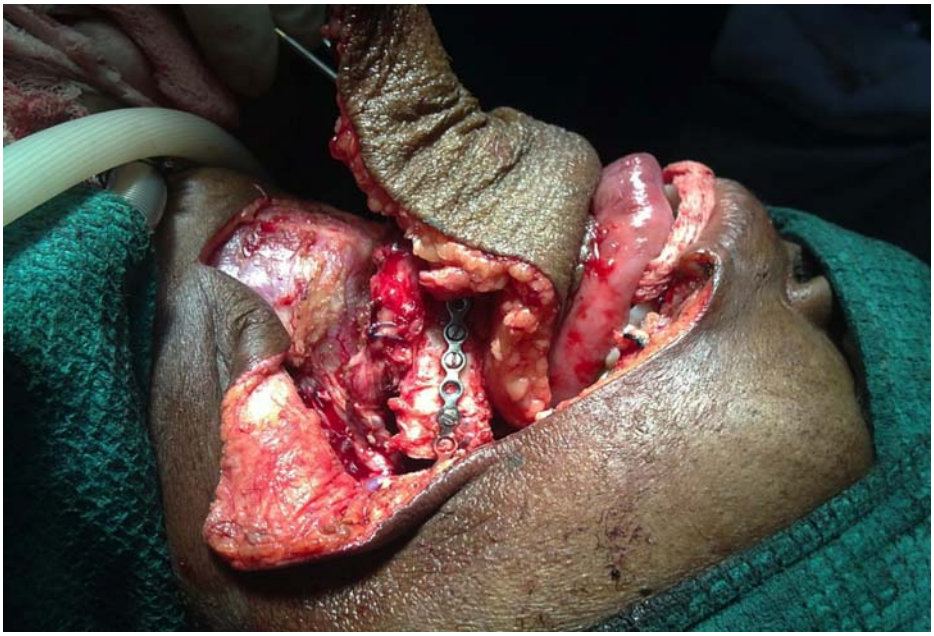




SURGICAL TECHNIQUE

SURGICAL TECHNIQUE

Fibula Flap Harvest:

Position:

Patient placed in supine position. The parts painted and draped with sterile cloth. Pneumatic tourniquet applied over the midthigh region after exsanguinating the lower limb by keeping it lifted for around 10 mins. and inflated to about 100-120 mm Hg pressure above the systolic pressure. The tourniquet time was recorded.

With the patient in supine position, the hip joint was flexed (~60°) and internally rotated and the knee was flexed (~130°) . This position helps in dissection without compromising the position for the wide local excision.

Flap markings:

All the relevant bony points like the head of fibula, the borders of fibula, the lateral malleolus were palpated and marked. A line is drawn from the lateral malleolus of the fibula to the head of fibula. The posterolateral septum lies just posterior to this line. The approximate position of entry of the nutrient artery into the fibula is marked at the mid-point of the head of fibula and lateral malleolus line. Depending on the size of the mandible and lining required, the skin island can be marked with the identified perforator centralized or eccentric in location.

Flap Dissection:

The dissection was usually started anteriorly (but can be started posteriorly also). The skin incision was given in the anterior marking of the flap extending both proximally and distally depending on the size of bone stock required. The incision deepened progressively cutting through the skin, subcutaneous tissue and finally entering the deep fascia. The muscles of the lateral compartment – peroneus longus and peroneus brevis once encountered were retracted medially to view the interosseus membrane. The muscles were detached from their attachement to the fibula leaving a thin cuff of tissue attached to the fibula to preserve its periosteal blood supply.

The anterolateral septum was identified and opened to gain access to the anterior compartment. The dissection continued further keeping close to the fibula, the attachements of extensor hallucis longus and extensor digitorum longus were then dissected off the fibula till the interosseus membrane is seen clearly. The anterior tibial aretery and vein with the deep peroneal nerve was seen in the anterior compartment in close relation to the inteosseus membrane and protected.

Now after completing the anterior dissection, the posterior incision was deepened through successive layers to reach the posterior compartment muscles deep to deep fascia. The posterior flap raised by contiuing the dissection anteriorly towards the posterolateral septum. The perforators were identified.

Taking care not to injure the vessels or damage the septum attached to the skin paddle, dissection was carried down to the fibula along the septum. The muscles of the posteior compartment visualised and lateralized to view the interosseus membrane. The muscles are separted from their fibular attachement leaving a cuff of tissue to protect the periosteal blood supply.

Now an incision was made on the periosteum of the fibula anteriorly and using Howarth's periosteal elevator a plane was created taking care to protect the pedicle. The mucoperiosteal vessels were seen on either side and separated without damaging them. This helps in visualising the planned ostectomy sites. Ostectomies were then made using oscillating saw – first distally and then proximally. If needed further dissections were done to visualise the entire course of the peroneal artery with its venae commitantes. The distal end of the vessels were ligated and cut. Now the entire fibula with the skin paddle hangs free from the pedicle.

Now leaving about 8 cm of bone proximally and 6 cm distally the required length of fibula was cut using gigly saw. The harvested bone is preserved immediately.

Osteotomy cuts to fabricate the fibula to the required mandibular contour was done as a bench surgery using oscillating saw and the contoured plates with screws were places over the ostectomy sites to stabilize the free fibula in the final curvature. Only then the pedicle was transected and transferred to the

recipeient site. The tourniquet removed and the donor site closed primarily if the margins could be approximated, else it was grafted.

Flap fixation:

The free fibula osteomyocutaneous flap with its pedicle was then transferred to the oro-mandibular region and the bone ends fixed with 1.5mm mini-plates and 2/8 mm screws to the segment left behind. L-plates were used for stabilization of the ostectomy sites. Symphyseal and parasymphyseal sites were fixed with at least two 4-hole plates with gap.

Now the microvascular anastomsis was first done between the peroneal artery and the recipient artery (usually facial artery) and then between the peroneal vein and recipient vein (usually facial vein). 9-0 nylon sutures with M.E.T. needles were used for anastamosis under 10x magnification, using operating microscopes, micro intruments and approximating clamps.

On completion of the anastamosis the flap perfusion is confirmed. Only then flap inset is given. The skin island is usually used for lining the mucosal defect.

PMMC Flap:

The defect if any on the cutaneous side was covered with pedicled pectoralis major myocutaneous flap harvested from the ipsilateral side.

Donor Defect:

The post-harvest defect in the donor site if small is closed primarily if possible else grafted with split thickness graft if large. A below knee POP slab applied to the donor limb with ankle in neutral position.

Oro-mandibular resection:

The resection of the tumour was always done by the primary surgeon (surgical oncologist/ENT surgeon/Dental surgeon). The neck was extended with interscapular pillow and the head rotated laterally to the contralateral side. The parts were cleaned with betadine and draped with sterile sheets. Usually Risdon's incision for approach to oral carcinoma and modified schobinger's incision for neck dissection were used.

In 2 of our cases of ameloblastoma only segmental mandibulectomy of the involved portion was done. In other cases of malignant tumours the wide local excision was done in all dimensions. The original incision was then extended to the neck and modified radical neck dissection was done in all cases of oral malignancy as a protocol. During these dissections care was taken to preserve the facial artery and vein to be used for anastamosis to the free fibula graft pedicle.

OBSERVATIONS AND RESULTS

OBSERVATIONS AND RESULTS

Cadaver Studies:

Injection studies performed in the 20 peroneal artery systems with the following objectives,

1. To find out the location is the single best perforator for the skin paddle
2. To study the configuration of the single best perforator in terms of location, course, size and length.
3. To study the course of the musculoperiosteal vessels of the fibula, to find a safe window for ostectomy without injuring the vessels.

In total 20 peroneal arterial systems were studied. We found that,

The middle third of the leg had the largest number of perforators with an average of 5.5 perforators; the upper third of the leg had an average of 3.5 perforators while the lower third had an average of 2.5 perforators

With the size measured at the origin of the perforator from the main vessel using ordinary calipers, we found that the upper third of the leg has the perforators with average external diameter of 1.3 mm, followed by the middle third of the leg with an average diameter of 1.2 mm, while the lower third had an average diameter of 1 mm.

When the length of the perforators were measured, we found that the middle third has the longest perforators with an average of 2.7 cm, next came

the upper third with an average perforator length of 2.5 cm followed by the lower third with an average vessel length of 1.8 cm.

Table 1: Cadaver Study – Locating the single best perforator

Leg segment	Avg. number of perforators	Avg. length of the perforators	Avg. diameter of the perforators
Upper third	3.5	2.5 cm	1.3 mm
Middle third	5.5	2.7 cm	1.2 mm
Lower third	2.5	1.8 cm	1 mm

Chart 1: Bar Chart comparing the average number of perforators

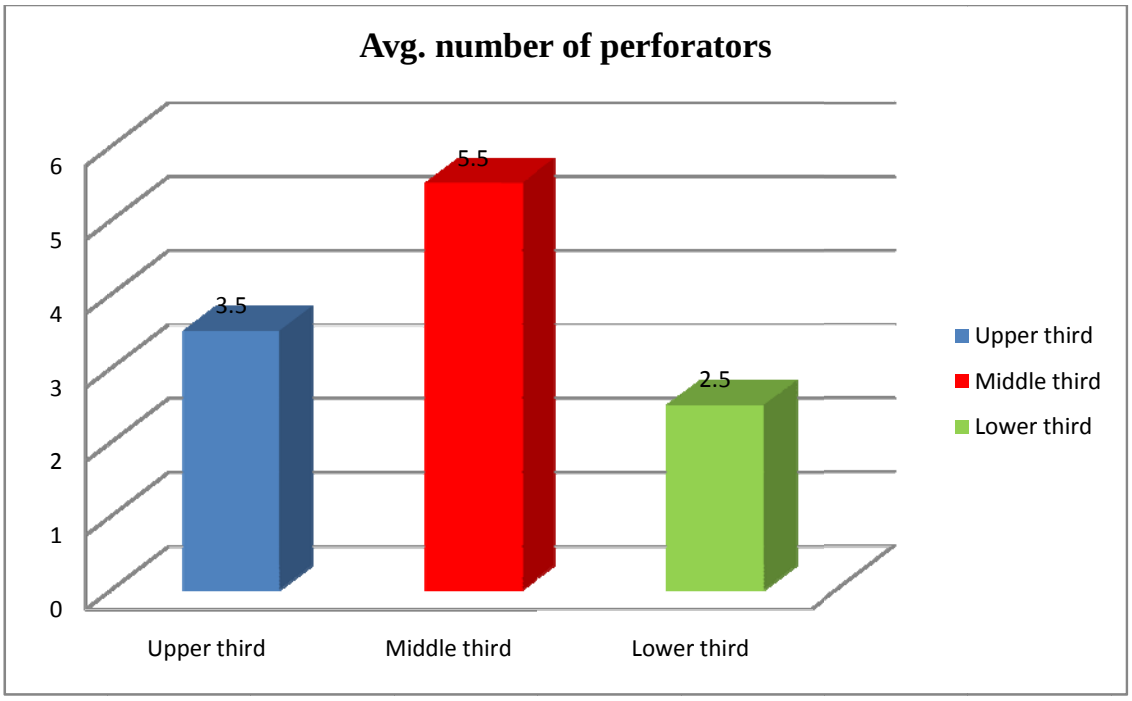


Chart 2: Chart Comparing the Average number of Perforators

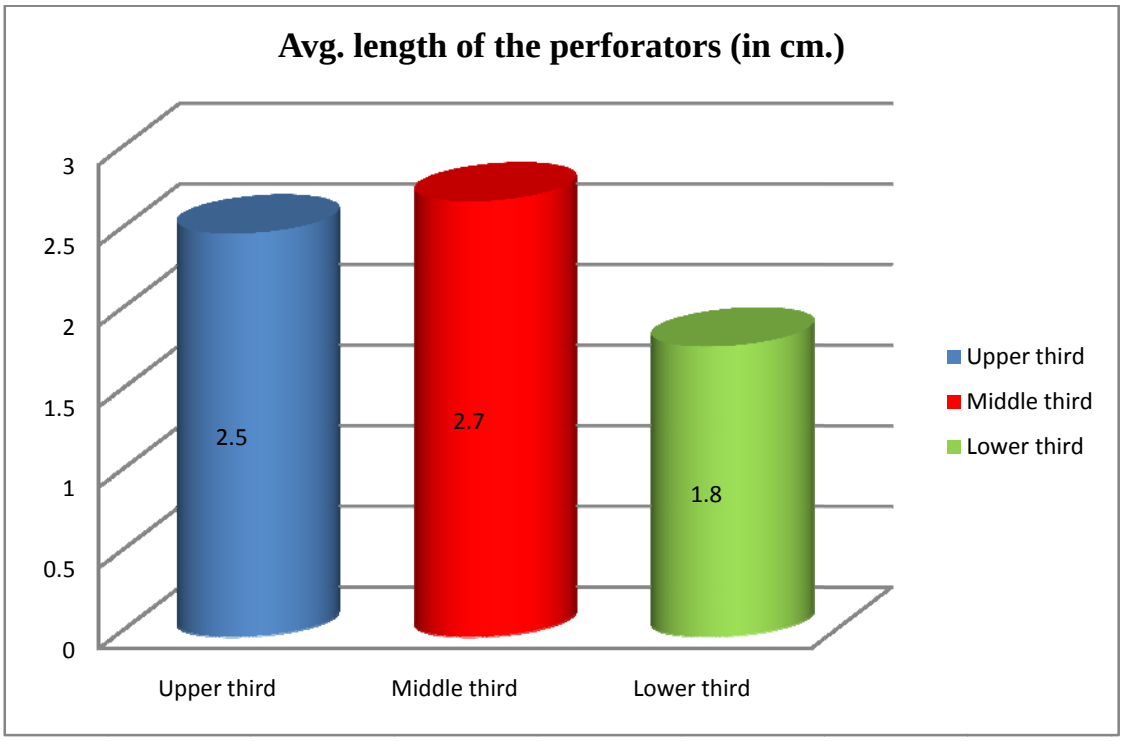


Chart 3: Chart Comparing the Average Diameter of the perforators

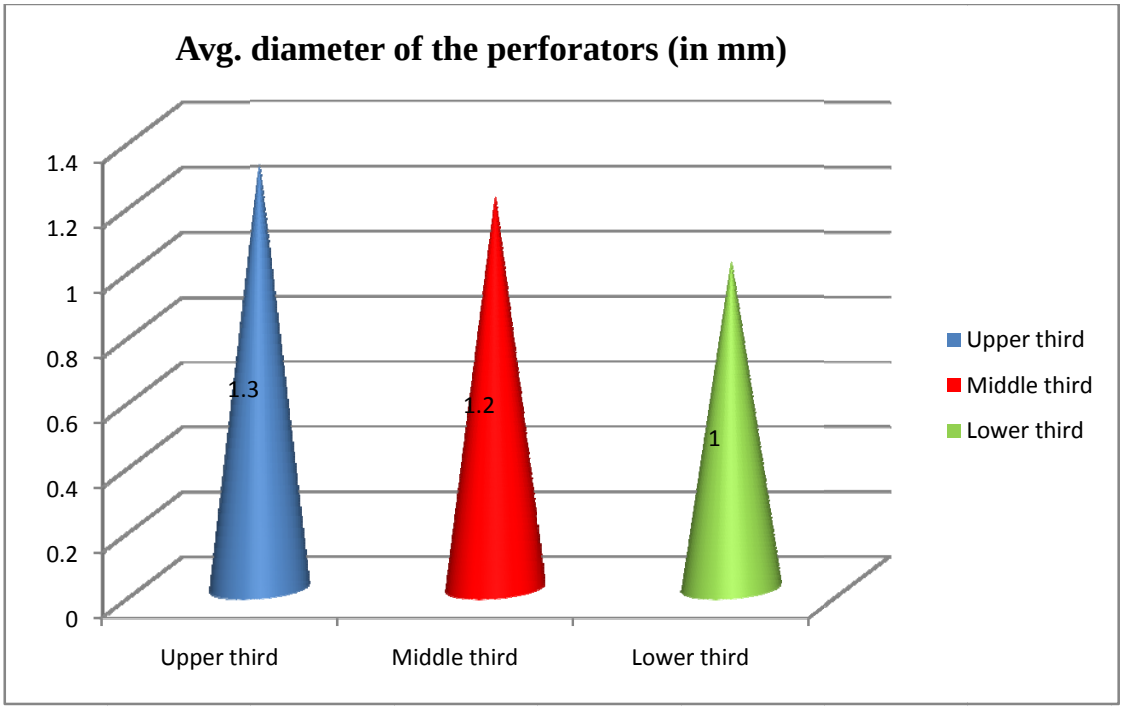
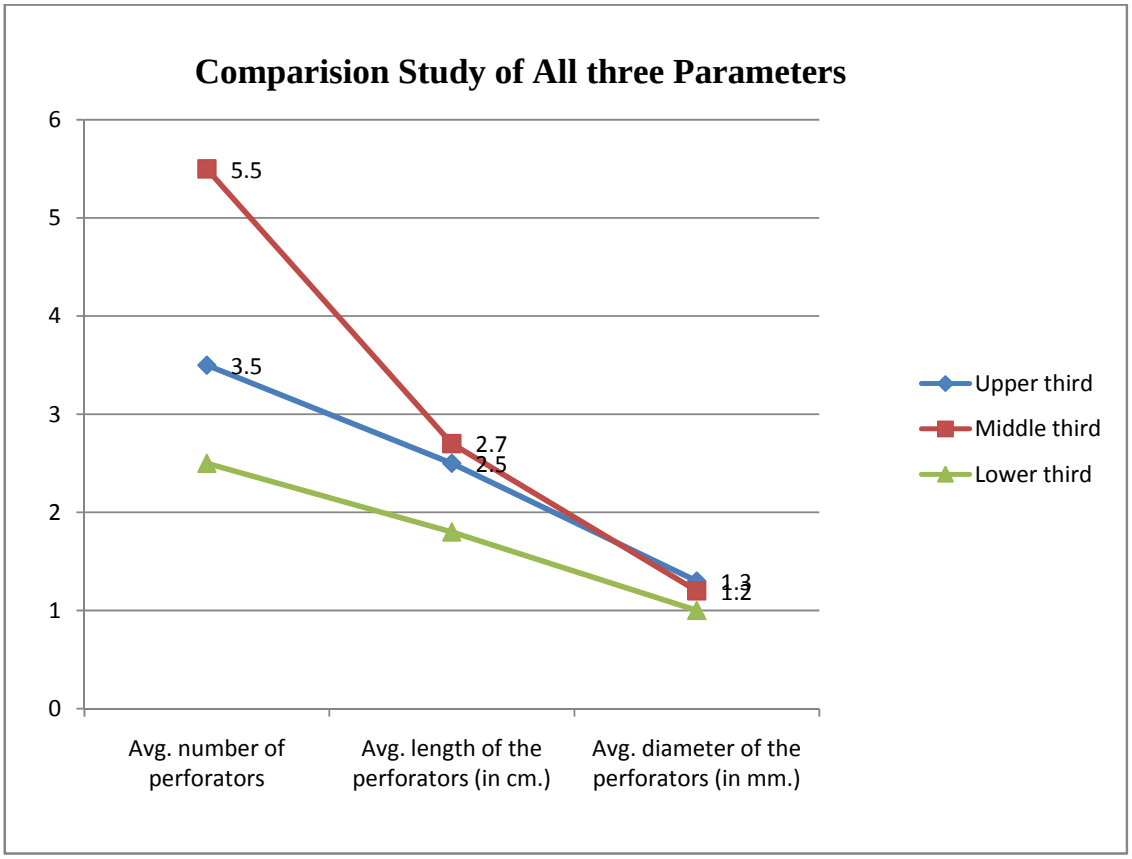


Chart 4: Scatter Diagram comparing all three parameters

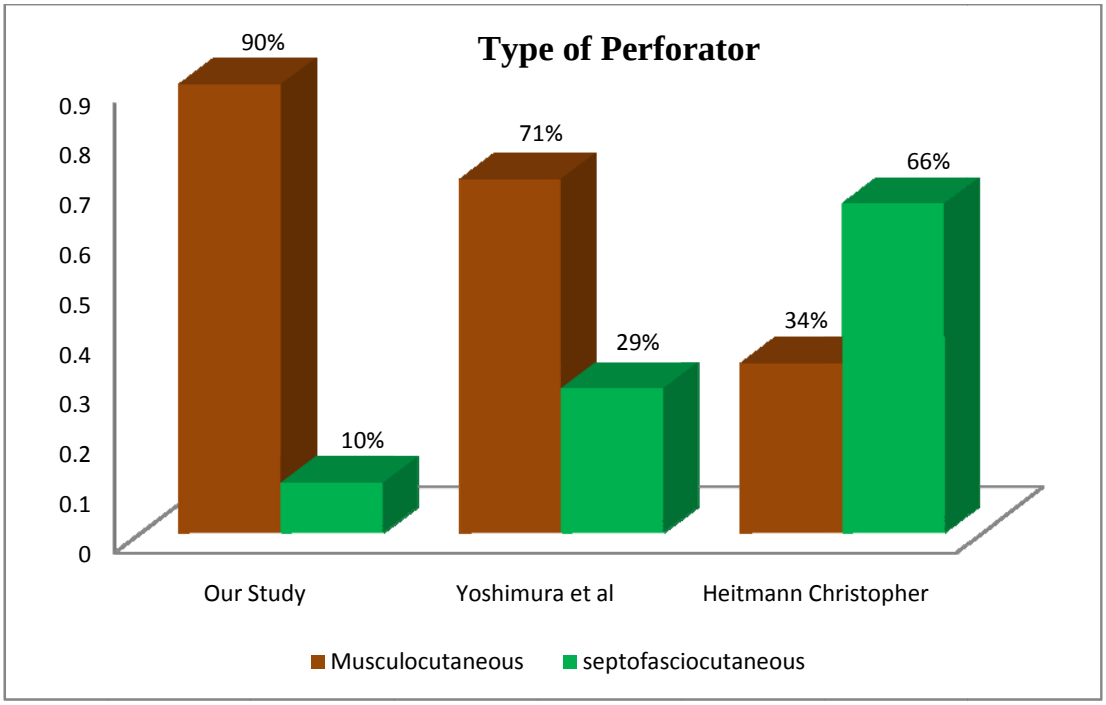


During our cadaveric injection studies we also found that about 90% of the single best perforators were musculocutaneous in origin while only 10% of the peforators were of septocutaneous origin. We also found that almost all of the single best musculocutaneous perforator passes through flexor hallucis longus and sometimes through the soleus. Comparing this finding of ours differs to various other studies; we found that our study showed a greater percentage of musculocutenous perforators than any other study. Our cadaveric study findings were later validated in our clinical studies where we found similar findings.

Table 2: Type of the single best perforator

Perforator Type	Our Study	Yoshimura et al[16]	Heitmann Christopher[34]
Musculocutaneous	90% thro FHL and soleus	71%	34% upper 2/3
septofasciocutaneous	10% proximal to fhl	29%	66% lower 1/3

Chart 5: Bar Chart comparing our study to other studies regarding the type of perforator



The second aspect studied in cadaveric dissection, is location and standardization of safe windows for ostectomies and plate and screw fixation. We found out that contoured plates can be fixed at the peroneal surface safely as they are the final site anastomosis of musculo periosteal vessels which run in

the anteromedial and posteromedial surface in the peroneal surface of fibula. That means that apex of wedge osteotomy at the peroneal surface and base at interosseous border does not cause any kinking on the pedicle vessel. As all of the musculoperiosteal vessels runs downwards and laterally they are safe widows for osteotomies as seen above is available after incising Periosteum and pushing the Periosteum cranially and caudally.

Clinical Studies:

We applied the knowledge obtained through the cadaveric studies to our clinical cases. 20 cases requiring oro-mandibular reconstruction were taken up for the study.

The general etiologies of the cases were: Trauma, Dental Cysts and malignancy. Sex distribution: Males 18, females 2. Of the 20 clinical cases, 2 cases of ameloblastoma and 2 cases of road traffic accidents did not require skin cover. They involved only mandibular reconstrution with lining. The rest of the 16 cases were malignant conditions, necessitating wide local resection. All the 16 cases required reconstruction of the mandible with both mucosal lining and skin cover.

In cases of post-excisional defects in the floor of the mouth, during harvesting of the free fibula flap, a segment of the soleus muscle was taken as part of vascularised free fibula chimeric osteomyocutaneous flap. The soleus

muscle was used to give padding to the floor of the mouth and to fill the cavity created by the excision procedure.

In cases where there is composite deficit in the peri-commissural and lip area, skin paddle was harvested in adequate dimensions as part of the vascualarized free fibula chimeric osteocutaneous flap and folded to provide both the lining and the cover.

In all malignant condition modified radical neck dissection was performed as protocol by the surgical oncologists and ENT surgeons.

The maximum size of skin paddle that was harvested with the pedicle in eccentric location was 15x8 cm. (120 cm^2). In all the cases the free fibula flap was harvested with the single best perforator to the skin paddle placed eccentric in location.

If the composite defect envisages distance apart from lining and cover, we harvest skin paddle of adequate size in eccentric location from the middle third of the leg (where we can get good length of perforator). Thereby we use the biogeometry of properllar flap due to the eccentric location of the perforator in relation to the paddle. On the other hand, if the composite oro-pharyngeal defect does not require cover but only a long bone stock, then the free flap is harvested from the lower third. The average operating time ranged from 3½ to 6 hours.

In our study, safe skin paddle with a maximum dimension 120 cm^2 was safely harvested in chimeric configuration with eccentric location of perforator to the skin paddle which allowed us to better manipulate the skin paddle three dimensionally during positioning of flap in composite reconstructions.

We found that it was advantageous to harvest from middle third as it contains the lengthy perforators. If there is need for long pedicle and robust perforator with good length next best choice is to choose from lower third of fibula

The next aspect studied is optimal positioning of peroneal vessel in relation to graft during fixation of ostectomies. The posteromedial surface of the fibula which contain peroneal vessel, when positioned inferiorly and posteriorly in mandible reconstruction site, is the optimal position without causing any kinking on vessel.

Complications:

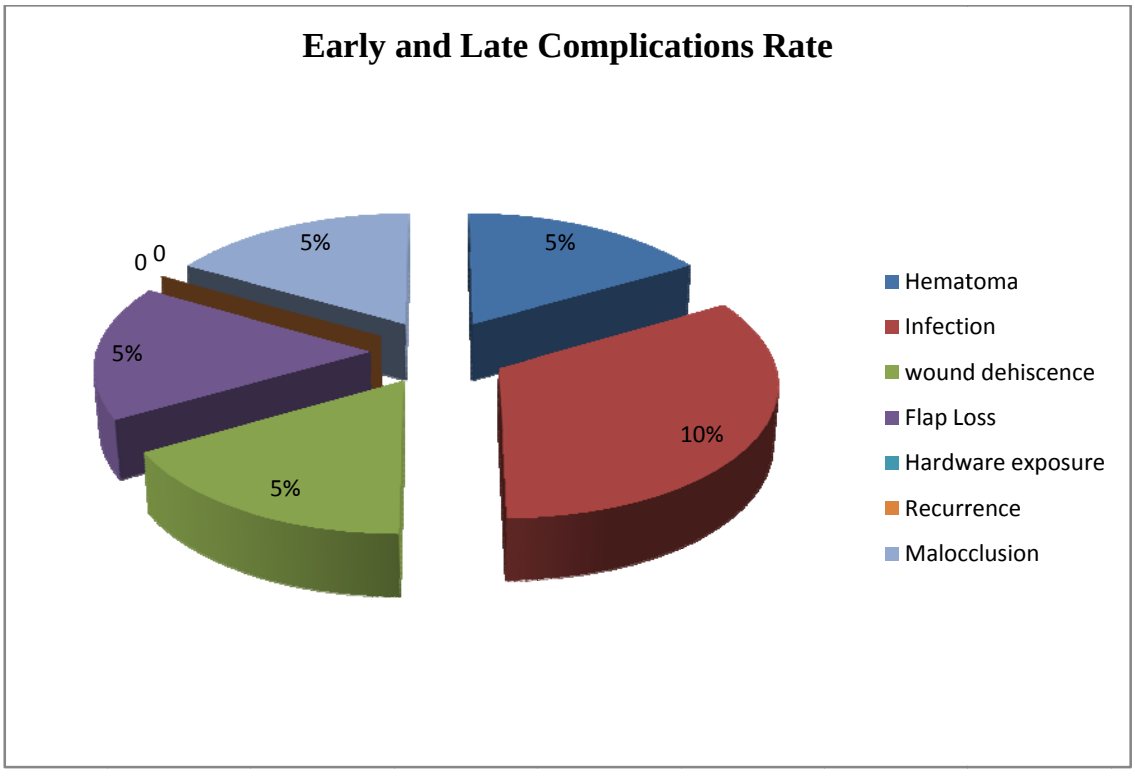
In the early post-op period, we encountered some complications like, 1 case of hematoma underneath the skin paddle – it was evacuated by taking out a stitch and letting it out. 2 cases of infection of the surgical site were noticed and treated immediately with broad spectrum antibiotics – the infection resolved and both went for secondary suturing. There was another case of venous thrombosis

for which re-exploration was done, and the thrombus evacuated, but the flap did not survive, resulting in the loss of flap.

Table 3: Flap Complications

Complications	**No. of cases**	**Percentage**
Early		
Hematoma	1	5%
Infection	2	10%
wound dehiscence	1	5%
Flap Loss	1	5%
Late		
Hardware exposure	0	0%
Recurrence	0	0%
Malocclusion	1	5%

Chart 6: Pie chart showing early and late complications rate



Morbitiy at the donor site was assessed after 1 month after the reconstruction surgery and the findings showed that the patients were generally symptom free except for some of the complication during the early post-op period like, mild pain, motor weakness. 3 patients who complained of mild eversion difficutly had the complaint spontaneously resolved in few months. All other complaints also resolved spontaneously during further follow-ups.

Table 4: Donor site morbidity

Factors	**No. of cases (percentage)**
Gait disturbances	Nil
Pain	Mild in 1 patient, nil in others (5%)
Sensory loss	Nil
Ankle joint instability	Nil
Knee Joint instability	Nil
Motor weakness	3 patients complained mild eversion difficulty which resolved after 1 month

On follow-up we found the patients were generally very satisfied with the functional and aesthetic results of the surgery.

DISCUSSION

DISCUSSION

Mandible is an important structure which not only forms the lower jaw but also gives character to the face. Loss of the mandible and the soft tissue of the oro-mandibular region, either due to trauma or post-surgical, cause great distress to the patients – both functionally and aesthetically. Hence it needs to be reconstructed to provide optimal functional and aesthetic outcome to the patient. With many regional, loco-regional and distant flap options available, the vascularized free fibula chimeric osseomyocutaneous flaps have become the gold standard for reconstruction of the oro-mandibular defects. With the increasing importance to the vascularizsed free fibula flaps, there arises a need to standardize as much as possible the marking, dissection of the soft tissue, ostectomy sites of the fibula and its positioning in the recipient site. With this in mind, we conducted anatomical study of the peroneal perforator system in cadavers with dye injection and studied various parameters with the objectives of,

- Location of the single best peroneal perforator in the leg,
- Location of the best site surface and site for ostectomy of the fibula

These cadaveric dissection findings were then applied to live surgeries and the outcomes observed. In addition two more parameters studied in the clinical cases

- Best position of the flap in the recipient site that does not cause strain in the pedicle.
- If the eccentric location of the pedicle of the skin paddle affect the survival of the flap.

Classification of Mandibular Defects:

Classification that combines the loss of bone and soft tissue is useful for determining the reconstructive method. Various classification schemes have been proposed for quantifying the segmental mandibulectomy defects, which helps with planning the reconstruction.

Initially there was Pavlov's classification, but it did not take into account the loss of condyle and mentum. But the loss of condyle makes reconstruction of articular surface difficult.

Later, Boyd[19] and colleagues modified Pavlov's classification by including the loss of condyle and mandible in their classification. In their classification,

H - lateral defects of any length up to the midline that include the condyle

L - lateral defects that exclude the condyle

C - defects involve the central segment containing the four incisors and two canines.

The three lowercase letters in this classification system describe the associated soft tissue components:

o - no skin or mucosal component

s - skin

m - mucosa

sm - skin plus mucosa

Loss of the central segment poses problems with restoration of stomal competence, restoration of an anterior gingivolabial sulcus to fit prosthetics for dental rehabilitation, and restoring the lip height for cosmesis.

Urken[17] and associates described another classification scheme is based on functional considerations due to detachment of different muscle groups and difficulties with cosmetic restoration. This reconstruction scheme has similar anatomic designations,

C - Condyle

R - Ramus

B - Body

S - Total Symphysis

SH - Hemisymphysis

P - Palate

This classification system also includes a detailed description of soft tissue and neurologic deficits.

It should be noted that neither of these classifications describes the absolute length of the defect. This is because with the advent of vascularized

osseous free flaps, outcomes are not dependent on the length of the graft required to bridge the defect.

Goals of Mandibular Reconstruction:

The primary objective of mandibulectomy in tumor resections is cure, but the functional and aesthetic rehabilitation are necessary for the psychologic and physiologic recovery of patients.

The ideal reconstruction for a segmental mandibulectomy should have the following goals:

1. Restoration of oral competency
2. Maintainence of the occlusal relationships with left over teeth
3. Give allowance for prosthetic dental restoration in the future if the patient desires
4. Restoration of bone continuity
5. Restoration of facial symmetry and the contour to the lower third of the face.

In addition,

- Wound closure should be immediate and complete with early functional recovery
- Avoidance of complications like orocutaneous fistula, infection, etc.,
- Creation of a safe wound that can undergo post-operative radiation later
- Facilitatation of early hospital discharge

Cadaver and Clinical Studies:

We found that from our cadaveric studies and clinical cases, single best perforator with good length is available in the middle third of the leg. This is because the posterolateral septum is proportionately larger in dimension in relation to to mid-calf muscle mass. Therefore longer septofasciocutaneous and musculocutaneous perforators can be harvested from the middle third of the leg.

When lining or skin cover flap needed to be planned for wider mobility in the reconstructed mandible site, for eg., lip reconstruction, cheek reconstruction, upper neck reconstruction, etc., we harvest the chimeric free fibular osteocutaneous flap with skin island based on the perforators from the middle third of the leg. Thereby we were able to obtain a lengthy single best perforator facilitating the wide three-dimensional positioning of lining or cover.

On the other hand, when longer osseus element is needed for reconstruction of larger mandibular defect, but only limited or no lining or cover needed, we keep the skin paddle only as a monitor flap to assess the viability of the submerged portions of the flap. This situation arose in 2 cases of ameloblastoma in our studies, where only the involved mandible segment was excised with no loss of the lining or cover. In such cases, we tend to harvest skin pedicles from lower third of the leg with single best perforator on this skin paddle being utilized only as monitor flap.

In both cadaveric and clinical studies, we observed that almost 70% of the single best perforator in the middle third and 80% in the lower third of the leg were musculocutaneous (pass through flexor hallucis longus and/or soleus).

We have studied both in the cadaver dissections as well as in clinical cases, the distribution of mucoperiosteal vessels. It is possible to find the safe window for wedge ostectomies to match the curvature of the mandible. A wedge shaped ostectomy can be safely made in the window between adjacent mucoperiosteal vessels, which runs downwards and laterally, with the base on the interosseus surface and the apex in the peroneal surface. This can be fashioned in a way that neither causes damage to the mucoperiosteal blood supply nor causes kinking of the peroneal artery, which runs in relation to the median crest of the posterior medial surface of the fibula.

Incision is placed in the periosteum in the oblique direction, parallel to the direction of the mucoperiosteal blood vessels. The mucoperiosteal vessels are elevated on either sides, enough to visualize the ostectomy site clearly. Now ostectomy is done with power instruments with copious cold saline continuoes irrigation to avoid damage to the osteoblasts and its progenitor cells. This sleeve of mucoperiosteal muscular cuff elevated allows enough space for fixing the contoured plates and screws.

In clinical cases, when a skin paddle, but there is necessity to manipulate the skin paddle to a distance relatively far away from the reconstructed

mandible, then we design the paddle so that the single best perforator is placed eccentric in location to the skin paddle. This provides a wider arc of rotation and three dimensional manipulations.

Here we incorporate the biogeometry of the properllar flaps. This is designed by an exploratory single incision to judge the length of the perforator before completing the total delineating incision of the skin paddle. From our clinical experience, we found that all the flaps harvested in the propeller fashion with the eccentric location of the pedicle survived without any complications.

Both from our cadaveric and clinical studies, in the reconstructed mandible, the peroneal arteries arising in the medial crest of the posterolateral surface of the fibula is always positioned inferiorly and posteriorly. This facilitates easy anastamoses of the pedicle vessels to the neck vessels. This position also prevents any kinking in the peroneal vessels after ostectomies and fabrication into the mandibular shape.

CONCLUSION

CONCLUSION

Vascularized free fibula osteocutaneous flap is an established procedure for reconstruction of the oro-mandibular defects but several questions arises like; what is the location of the single best perforator for the skin paddle? What is the safe skin paddle dimension that can be harvested on a single eccentrically located pedicle? Where are the safe windows for ostectomy located on the harvested free fibula? What is the best position of the skin paddle in the recipient site which does not cause kinking of the vessel? etc.,

We have done cadaver studies and clinical studies to answer some of these questions. It was found from our studies that the perforators of good length and calibre are best found in the middle third of the leg, and most of the perforators were musculocutaneous travelling through the flexor hallucis longus muscle. Hence if a larger skin paddle is needed, it can reliably be harvested from the middle third of the leg with the pedicle placed eccentrically. But if the defect requires a longer bone stock and a smaller pedicle, it is better to harvest from the lower third of the leg.

We also found from our clinical studies that designing the skin paddle with the pedicle eccentrically located allows for better three dimensional manipulation of the skin paddle in the recipient site, allowing it to cover wider area in the facial region like, cheeks, chin, upper neck, upper and lower lips etc.,

Also from our clinical studies we found that a single eccentrically located perforator of good length and calibre can support a skin paddle of 120 cm^2.

We also found from our studies that the safe window for ostectomies can be found in the peroneal surface of the fibula as the musculoperiosteal vessles runs in the anteromedial and posteromedial surface of fibula. Hence ostectomies can be performed with the apex of the wedge located at the peroneal surface and base at the interosseus border.

We found from our studies that the posteromedial surface of the fibula which contains the peroneal vessel, when positioned inferiorly and posteriorly in mandible reconstruction site, gives better manoeuverability during anastamosis of the flap pedicle to the recipient vessels and also does not cause kinking of the vessel.

From of cadaveric and clinical studies we have tried to answer some of the burning questions of the free fibula osteomyocutaneous flap procedure.

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ANNEXURES

PROFORMA

ERGONOMICS OF FREE FIBULA FLAP IN MANDIBLE RECONSTRUCTION

Patient's Name : ……...
Age/Sex : ……...
IP No : ……...
Contact Address : ……...
……...
……...
Contact Number : ……...
Admitted Under : Plastic Surgery/Surgical Oncology/ENT/Dental Surgery

Pre-Operative Details:

1. Diagnosis :
2. Aetiology :
3. Expected Bone Defect (Boyd's Classification) :
4. Expected Soft Tissue Defect (Boyd's Classification):
5. Tissue Diagnosis :

Co-Morbid Conditions : ……
Risk Factors : ……
Donor Site Assessment : ……

Operative Details:

1. Procedure Done : ……
2. Date : ……
3. Incision for Harvest: ……
4. Pedicle: Length: …….. Diameter: …….
5. Ostectomies Done: ……
6. Fibula Length Harvested: ……..
7. Skin Paddle Dimensions Harvested: …….
8. Recipient Artery: ……. Vein: ……...
9. Suture Materials Used: ……..
10. Duration of Surgery: ……

Post-Op Drugs Used : ……
……
……

Post-Op Complications: ……

Follow-up Findings : ……
……
……
……

Investigator(s) Name & Signature: ……

MASTER CHART OF CADAVER DISSECTION

Parameters	Number of perforators			Avg. vessel diameter (in mm)			Avg. vessel length (in cm)			Type of Perforators	
Cadaver No.	**Upper third**	**Middle third**	**Lower third**	**Upper third**	**Middle third**	**Lower third**	**Upper third**	**Middle third**	**Lower third**	**Septocutaneous**	**Musculocutaneous**
1	2	6	2	1.2	1.2	0.9	2.5	2.2	1.9	1	9
2	3	6	2	1.5	0.9	0.8	2.3	3	2.1	1	10
3	5	4	3	1.2	1.3	1.1	3.2	3.3	1.6	1	11
4	2	6	2	1.4	1.4	1.2	2.6	2.6	1.6	1	9
5	5	6	3	1.2	1.1	0.9	2.2	3.1	2.2	2	12
6	4	5	2	1.3	0.9	1	3.1	2.5	1.5	2	9
7	4	5	3	1.1	1.2	1.1	2.2	2.5	1.6	1	11
8	2	7	2	1.2	1.3	0.9	2.3	3.4	1.8	1	10
9	5	5	2	1.5	1.3	0.9	2.5	2.5	1.7	1	11
10	3	6	3	1.4	1.2	1.1	2.6	2.7	1.7	1	11
11	4	4	3	1.4	1.3	1	2.5	2.5	1.6	1	10
12	2	5	2	1.2	1.1	1.1	1.9	2.4	1.6	2	7
13	2	6	1	1.3	1.2	0.9	2.6	3.2	2.1	1	8
14	5	5	3	1.3	1.3	0.9	2.9	3.3	1.9	1	12
15	3	6	2	1.4	1.2	1.1	2.3	2.5	1.8	1	10
16	4	5	4	1.2	1.3	1.1	2.4	2.3	1.8	2	11
17	4	6	3	1.3	1.2	0.9	2.5	2.6	1.7	1	12
18	5	6	3	1.2	1.2	0.9	2.7	2.6	1.7	1	13
19	4	6	3	1.4	1.1	1.1	1.9	2.4	2.2	1	12
20	2	5	2	1.3	1.3	1.1	2.8	2.4	1.9	1	8
Average	***3.5***	***5.5***	***2.5***	***1.3***	***1.2***	***1***	***2.5***	***2.7***	***1.8***	***10.44%***	***89.56%***

MASTER CHART OF CLINICAL CASES

Sl. No	Diagnosis	Age	Sex	Dept.	Oro-Mandibular Defect (Boyd's Classification)		skin flap dimension (in cm)	length of fibula harvested (in cm)	No. of ostectomies done	Location of pedicle in skin paddle	Flap Outcome	Complications	Aesthetic Outcome	Functional Outcome
					Bone Defect	Soft Tissue Defect								
1	RTA	24	M	Plastic	LCL	O	3x3	15	2	eccentric	survived	surgical site infection	Good	Good
2	Ameloblastoma	22	F	DS	C	O	3x3	7	1	eccentric	survived	Nil	Good	Good
3	Ca. Left Cheek	57	M	S.Onc	CL	Sm	7x5	9	2	eccentric	survived	wound dehiscence	Good	Good
4	Ca. Alveolus	44	M	ENT	L	Sm	6x4	5	1	eccentric	survived	Nil	Good	Good
5	Ca. lower lip	56	M	ENT	C	Sm	7x5	7	1	eccentric	survived	Nil	Good	Good
6	Ameloblastoma	27	F	DS	C	O	3x3	6	1	eccentric	survived	Nil	Good	Good
7	Ca. Left Cheek	54	M	S.Onc	CL	M	5x4	9	2	eccentric	Flap Necrosis	Flap Necrosis	NA	NA
8	Ca. Buccal mucosa	59	M	S.Onc	CL	M	7x3	10	2	eccentric	survived	Hardware exposure	Good	Good
9	RTA	32	M	Plastic	L	O	3x3	5	1	eccentric	survived	Nil	Good	Good
10	Ca. lower lip	63	F	S.Onc	CL	Sm	5x3	12	2	eccentric	survived	Nil	Good	Good
11	Ca. Cheek	45	M	ENT	CL	M	5x2	8	2	eccentric	survived	Nil	Good	Good
12	SCC chin	62	F	S.Onc	LCL	Sm	12X8	14	3	eccentric	survived	Nil	Good	Good
13	Ca. Right cheek	63	M	S.Onc	L	Sm	7x3	5	1	eccentric	survived	surgical site infection	Good	Good
14	Ca. Alveolus	55	M	S.Onc	L	Sm	6x3	7	1	eccentric	survived	Nil	Good	Good
15	Ca. Left Cheek	52	M	S.Onc	CL	M	5x3	8	2	eccentric	survived	Nil	Good	Good
16	ca. lower lip	47	F	S.Onc	LC	Sm	7x4	7	2	eccentric	survived	Nil	Good	Good
17	ca. right commissure	61	F	S.Onc	L	Sm	6x3	4	1	eccentric	survived	Nil	Good	Good
18	Ca. Alveolus	51	M	S.Onc	L	M	7x2	6	1	eccentric	survived	Nil	Good	Good
19	ca. buccal mucosa	58	M	S.Onc	L	M	5x3	5	1	eccentric	survived	Nil	Good	Good
20	Ca. Right cheek	49	F	S.Onc	LC	Sm	9x3	8	2	eccentric	survived	Nil	Good	Good

INSTITUTIONAL ETHICS COMMITTEE
MADRAS MEDICAL COLLEGE, CHENNAI-3

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

CERTIFICATE OF APPROVAL

To
Dr. Sendhil Nathan .K,
PG in Plastic and Reconstructive Surgery,
Department of Plastic and Reconstructive Surgery,
Madras Medical College, Chennai-3.

Dear Dr. Sendhil Nathan .K,

The Institutional Ethics Committee of Madras Medical College, reviewed and discussed your application for approval of the proposal entitled **"Ergonomics of Free Fibula Flap in Mandible Reconstruction"** No.20032014

The following members of Ethics Committee were present in the meeting held on 11.03.2014 conducted at Madras Medical College, Chennai-3.

1.	Dr. C. Rajendran, M.D.	-- Chairperson
2.	Dr. R. Vimala, M.D. Dean, MMC, Ch-3.	-- Deputy Chairperson
3.	Prof. Kalaiselvi, MD Vice-Principal, MMC, Ch-3	-- Member Secretary
4.	Prof. Nandhini, M.D. Inst. of Pharmacology, MMC, Ch-3.	-- Member
5.	Prof. Bhavani Shankar, M.S. Prof & HOD of General Surgery, MMC, Ch-3.	-- Member
6.	Prof. V. Padmavathi, M.D. I/c Director of Pathology, MMC, Ch-3.	-- Member
7.	Thiru. S. Govindasamy, BABL	-- Lawyer
8.	Tmt. Arnold Saulina, MA MSW	-- Social Scientist
9.	Thiru. S. Ramesh Kumar, Administrative Officer, MMC, Ch-3.	-- Layperson

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

Sd/Chairman & Other Members

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.

13/3/14

MEMBER SECRETARY
INSTITUTIONAL ETHICS COMMITTEE
MADRAS MEDICAL COLLEGE
CHENNAI

Member Secretary, Ethics Committee

13/3/14

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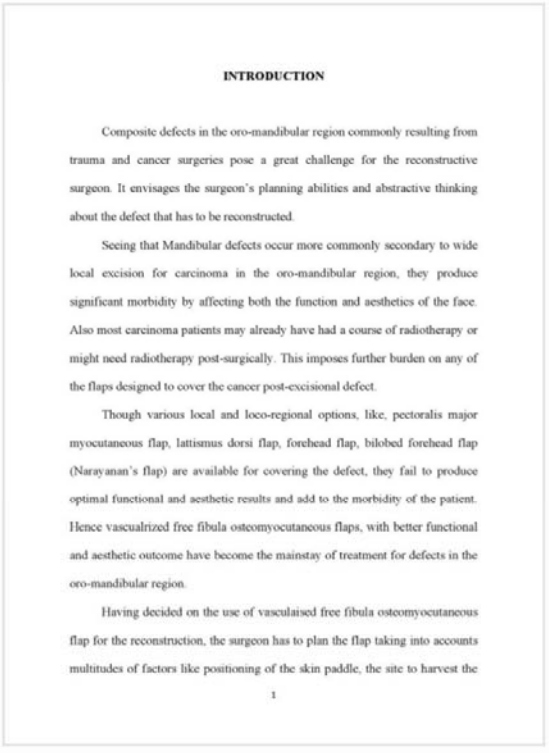

INTRODUCTION

Composite defects in the oro-mandibular region commonly resulting from trauma and cancer surgeries pose a great challenge for the reconstructive surgeon. It envisages the surgeon's planning abilities and abstractive thinking about the defect that has to be reconstructed.

Seeing that Mandibular defects occur more commonly secondary to wide local excision for carcinoma in the oro-mandibular region, they produce significant morbidity by affecting both the function and aesthetics of the face. Also most carcinoma patients may already have had a course of radiotherapy or might need radiotherapy post-surgically. This imposes further burden on any of the flaps designed to cover the cancer post-excisional defect.

Though various local and loco-regional options, like, pectoralis major myocutaneous flap, lattismus dorsi flap, forehead flap, bilobed forehead flap (Narayanan's flap) are available for covering the defect, they fail to produce optimal functional and aesthetic results and add to the morbidity of the patient. Hence vascualrized free fibula osteomyocutaneous flaps, with better functional and aesthetic outcome have become the mainstay of treatment for defects in the oro-mandibular region.

Having decided on the use of vasculaised free fibula osteomyocutaneous flap for the reconstruction, the surgeon has to plan the flap taking into accounts multitudes of factors like positioning of the skin paddle, the site to harvest the

1

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