ALTERNATIVE FREE FLAPS
(EXTRACORPOREAL TISSUE TRANSFER)

Govila & Govila
Professor Ashok Gavila – A Pioneer in the Annals of Plastic Surgery

Prof. Ashok is well known in the field of Plastic and Reconstructive surgery, thanks to a legacy that has spanned three decades. During this time, he gained invaluable experience from the farthest reaches of the world, from the East, the West and the Middle East.

A masterful medical professional, Prof. Ashok worked in unusual locations and conditions that presented him with a unique understanding of the subject of reconstruction. This resulted in many improvised methods he has invented and evolved over the years, which are of great use to many surgeons in the present day.

Among the significant ones is the technique and procedure of extraocular tissue transfer, also known as the Alternative Free Flap procedure. This work is presented as a treatise in the form of a clinical and surgical colour atlas.

He obtained the degree of Master of Surgery (MS), at the Gajra Raja Medical College in Gwalior, India, in 1974, under the tutelage of renowned neurosurgeon, Prof. R.S. Dhanker.

The irresistible draw of melding art with surgery led him to the Father of Indian Plastic Surgery, Prof. C. Babukrishnan, at PGIMER, Chandigarh. He trained consistently for three years with two of the most renowned Indian plastic surgeons, the aforementioned Prof. C. Babukrishnan and Prof. C.P. Salway, between 1974 and 1977.

In 1978, Prof. Ashok was exposed to microsurgical methods of reconstruction by Prof. D.K. McGrouther, at Riding Bridge Hospital, County Durham, in England. He drew on his experience in great measure when he returned home in 1980, to join as Asst. Professor at the parent institute PGI Chandigarh. It was here that, due to the inability to practice microsurgery, the birth of the method described in the book took place.

Prof. Ashok progressed quickly to the level of an associate, and then to that of an additional professor in 1986. In 1991, he moved to the Middle East and with him moved his technique of reconstruction. To this day, he continues to practise the technique and recommends it strongly when other methods of reconstruction cannot be used.
DEDICATION

Dedicated to my Mother, Father, and the Lord to whom I owe my existence and experience.
I now take on the most pleasant task at the final stage of compilation of this book – acknowledging, with gratitude, those who matter so much in my life and to the book.

A journey is easier and more pleasant when you travel together. My journey with this book was blessed with many companions along the way, most of whom were known, and many less familiar, on several fronts that lay in silence, undisturbed by the Maya (illusion) of creation and destruction, who I must thank most sincerely. Such aspects of this journey can never be fully understood – these are beyond human intelligence.

This book is a joint effort of several people who contributed in innumerable ways during the last twenty years of its compilation. Words are a very poor medium of expression of the emotions that surface now, but for the present task at hand, they will suffice.

First and foremost are those who suffered as patients, on whom an additional suffering was inflicted by me as a treating surgeon. Those who allowed me to operate on them in a rather experimental manner deserve more thanks than I can offer now. This book would not have been written if Radha, the first girl child that I operated on using this method in 1984, did not allow me to do so. She remains a part of me and of the book.

"Gurur Brahma, Gurur Vishnu, Gurur Maheshwara", which represents and means the trinity of the Godhead (creation, sustenance and destruction), lies within the ‘Guru’. "Guru Govinda dauo khade ka ke lagon pavan" asks the question, "If the Godhead and Guru are both present in front of you, who will you salute from the depth of your heart?" I was told the answer was ‘Guru’ by my parents. If you ask the same question of a Guru, he directs you to Govinda. The vision of Govinda (the Godhead) that comes to me in the form of this work through the guiding hands of my Gurus cannot be expressed or paid for in the currency of gratitude. It just has to be experienced. I am fortunate to have the experience that came to me through such stalwarts as my teachers, like Prof. C. Balakrishnan, Prof. C. P. Sawhney, Prof. D. A. McGrourther, Dr. John Kirk and Dr. R. C. Bell. The combination of my training in the East by Prof. C. P. Sawhney and in the West by Prof. D. A. McGrourther, has culminated in this work.

I am grateful to my wife Dr. Shashi, who bore the hardships along with me, when I took this project up, almost as if it were my second wife, especially during the last five years. I am sure she suffered negligence and inattention that can never be undone. She, however, remained not only very supportive, but also joined in the proofreading over the past several years, whenever she could find time away from her work, both at home and at her job, as did other family members such as my father, my mother, my son Anshul and my daughter Angela.
My father always quoted his oft-emphasized saying, "The greatness achieved in the lives of great men was not attained by sudden flights, but while their companion slept, as they toiled upwards in the night". I was fortunate not only to have his guiding light in my life, but also, importantly, the genes that will keep me going, now that he has gone.

His name was Dr. K. C. Govila, and he was a very popular physician in the state of Madhya Pradesh in India. He worked at Akodia Mandi, Sironj (Visdisha) and Gwalior, and his greatest wish was to see me become a 'surgeon who served the society'. This still provides me constant inspiration, as I continue on this journey. The philosophy of burrowing right through obstacles if you cannot go around them was learned much earlier from my father, and that kept me going during my tumultuous experience in India, on my return back home from England in 1983.

My mother, Mrs. Manorma Govila, taught me all the good things that matter in life, not only as a mother, but also as a teacher, since this was her profession as a principal in a school. This little frail but strong lady stood as a strict disciplinarian all through her life, and even today, at the age of 78, she hasn't shifted out of gear.

A sparkling event was my son Anshul's arrival into our family some 25 years ago. He has grown to be the second author of the book, and now has the daunting task of carrying this work further. I vividly remember him standing on an open Grant's Coloured Atlas of Anatomy as a child, a femur in hand, picked out as a toy from the wooden box that used to carry the synthetic skeleton for my study.

My daughter Angela, who helped me design the book, is now an engineer in the US. She was born in Scotland, and when she was old and naughty enough, mixed up the transparencies, keeping me busy at home to sort them out for hours on end.

During the budding years of the book, much time was lost typing the text on a now obsolete computer, the Sinclair, and in creating the illustrations, since I wanted to do them myself. It was only much later, when the laptop and PC came around, that my job was made much easier.

Having burned my fingers before, I was looking for a reliable and reputable printing house, and came across Medad Printing & Publishing in Sharjah. The General Manager, Mr. Ravi Vasandane, who is also Managing Director of Campbell-Ewald Middle East, was known to a friend of mine, Dr. Anwar Halim, a prominent urologist, who successfully completed his book through him. Ravi, a handsome and highly professional man in his forties, also had a team of skilled graphic designers. He entrusted the responsibility of the job to the willing and eminently capable Maxley Wilkins.

The manuscript was submitted to Max for printing, and I thought that it was now all over. Little did I know that printing was a far more complex endeavour, especially when you're dealing with perfectionists. Rather it was the beginning of yet another chapter on book writing.
Max is a perfectionist in every aspect of his life, and this came to the fore when it came to the imaging work. We discovered a whole new dimension to writing the book, which appeared when the time came for it to be composed on the computer. Many of Max’s team members came together and played their roles, though at some instances, the project had to be shelved only to be revived again, and the work finally came to fruition in the form of this book.

The principle to see good in everything and be a constructive part of the whole made me follow a group of people who had regular meetings and discussions on the subject of universal love and universal consciousness, which is equally important for living and for scientific pursuits. It is called the Sathya Sai organization. They follow the valuable teachings of all religions in the name of Sanatana Dharma, and do not ever mean to spread and promote any religion.

The chain of my gratitude would be incomplete if I forgot to thank the ‘Prime Mover’ for making me walk behind him, holding his stick. Where the waters were deep I saw myself in his arms – I am glad he stays all around me always.

Prof. Ashok Govila
I have great pleasure in writing the foreword for this book on "Alternative Free Flaps", which makes excellent reading and provides guidelines for every surgeon involved in the techniques of tissue transfer. With the rapid pace of development in clinical practice and basic research in the field of reconstructive plastic surgery, it becomes important to understand and master an alternative approach to undertake composite tissue transfer for complex clinical situations or wherein an ideal set-up for microsurgical free tissue transfer is not available. A book of this nature will go a long way towards this end.

Having practised these procedures over the last ten years and successfully patronised a varied spectrum of clinical situations, including pre-fabricated nose, lips, mandible, phallus etc., I fully endorse the usefulness of the technique and would recommend this book on "Alternative Free Flaps" as a reference book to be kept in every library.

Being a founder and an active member of the World Society for Reconstructive Microsurgery, immediate Past President of the Indian Society for Reconstructive Microsurgery, and Founder President of The Microsurgery Group of India, I fully endorse the views and ideas of the author, and justify the need for such useful and illustrated clinical material in book form.

Prof. Govila’s effort in bringing out and publishing the book on "Alternative Free Flaps" itself is a great achievement, which deserves to be commended. I have no doubt that the contributions made by the author would be an asset in the armamentarium of reconstructive plastic surgery, and will go a long way towards a better understanding of the process of tissue transfer in less than ideal clinical situations.

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I must say that Dr. Govila must have had a painstaking experience trying to set up a microsurgical service in the face of the daunting clinical problems he was facing in his practice in the third world, as we all face as well. The development of the extracorporeal approach is something that he should be congratulated for.

His approach to these difficult reconstructive surgical challenges has added a lot to the arsenal of existing surgical procedures. I had witnessed the procedure performed for a few cases in our institution, and must admit that the results were very encouraging.

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A Pioneer in the Annals of Plastic Surgery

Prof. Ashok is well known in the field of Plastic and Reconstructive surgery, thanks to a legacy that has spanned three decades. During this time, he gained invaluable experience from the farthest reaches of the world, from the East, the West and the Middle East. A masterful medical professional, Prof. Ashok worked in unusual locations and conditions that presented him with a unique understanding of the subject of reconstruction. This resulted in the many improvised methods he has invented and evolved over the years, which are of great use to many a surgeon in the present day. Among the significant ones is the technique and procedure of extracorporeal tissue transfer, also known as the Alternative Free Flap procedure. This work is presented as a treatise in the form of a clinical and surgical colour atlas.

As a distinguished alumnus of PGI Chandigarh, India, his work carries considerable authority, and the clinical experience illustrated in this book speaks volumes. Prof. Ashok enjoyed popularity among students and teachers alike as a medical student at the Gajra Raja Medical College in Gwalior, India, thanks to his professional approach to the college’s cultural activities. During his tenure as the cultural secretary of the college from 1972-74, he claimed first prizes in several art disciplines like fine art, oil painting, sculpturing, solo instrumental music, and ‘rangoli’ painting (Indian folk art). He completed his master’s training and obtained the degree of Master of Surgery (MS), in the same institute in 1974, under the tutelage of one of the most renowned neurosurgeons, Prof. R.S. Dharker, who was also the head of the Department of Surgery. Little did he know then of his eventual calling to plastic surgery, but his keen inclination towards fine art and sculpturing had created a foundation for the making of a future plastic surgeon.

The irresistible draw of melding art with surgery led him to the Father of Indian Plastic Surgery, Prof. C. Balakrishnan, at PGIMER, Chandigarh. Here, he trained ceaselessly for three years with two of the most renowned Indian plastic surgeons, the aforementioned Prof. C. Balakrishnan and Prof. C.P. Sahney, between 1974 and 1977.

The desire to serve the masses better took this young and well-trained plastic surgeon to England in 1978, where he was exposed to microsurgical methods of reconstruction by Prof. D.A. McGrourther, at Shotley Bridge Hospital, Consett, County Durham, in England. The association with Prof. McGrourther lasted four full years, but ended abruptly, when Prof. McGrourther had to leave Shotley Bridge to take the First Professor’s Chair for Britain, in London. The memories of those golden days, however, will be cherished for a lifetime.

Prof. Ashok drew on his experience in great measure when he returned home in 1983, to join as Asst. Professor at parent institute PGI Chandigarh. It was here that, due to the inability to practice microsurgery, the birth of the method described in the book took place. Prof. Ashok progressed quickly to the level of an associate, and then to that of an additional professor, in 1986. In 1991, he moved to the Middle East and with him moved his technique of reconstruction. To this day, he continues to practise the technique and recommends it strongly when other methods of reconstruction cannot be used.
PROFILE OF DR. ANSHUL GOVILA

Extending the Legacy

Doctor Anshul had the best of both worlds. Not only did he, as a child, witness the making of a plastic surgeon in his father, but in the process opted to become one himself. His unusual intellect was nurtured at King Edward Medical College in Bombay, India. This was followed by extensive training at Sir. J.J. Hospital, also in Bombay, which helped him mature into a dynamic thinker in his area of specialisation.

Bearing a strong inclination towards the literary and graphic arts, Dr. Anshul used these gifts to great advantage in his writing and in all his national and international presentations. Time spent with great masters in the field like Dr. Fu Chen Wei in Taiwan refined his understanding of microvascular surgery and added substantially to his perspective of the subject.

Dr. Anshul was introduced to the world of organized medicine at a hospital that featured a 74 operation theatre complex, and a parallel complex with around ten dedicated theatres for microsurgery. The hospital also boasted a 24 bed microsurgical ICU.

Admittedly, Dr. Fu Chen Wei’s enthusiasm and diligence set standards that Dr. Anshul finds difficult to match even now. Though imitation of these Chinese masters is not an easy task, he has nonetheless tried to imbibe some of their thoughts and many of their teachings into his practice.

Dr. Anshul learned the importance of documentation of cases from his father, Prof. Ashok Govila, very early on, and used this to his advantage all through his residency and training. His collection of surgical photographs will, in fact, soon be published as the simply titled "Surgical Workbook", which is inspired by Disraeli’s principle, "The best way to learn a subject is to write a book on it." It will not only be a culmination of the efforts of his residency but also a practical guide for surgical residency candidates in India.

Seven years were spent in the UK as a child, and little did he know that those years would help him establish benchmarks against which he would measure the years thereafter. He spent a great part of a delighted childhood and his teenage years in Chandigarh, which is nestled in the Himalayan foothills of India. Here, St. Anne’s Convent helped him explore the talents that lay within. Not only did he get his first lessons in competitive dramatics and public speaking here, but he also developed a great fondness for literature, both English and Hindi, which he has maintained till date. Besides, he also took his natural gift for the fine arts to a competitive level. This foundation has helped him all through his life and is one of the reasons he opted for plastic surgery as a vocation.

If his school epitomised conservative convent education, his college, DAV Chandigarh, bore an atmosphere of brash realism. However, it was the ideal place to learn to face the world in the years to come.

Apart from guiding him to be among the top rankers of the various national merit exams, the college helped make a man out of this teenager. The year he passed out of the college, there were more than 150 national merit candidates and top rankers of some of India’s most prestigious exams.
Dr. Anshul decided to join King Edward Memorial Medical College in 1994, much against his decision to join the Armed Forces, for which he was selected through national merit. Here, he met his better half, Manjiri, a Senior Registrar in the Otorhinolaryngology department of KEM hospital. Incidentally, Manjiri has helped tremendously with the design of this book.

KEM and the metropolis of Bombay were another ball game altogether. The professionalism of this city and the earnestness of its people were to reflect in his practice. While KEM offered a grand display of tropical medicine, life in India’s biggest metropolis, all alone at the age of 17, was making its mark. The city gave him an opportunity to take his childhood hobbies seriously, and he ended up getting a university award in sculpture and becoming an avid freelance photographer.

Following his MBBS degree, he was commissioned to work at Maharashtra Health Services for a year. He spent this year in the bowels of poverty; it was a great lesson in humility, and taught him to amalgamate modern medicine and modern surgery in the depths of rural India. Being the sole medical officer in a 110 square mile Tiger Sanctuary within a dense teakwood forest, with 46 employees and a population of 32,000 tribals, not only taught him medicine but responsible medicine. He had heard stories of his grandfather conducting deliveries and surgery by lamplight, but to do them himself was a thrilling prospect.

His residency brought him back to Bombay, this time to Sir J.J. Hospital, one of India’s oldest medical establishments and the biggest government hospital in modern India’s biggest state.

To learn surgery from India’s leading medical professionals, in one of the most contemporary set-ups, was as exciting to him as the subject itself. The structure of the residency program at Sir J.J. Hospital facilitated a lot of supervised surgical work, and at the same time instilled the essentials of becoming a ‘safe’ surgeon rather than a ‘smart’ one. Dr. Daver, his dean and the head of the establishment, was a mentor for all budding surgeons. Besides, his post graduate guide, Dr. A. H. Bhandarwar, a gem of a man, shaped most of his surgical skills and guided him into the world of laparoscopic surgery at a very young age in his surgical career.

Dr. Anshul’s contribution to this book includes the unseen contributions of all his teachers. The book also draws on the teachings of the hardships of his professional life, making it a more holistic reference for other microvascular and reconstructive surgeons in years to come.
Some learn from their teachers, some from experience, and some by observation. Some, however, don’t learn at all. And then there are those who learn from necessity and they learn their lessons well.

We are the ones who learn from necessity and this book is a portrait of a surgeon’s attempt to survive micro-vascularly in a non micro-vascular world. It is an attempt to reinstate the belief that man rises over matter when need be.

Before I go ahead and describe what precisely is so extracorporeal or alternate about the technique of tissue transfer we have been successfully practicing, let me pose a pertinent question to all those budding plastic surgeons: What is our mission? In essence, what is a reconstructive plastic surgeon ultimately trying to do? To simplify the issue, we are in the business of transferring chunks of tissue. We refurbish tissue defects, and transfer tissue from more fortunate parts of the human body to the less fortunate ones.

We are all here to do one thing, and that is to restore the body’s loss at a cost that is acceptable. It is our responsibility to see to it that this is done with the utmost respect, while trying to come as close to perfection as possible, and while always maintaining the philosophy, "Do no harm if thou cannot do any good."

What is the basic principle of tissue transfer? We all know that the tremendous advances in reconstructive plastic surgery came after Taylor described the concept of angiosomes. Today, we have a clear understanding of the vascular infrastructure of the body and a respect for maintaining the same while we undertake any tissue transfer. The only reason we can get away with such miraculous reconstructions is because we have learned to respect the vascularity of the tissue we are transferring – be it an axial flap or a free one.

If you don’t maintain the blood supply, you don’t win the game. Now we can pluck various tissues and reinstate them at a different site; wherever you decide to take your tissue, you decide to take its blood supply. What makes you more proficient than the plastic surgeons of yesteryear is that not only have you been able to harvest tissue in a manner that it can be perfectly placed into the defect but you can also re-establish its vascular continuity reassuringly. That’s what you are trained to do as a micro-vascular surgeon.

Obviously, this is not as simple as it sounds. We all know how vulnerable a vascular anastomosis is. Essentially, it’s an attempt to establish a broken relationship. Two very delicate and sensitive tissue ends are involved, as are two very different parent tissues – all attempting to gel into place. It is here that the plastic surgeon lends his feathery touch and the reconstructive surgeon learns that invaluable lesson, "Do no harm if thou cannot do any good."

Anastomosis keeps many a micro-vascular surgeon awake through the night. There are
worries of venous obstruction and congestion, surrounding haematomas and anastomotic leaks, to name a few. These have been known to keep more surgeons up at night than their wives do!

Microsurgery is exciting and cutting edge, and proves that your hand-eye coordination outshines the Swiss watchmaker’s, but doesn’t prove you to be any smarter than conventional surgeons, if your weakest link, your anastomosis, does not live up to your expectations.

In the following pages, we describe a technique that we developed more out of our love and respect for the discipline of microsurgery than out of the awe of it. It is a technique which evolved with me, and one with which I evolved as well.

We’ll tell you the story of a trained micro-vascular surgeon who tried to establish a micro-vascular unit but in turn learned how to perform the regular stuff and much of the extraordinary without the help of a microscope – all thanks to the circumstances he faced.

After completing a diligent, arduous and exhilarating M.Ch (Majestica Chirurgica) in Plastic Surgery from PGI Chandigarh, under the fathers of Indian Plastic surgery, Prof. C. Balakrishnan, and Prof. C. P. Sawhney, I spent most of my prime with Mr. John Kirk, Mr. Rubin Bell and Prof. D. A. McGrouther.

The friendship with then young Gus McGrouther, who later took the first chair of Professor in Plastic Surgery in Britain at University Hospital in London in 1981, brought several international figures from Canniesburn, Glasgow, into my life at a very young and formative age. Among these were Mr. Tom Gibson, Prof. Ian Jackson, Mr. Ian McGregor, Mr. Mark Webster and Mr. David Souter, to name a few. Under their tutelage, and in their professional company, I honed and developed my micro-vascular skills. Living and working for six long years with the masters of the technique of free tissue transfer almost instilled in me the belief that the limit a reconstructive surgeon sets are nothing but his own.

We replanted upper limbs at various levels. In fact, one of the early replants in world history at mid-arm level was done at Sunderland Hospital in Scotland. In the early 1980s, this was done using a very rudimentary portable assembly—a simple microscope without a light source, one that was remarkably poor in its optics, that we carried in our cars from Shotley Bridge General Hospital, Consett, Co. Durham, and crossed several corridors with a heavy load on our shoulders before reaching the operation theatre.

Spending twenty hours, day and night, Gus (Prof. D.A. McGrouther) and I together managed to do a successful job. That day still is one of the most memorable of my life. This was before National Health Services of Britain could arrange for a better microscope for us. Once we had one, we did free flaps of all kinds. Even those free flaps were in their infancy then, like the radial forearm flap. Up until then, late 1980, only three cases were taken up in Shanghai and were not yet published.

I finally returned to my parent institute in India to give it all I had learned, only to realise that I’d have to relearn the entire art.
PGI Chandigarh is one of the seven Central Government sponsored hospitals in India, and since its inception with the city of Chandigarh 40 years ago, it has been an apex tertiary referral centre for the entire country.

A masterwork of simplistic design and ergonomics, Le Carburzier’s brainchild is spread over roughly four square kilometres. Our plastic department was headed by none other than the Father of Indian Plastic Surgery, Prof. C. Balakrishnan, who in his forties had established what is now one of the oldest departments of plastic surgery in the country in the Government Medical College of Nagpur. Sir Harold Gilles, the father of Plastic Surgery himself, had made a couple of visits in those years and had a lot to say about the pioneer. I happened to witness a most fascinating sketch of Sir Gille’s wife done by Prof. C. Balakrishnan, titled ‘Ballerina’.

From the premises of this institute, I returned with hope, expectation and eagerness to help our masses. But in the underprivileged part of our planet, a micro-surgeon is trapped in his own cosmic niche. Little does he know how the administration and red-tapism could eat away into his years. Here I was, a trained micro-vascular surgeon, ready to establish a division of micro-vascular surgery. But I had one little problem: I had no microscope.

Between 1983 and 1986, I begged every clerk in the procurement branch of our hospital to arrange for an operating microscope and some micro-instruments. The purchase order had to be sanctioned by an organizing committee, but where was the time to organize that committee! There was postponement after postponement and I was faced with the conundrum of asking for global tenders. Questions were thrown at me: “Why do you want a Zeiss, which is twenty times the cost of an Indian make? Why the Zeiss OPM 6 P/H, and why not a Zeiss 99, which is one-tenth the price? They almost doubted my credibility and suspected that I was working in liaison with the Zeiss people in West Germany. After three long years, I eventually succeeded, but not without sprouting more than my fair share of grey hair.

Little did I know that this was to be the beginning of a new tussle – micro-vascular versus non micro-vascular. In an institute where there were not less than twenty operating theatres working round-the-clock, not one could be sanctioned for dedicated micro-vascular work. This said a lot about the state of our administration, from the grass roots to the top brass. We trudged along. Most of our micro-vascular work was done in regular plastic surgery operating hours.

It was here that the plastic surgeon and the surgeon in me rose to the occasion and performed all those challenging, sophisticated and modern procedures that are witnessed only in the affluent nations of the West. It is here that the children of an underprivileged nation, who learn their lessons of simple living and thrift the hard way, use them to their advantage. It is here that the guts and skills of a micro-vascular surgeon are put to the test when he has to perform micro-vascular procedures single-handedly and without a stool to sit on.

Expensive operating equipment and pre- and post-operative gadgets take such a toll on the hospital budget and the healthcare budget that a sanction for those could consume the few young years of an enthusiastic micro-surgeon. Paramedical and supportive manpower have to be
trained by the surgeon himself, and that may consume the next half of his life, since all jobs are transferable. Red-tapism, which is national property, has tagged us to the list of developing nations. Words are a very poor medium to express the umpteen hurdles a surgeon can face.

We expressed, very dramatically, the whole affair in a letter to the editor of Plastic and Reconstructive Surgery. I am sure this represents the problems faced today in a rather pleasant and readable manner. I take the liberty of quoting the whole play, which in fact was a real event.

The letter states that: "The general impression among plastic surgery units about a microvascular set-up is essentially a thoroughly efficient, well organised and streamlined one. However, at a closer look, on this part of the globe, the situation is to the contrary."

The dilemma evolves as the day progresses in a microsurgical set up. Difficulties unfold on several fronts. Administrative extinction, technical paucity in the paramedical staff, dozy manpower, an ulcerated Microvascular surgeon, and professional jealousy between a micro- and a nonmicro plastic surgeon (who unfortunately heads most of the conventional plastic surgery units and, therefore, clips the wings of the microsurgeon to keep him or her trimmed) are some, if not all of the problems one is faced with.

To secure an operation theatre exclusively meant for microsurgical work, to procure an anaesthesia team trained for 12 or more hours of trouble-free functioning, to have a couple of superbly gliding circulating nurses and a few deeply attached noncirculating nurses, and to desire a devoted disciple to sit under magnification without vibrating (which may be infectious and may be transmitted to the optical head) is nothing but a microsurgeon’s distant dream.

In the theatre, difficulties ascend in a crescendo as the procedure proceeds and only ends in the climax of the drama, which is about to begin: At 11.30 p.m., a patient arrives with a chopped-off right thumb. This is a professorial unit in the biggest teaching institute of the country. The senior resident is sweating and running around (not for the sake of learning, but for the sake of a thumb). And this sets the stage for this drama: "Sister I have a thumb to replant straightaway. I must save it," the poor boy mumbles. "Shut up," says the sister. "Don’t you dare. A Caesarean is on – we have to save the mother and the baby (not a thumb), and another is booked for 1 a.m., and I shall see what I can do for you, or for your thumb." At 3 a.m., the bell rings in the bedroom of the consultant microvascular surgeon. "Sir, I am sorry to disturb you at this odd hour, but I have managed to fix everything now (please do appear on the stage, your role is about to begin)," says Sam from the other end.

Outwardly half-dozy, but with a fire of hope inside, the young microsurgeon (who is getting old faster than his colleagues – the man with a golden gun) appears, and his never-ending role begins. Dissection followed by haemoclips, exploration and anastomosis, re-exploration and re-anastomosis, vein grafts and nerve grafts continue, and poor Tom’s thumb turns colours between pale and blue, and so does Sam. However, the microsurgeon continues his pink discoloration until a bright red is reached at 8 a.m. (which, incidentally, is his breakfast time).
As time clicks away, Sam and his boss are the only two members left on stage (other than the patient and the ventilator). The rest of the artists have either completed their roles or have presumed their completion. All night, the theatre wall kept on hearing "Can somebody adjust the light?"; "Can I have another pack of 10-0 Prolene?"; "Can somebody wipe my forehead before my own saline irrigates the anastomosis?"; "Oh my God! I have blood trickling into my shoes!"; "Oh, the bipolar paddle is muddled in the pool of blood"; "Oh, leave a gown over this bloody mess!" – but not a creak is heard.

Through his temporal field, the consultant microsurgeon notices the junior resident in one corner of the theatre, lying on the floor in deep slumber. The monotony of the microsurgery was eventually broken by this resident in his eternal silence and snores. The first smile appears on the face of the surgeon when he utters, "Thank God, this chap knows how to snore."

At 10 a.m., physically shattered and mentally broken, the team of twin microsurgeons and a vibrating microscope were all that remained. Suddenly, up comes the troll and says, "I will eat you up." This is the most powerful man in the area and the oldest gynaecologist (he even delivered poor Sam). "Oh my God, the microsurgeons are once again making a bloody mess inside," was the loud voice of the troll that was heard inside the theatre. "Let me go in and see what are they up to."

"Goodness me, what a mess," shouted the troll. "It will take another 24 hours to clean all this," he continued. Unless something is offered, the troll will not budge and Tom’s thumb will fall a prey to this beast. Quietly, the team of microsurgeons walks out.

At 10 a.m. the next day, at morning rounds, the senior-most professor and head of the department (General Plastic Surgeon) leads a team of 25 disciples (trained and untrained) and 4 other senior and junior consultants (including this microsurgeon). "Let’s have a look at the handy work of Sam, who has been up and about for the past 24 hours." Sam slowly opens the envelope hiding his work. The thumb is dusky, Sam is pale and the professor is pink. "Well done, Sam," says the Big Boss and walks away.

"Sir, shall we re-explore?" Sam whispers into the ear of the microvascular surgeon.

"Never say never again," replies the surgeon.

Those born of the deprived soil learn their lessons fast. If I had to survive, not only did I have to continue my struggle for sustaining a micro-vascular facility but also to develop other methods of doing my micro-surgical work equally well. Patients with large head and neck defects and those of other parts, along with gross malnutrition and poverty, continued to pour in from all over the country. For the first time in my life, I saw some horrendous and massive faciomaxillary defects caused by bare mole bites taking away virtually half of the face including the bones and extensive censer extirpations showing the post pharyngeal wall as the only visible structure in that area. There were cases of homicidal burns caused by husbands to their wives, of a nature and extent that the most trained plastic surgeon would feel shaken and, for an instant,
dismayed as to what to do in such a situation. Besides, we were presented limbs crushed into a bag of pulsatile worms without bones, due to highway accidents and industrial accidents with machines without guards, as well as untreated massive congenital defects in adults.

Under the bitter frustration of not being able to help such patients, the birth of our alternative technique took place. We christened it the extracorporeal tissue transfer technique.

During my childhood training in this very institute, the last limit of our teacher’s reconstructive efforts was an arm tube. Even simple axial pattern flaps such as the groin and the deltopectoral were not performed. However, during this exposure, we were well taught with regard to fixing two parts of the body in ergonomic postures. This I used to an advantage in my later reconstructive efforts.

The experience of both the worlds was entrusted to me not for the sake of better patient care but for the sake of survival. I felt that I could raise free flaps of any kind, but the trouble was thereafter, when the role of microsurgery (anastomosis) began. Where was the microscope, where were the instruments… and where was the operating time? The solution appeared in desperation. Once a radial forearm flap was raised to be transferred as a free flap for a cranial defect following a high voltage electric burn in an 11-year-old girl, I was forced not to continue the procedure further, since there was dying emergency to take over, over this relatively cold surgical reconstruction, or at my best finish the procedure quickly or else the anaesthetist will be taken away for the dying patient. They sure meant business.

I needed to wake up to the situation and rise to the occasion, which I did. Under pressure from all quarters I decided not to divide the flap from the wrist (that is, not to make it a ‘free flap’) but to take the limb to the cranial defect, keeping the vascular continuity from the radial’s intact. Fixation of the limb in a comfortable position was a well learned experience of our childhood training camps. That came in handy that day. Quite dejected, I left the theatre cursing myself for being part of such a congregation.

Beyond our expectations, the flap survived completely and healed perfectly. After three weeks, we separated the limb. This was the birth of the technique which was to be known as the ‘extracorporeal tissue transfer’. Never thereafter did we look back… from then on, we exploited all its dimensions to the maximum. Complex reconstructions like that of the oesophagus and the penis were undertaken soon thereafter. Now, unlike free flaps, the boundaries were broken. We had no limits for reconstruction… we could reconstruct any organ anywhere in the body, wherever our hand (wrist) could reach. We then reconstructed a total penile loss by prefabrication, oesophagus, total nose, and the more we used it, the more we learned that the prefabrication is not the ultimate goal. There are better methods.

A further extension of the same thought was the birth of symbiotic tissue transfer that remains to be popularised even today. Maybe one day, some young plastic surgeon will enter this dimension of thinking and come out with the result that I dreamed and could not pursue since my age fell in between my aspirations and my being. Salvage reconstruction was evolved then
for saving those limbs which could not be replanted because of the element of crush. Pharyngeal reconstructions, tracheal reconstructions were the final outcome of the episode that began on entering India, the homeland, the land of the sick and the rich living side-by-side as unknown neighbours.

Before it could be presented and published, the technique and its extensions would spread like wildfire, and this was not known to me then. Today, it is the method of choice for most plastic surgical units around the country. Wherever the requirement dictates a ‘free tissue transfer’, the answer is ‘extracorporeal’.

So what are we discoursing? Nothing much. There are no supercilious claims of the superiority of this technique over the free flap. Its an ‘alternative’ to the free flap for those who do not have the advantage of a prosperous micro-vascular set-up. It is to decrease the seven percent failure rate of a free flap which, though seven percent for you, is hundred percent morbidity for the patient.

So, what do we do? We just save the weakest link of the tissue transfer for the last. A flap, generally a fasciocutaneous island flap of the extremity which has a long vascular leash like the radial forearm flap is raised. The flap, along with the extremity, is approximated to the defect, the vascular anatomy of the flap being maintained in continuum with the parent extremity on which the flap was based. This pedicle behaves like an umbilicus for the flap. The vessels hence travel outside the corpora, the body, to the defect, and hence the choice of the word ‘extracorporeal’. A split-thickness skin graft is wrapped around the vessels to prevent their drying, dehydration and desiccation. After roughly ten to twelve days, the flap has good vascular pick-up. The vascular umbilicus can be excised after serial clamping for a few days. This vascular stalk can be excised without local anaesthesia as it has no sensation. However, for the sake of completion of the flap inset at the site of attachment of the vascular stalk, revision under local anaesthesia can be performed.

Since the microsurgical training, teams and equipment are made superfluous by this technique, it has gained enormous popularity in this part of the world where surgical luxuries have still not percolated.

We use those fasciocutaneous island flaps which can be based distally on an extremity. The radial and ulnar forearm flaps in the upper limb and the posterior, anterior tibial, the dorsalis pedis, the peroneal flap and the sural artery flap have been used in the lower limb.

For rare and difficult problems like hemifacial atrophy, we have used vascularised fat and fascia too on the same principle.

Henceforth, we have resurfaced and reconstructed most of the human body with our technique. We hope you find it interesting and practise it in your surgery, while adding more to its credibility.
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CHAPTER 1

ALTERNATIVE FREE FLAP
(EXTRACORPOREAL TISSUE TRANSFER)

INTRODUCTION

Much of my work on alternative free flaps has been published as ‘Extracorporeal Tissue Transfer (ECTT)’ since 1984 when it was devised for the first time. The term ‘Extracorporeal’ has confused several plastic surgeons who have complained to us about its suitability for the method, perhaps because of the association of the term with the Heart Lung machine. This led to the more easily understood term ‘the alternative free flap’.

An alternative free flap (AFF) is a kind of free flap that is ‘Free’ only to a certain extent. The basic difference between a free flap and an alternative free flap is the absence of microvascular anastomosis in the later case. ‘Free to a certain extent’ implies that the flap is raised just like a free flap until the very last stage and only the flap elevation is stopped at the last stage of severing the vessels. Instead, the vessels are left intact and are not severed from the body.

This alternative free flap is now attached (interfaced) to the recipient defect where it remains attached for the next 10 days when it has healed completely.

The vascular lifeline that supported the survival of the flap in these past 10 days is now disconnected, having achieved total healing of the flap inset. Since the vascular lifeline is not tampered with in any way during the flap transfer, the margin of safety and total survival of the flap multiplies exponentially. Chances of total disaster, as sometimes seen in a free flap, are eliminated once and for all.

Those flaps that have a long vascular pedicle are preferred, like the fasciocutaneous flaps over the extremities. The ideal ones are those which have the connecting vessel link at the distal end on an extremity such as a distally based radial forearm flap, ulnar forearm flap, anterior tibial flap and posterior tibial flap, and the sural artery flap.

Since a microsurgical team, training, equipment and other paraphernalia are made superfluous by this technique, it has gained enormous popularity in the underprivileged parts of the world where surgical luxuries have not yet reached.

The night following a free flap reconstruction, a microvascular surgeon finds little reason to sleep and tosses with nightmares of anastomotic leak, surrounding haematoma, compression and blockage or anastomotic tension, venous obstruction, congestion, failures and disaster.

The alternative free flap surgeon on the other hand sleeps with dreams of a vacation in Switzerland, since the bond that he created between the recipient and the donor area is going to tie the surgeon and the patient for a lifetime.

WHY EXTRACORPOREAL, NOT FREE?

Why should a microvascular surgeon opt for something less than microvascular, knowing fairly well the inherent advantages of the
technique?” is a question often asked to me, in most professional congregations, whether I am in Europe or somewhere else in the West. Little do they know what transpires in the East. How plastic surgeons survive the onslaught of deficiencies and yet defy the defects of undefinable dimensions!

I wish that, one day, I could sit and write all I have gone through in the past 25 years working in the underprivileged part of the globe. Not to condemn, but to cherish the experience earned, the desire persists to share with the rest of the world the facts that they remain untouched by.

About the unequal distribution of health, wealth and prosperity on our planet, the author once wrote a letter to Mr. Goldwyn, Editor of Plastic and Reconstructive Surgery, which was quickly published in the column ‘Letter to the Editor’, and is worth quoting here. It says, "We live on a planet where mother nature, exploring human potential and efficiency, watches the human effort happily in overcoming the ‘acute disaster’, such as in Armenia (Russia), but sulks in sorrow and shame on apprehending the dead human potential and effort in the management of chronic disasters, such as the prevention and cure of "living skeletons". It might sound uncivilised in the world of civilised people, to point out that the exploitation of this mass of "living skeletons" being caused by devastating economic and primitive educational conditions, has not only continued, but has grown over the years. This mass of "living skeletons" is utilised unconsentingly for experimental purposes, and the effect of lethal gases, for warfare, is effectively studied, in the form of the Bhopal gas disaster, by some groups of people sitting in some remote corner of this earth.

It goes on to say, "A major part of this globe lives under the trees (slums), wears tree bark (stinking, filthy and torn clothes), and eats grass (non-edible food). It is here that a thirsty mother, under the effect of drought, spits sputum into the dry throat of her dehydrated child in an insane attempt to save him, and in the end, neither survives. This situation continues year after year, endlessly. To this part of our globe, a free availability of a ‘free flap’ is going to remain a far-fetched dream for many more years to come”.

It continues further and says, "on such an incomplete planet, where abundance here is the product of scarcity there, where butter is consumed at the cost of someone’s bread, where such an unequal distribution of health, wealth, means and methods prevails, there cannot be one method applicable to all. The method has to suit the situation given and in effect has to be evolved by the people affected. It is in this respect, a method most suited to these situations had to be evolved which should be a direct equivalent of a ‘free flap’ of the West.

"India is unique, not only for its glorious past but for its dreadful today. It is pathetic that a country with such strong cultural heritage, which for several centuries has supplied intellectuals the world over, is witnessing today a phase of extremely complex combinations of development and stagnation, both prospering together and at the cost of each other. Such exceptional, environmental psychosocial patterns, have to raise reconstructive problems of exceptionally intricate and complex nature. No doubt solutions cannot drop form the heavens but have to be evolved indigenously by the man of the soil. On this very soil, people still throw concentrated acids on the illuminating
faces of others. Life is extracted out without killing them. It is here that noses are still chopped off as punishment for adultery.

However, it is here that the plastic surgeons and a surgeon in general, rises to the occasion and performs all those challenging, sophisticated and modern procedures that are available only to the affluent nations of the West. It is here that the guts and the skills of a plastic surgeon are put to the test, when he has to perform microsurgical procedures, single-handedly, and without a stool to sit on. It is here, that indigenous tricks evolve to substitute the deficiencies. It is here, that the vasectomy operation is performed under tree shade, with the only available instrument being a single hypodermic needle. These are among that dextrous lot of surgeons who use a hypodermic needle for dissection and for cutting the cords. These ‘under the tree camp surgeons’ finish at least fifty operations by sunset, every day, but hardly make a scratch.

Under this background of exceptionally pressing circumstances, it was here that ‘Extracorporeal tissue transfer’ was evolved, as a substitute for ‘free tissue transfer’, later called ‘Alternative Free Flaps’.

**WHY NOT MICROSURGERY?**

Microvascular surgery is that luxury of the West that occasionally turns into a liability, when the technique hits a disaster. Although the disaster rate (anastomotic failure) may be as low as 7 percent in the best of hands, it is 100 percent for the one who is the victim of such a calamity.

In the underprivileged part of our planet a microsurgeon is trapped in such a cobweb where crossing one hurdle is in fact the beginning of the other. Expensive operating equipment, pre- and post-operative gadgets, are such a jolt on the hospital economy, that a monetary sanction for them may consume a few young years of an enthusiastic microsurgeon. Paramedical and supportive medical manpower has to be trained by the surgeon himself and that may consume the next half of his life, since all jobs are transferable. The team effort required for sustaining such a facility is impossible to create in such a transferable team. Words are a very poor medium of expression; therefore, only by living with such problems may one have a feel of them.

The fire that burns high inside, of the establishment and propagation of microsurgery – an art that has been learnt after spending long hours in the lab and clinical work of many years in England, slowly simmers and eventually gets extinguished. Finally, the only clinical indication to struggle one’s way out and perform a microsurgical procedure remains to be the replantation.

Under such pressures, ‘free flaps’ are left only to be used where ‘extracorporeals’ cannot reach. I wonder if I can find a place where it cannot. This is not all. Yet another hard fact of life in this developing part is the red tapism. It is this phenomenon that keeps the country attached to its tag of ‘developing’ year after year and it never achieves the status of a ‘developed’ nation. Red tapism is national property. It has hit more than the under-educated; doctors are not immune either. Most severely effected are the secretarial (clerical) staff of the administrative offices.
BASIC CONCEPT

The idea is that if an island flap consisting of a long vascular stalk (pedicle) is raised in a manner that it remains attached only to the distal part of an extremity, then such an extremity could well be positioned in a manner that the flap reaches the defect on a far-off location on the body, as far as the extremity can reach without undue inconvenience to the patient, and that is the basis of this concept. If this position can be maintained while the healing is taking place, (which is commonly about 10 days) and if the vessels are prevented from drying, dehydration, desiccation, then there is no reason why such a flap should not survive the transfer and the technique.

Vessel damage during the healing period is prevented by wrapping them in a sheet of split thickness skin graft. Since the umbilical cord of the flap, at the site of the interface, hangs outside the body, the blood circulation leaves the body at one site, goes outside the body and then re-enters the body. This has been termed as ‘extracorporeal’. The term, however, does not justify its intricate medical meaning but nevertheless it does describe the gist of the technique, and until a better term is coined, it is going to stay. Later, in 1991, Olding M. and in 2000, Topalan M. et al used the term ‘exteriorised’.

Methods of immobilisation are not new to a plastic surgeon. All methods such as PoP fixation and elastoplast fixation are good enough. We use the lightest possible fixation in children and heavy fixation devices are left only to be used in adults. In 10 days’ time, vascular pickup, both arterial and venous, sets in very well and therefore vessels are excised. Excision of this umbilical cord by the extracorporeal technique does not require even local anaesthetic since it has no sensation. However, for the sake of completing the flap inset at the site of attachment of the vascular stalk, revision under local anaesthetic is performed.

CONCEPT EXTENDED

The last decade has witnessed the filling of the gap between the well defined conventional pedicle flap and the free flap, with an innumerable variety of techniques involving the transfer of various tissue combinations.

New terminologies for such techniques have emerged, coined by the authors’ understanding of the subject of reconstruction as a whole. For example, terms like ‘semi-free flap’, ‘hybrid flap’, ‘exteriorised pedicle transfer’, ‘arterialised venous flaps’, ‘prefabricated flaps’, ‘prelaminated flaps’, ‘sequential flap transfers’ and many more that are closely linked to extracorporeal tissue have now been introduced into world literature on this subject.

The term ‘exteriorised pedicle’ is understandable and is essentially the same as extracorporeal or alternative free flap (Olding M, 1991, Topalan M, 2000). The semi-free flap, also called a hybrid flap, is associated with the method used when only arterial anastomosis is required for the transfer, and venous drainage remains undivided at all the stages of tissue transfer (flap transfer), for example, when the cephalic vein is kept undivided for a radial forearm flap transfer, when it is used for head and neck reconstruction. Only the radial artery needs to be anastomosed to the recipient artery in the neck. (To EW et al, 1999, Kamei K et al, 1993).

Prefabrication and prelamination went hand-in-hand during the evolution of the alternative free flap technique, and in fact, was the by-product of such thinking. Prefabrication is the process of fabrication of the part or an organ partially or totally before its transfer, so

Prelamination differs from prefabrication in the sense that tissues are added from other places in the prelamination process, while in prefabrication they are not. This creates a multi-layer structure. Usually a skin graft, mucosal graft or a cartilage or bone, or some synthetic material, is added (Pribaz JJ et al, 1999, Poesschl PW et al, 2003).

Micro-surgeons transferring tissues freely (free flaps), too, have benefited from such ideas. What a micro-surgeon obtained from it was the idea to sequentially connect free flaps, a phenomenon called ‘symbiosis’ in 1993 (by the author), since such combinations are mutually beneficial to both the flaps. The proximal flap provides arterial blood to the distal flap and the distal flap supplies venous blood to the proximal, helping to establish through and through venous circulation that helps alleviate the venous congestion in the proximal flap. (Govila A., 1993, Pshenisnov K et al, 1994, Hung LK et al, 1995, Culp RW et al, 1995, Dzwierzynski WW et al, 1997, Sasaki K et al, 1999, Yildiz M et al, 2003).

Creation of an extracorporeal loop (blind loop) for free tissue transfer is yet another dimension of alternative free flaps. In this case the vascular pedicle is left outside the body when there is not enough space for the vessels to be kept inside such as web spaces of the fingers and this blind loop then could be used later for additional tissue transfer (Olding M, 1991, Topalan M et al, 2002).

Learning the lessons in retrospect on the same lines it was also discovered by micro-surgeons that free flaps could be preserved for a long period, up to 55 hours, and to transfer them when the conditions are more congenial (Thoma A, 1986).

Arterialised venous free flap transfer is another extension of the same thought process. Such a flap could be prefabricated in advance by creation of an arteriovenous shunt, so as to increase the vascular territory of flaps to borrow larger flaps, such as for a dorsalis pedis flap (Cho BC et al, 1999).

This method makes the dissection of flaps easier, since the dissection stays up to the level of deep fascia only, no major artery is used, and at the time of transfer only one anastomosis is required between the recipient area artery and the donor flap vein. This reduces the operating time significantly and has less chances of anastomotic failure and consequently less chances of flap failure.

An arterialised venous flap has also been used as a semi-free flap transfer. A flap from the medial arm has been used for the defects in the neck when the only attachment of the flap left to the body was the cranial end of the cephalic vein. The distal end of the vein was anastomosed to the artery in the neck to supply arterial blood to the flap (Safak T et al, 2001).

Extracorporeal perfusion of free flaps is another growing concept which has been used for venous flaps so far, and needs more exploration (Maeda et al, 1993, Japan).

The pedicle venous flap and ‘flow through’ venous flap is yet another step in the same direction (Fukui A et al, 1989).
There are some revolutionary new ideas based on the same concept of ECTT that need more work in the future and are likely to create another chapter in the field of reconstruction.

One such method that is to be complimented was developed and executed by Dr. Sanger JR et al, who in 1992 combined prefabrication and ECTT, when he used the abdominal skin to receive its blood supply from the radial artery via a radial forearm fascia-fat flap in the first instance (by prefabrication) to be transferred to the scalp later (Sanger JR et al, 1992).

Similarly Dr. Lin TS et al provided another extension to the same thought, when he transferred in April 2002 the avulsed and lost heel of a foot after initially storing it on the calf. The heel pad once taken completely as a full thickness graft was then transferred to its original location on the foot as a reverse sural artery flap (Lin TS et al, 2002).

Some isolated case reports have been described in the literature showing the robust nature of the radial forearm flap. A distally based radial forearm flap has survived on several occasions, even when both superficial and deep palmar arches have been damaged (Naasan A et al, 1990).

Occasionally, the radial forearm flap has survived even without the venous drainage, as published by Erer CM et al in 1991.

Godden et al have recently reconfirmed our findings when they disconnected the vascular lifeline on the 9th day in a free flap (Godden DR et al, 2002).

The donor area of a radial forearm flap has been closed by several methods to improve upon the morbidity, such as the use of full thickness skin grafts, double opposing rhomboid flaps, the use of ulnar forearm flaps and even purse string closure. A pre-expanded flap is used sometimes for easier donor area closure.

I am sure that, in the future, free flaps will be transferred without anastomosis and without pedicles, with the help of tubing and canulation of vessels, using synthetic materials that don’t react to the body like the PTFE used by vascular surgeons.

**BASIC CONCEPT IN USE**

We have used those fasciocutaneous island flaps which could be based at the distal part of an extremity, both in the upper and the lower limb.

Flaps used in the upper limb include the radial forearm flap (most commonly employed of all) and the ulnar forearm flap.

Flaps employed in the lower extremity were posterior tibial flap, anterior tibial flap, dorsalis pedis flap, the peroneal flap, and the sural artery flap.

Although we used only those flaps where a long vascular stalk was a possibility, it by no means prevents others from using a cutaneous or a myocutaneous flap on the same principle. For rare and difficult problems such as for hemifacial atrophy, we have used vascularised fat and fascia (radial forearm flap without skin).

**PARTS OR ORGANS RECONSTRUCTED USING THE BASIC CONCEPT**

So far, we have resurfaced or reconstructed the following parts of the body with this technique:

**Head & Neck**

1. Cranium
2. Forehead
3. Cheek
4. Mandible
5. Hemiface
6. Scalp
7. Maxilla
8. Complete Nose
9. Palate
10. Neck
Upper Extremity

1. Thumb
2. Tripod hand (single stage)
3. Salvage reconstructions of all fingers
4. Salvage replantation of index finger
5. Thumb and the first web space
6. Symbiotic tissue transfer

Lower Extremity

1. Sole of foot
2. Dorsum of foot
3. Lower third of leg
4. Middle third of leg
5. Knee defects

Perineum and Trunk

1. Penis (complete)
2. Oesophagus

REFERENCES


CHAPTER 2

FLAPS IN THE UPPER EXTREMITY

The availability of fasciocutaneous flaps in the forearm such as radial and ulnar forearm flaps, transferred extracorporeally, has added a new dimension to the reconstructive procedures, especially when it comes to massive and difficult defects of the head and neck and upper extremity, specifically to the problems of the hand.

The following flaps will be described in detail:
1. Radial forearm flap
2. Ulnar forearm flap

Each flap will be discussed under the following sub-headings:
1. Anatomy
2. Flap elevation
3. Positioning the limb
4. Immobilisation
5. Excision of extracorporeal vascular stalk
6. Compression

SURGICAL ANATOMY OF UPPER LIMB AS APPLIED TO FOREARM FLAPS

A reconstructive plastic surgeon should be well conversant with the anatomy of all the structures that he will encounter when radial or ulnar fasciocutaneous flaps are being raised for ease of dissection and for the safety of the flap. Of great importance and interest are a few structures, which we shall study before discussing the flaps individually. These are:

1. Radial artery
2. Ulnar artery
3. Cephalic vein
4. Basilic vein
5. Median cubital vein
6. Medial cutaneous nerve of the forearm
7. Lateral cutaneous nerve of the forearm
8. Radial nerve in the forearm
9. Ulnar nerve in the forearm.

RADIAL ARTERY
(Fig. 2-1, 2, 3, 4, 5)

This is the smaller of the two branches of the brachial artery and is a direct continuation of the parent trunk. It takes origin opposite the neck of the radius, in the cubital fossa, and runs down the limb on its lateral side, up to the distal end of the radius. The artery is deeply placed in the upper half of the forearm, where it runs over the fourth layer of the muscles of the forearm, attached to the anterior surface of the radius. In the distal half of the forearm it becomes superficial and lies between the tendons of brachioradialis and flexor carpi radialis. It runs in close contact with the undersurface of the tendon of brachioradialis along with its venae comitantes and sensory branch of the radial nerve. The nerve lies lateral to the artery in the upper two-thirds of the forearm, and then in the distal third of the forearm it takes a lateral course to travel towards the lateral and extensor side of the limb, crossing the undersurface of the tendon of brachioradialis.
ARterial Anatomy of Right Forearm (Deep Fascia Has Been Removed)

Fig. 2-1

THE ARTERY GIVES THE FOLLOWING BRANCHES:

1. Radial Recurrent Artery (Fig. 2-2)
   It takes origin from the lateral side of the radial artery close to its commencement. It runs an upwards (retrograde) course to join with the radial collateral artery, a branch of the profunda brachii artery, anterior to the lateral epicondyle, sandwiched between the brachialis and brachioradialis muscles.

ARTERIAL ANATOMY OF RIGHT FOREARM (DEEP FASCIA HAS BEEN REMOVED)

Fig. 2-2
2. Muscular Branches (Fig. 2-2)

Several muscular branches to the surrounding muscles are given at variable intervals in the forearm.

3. The Superficial Palmar Artery (Fig. 2-2)

It arises as a small branch at the level of the styloid process of the radius, just before the radial artery passes into the anatomical snuff box. It travels distally towards the Thenar muscles, which it pierces and supplies. It is the termination of this branch that participates in the formation of the superficial palmar arch by connecting itself to the superficial branch of the ulnar artery.

4. The Anterior Carpal Artery (Fig. 2-2)

It arises from the ulnar side of the radial artery at the level of the distal border of pronator quadratus, and anastomoses in front of the carpal bones with the anterior carpal branch of the ulnar artery to form the anterior carpal arcade.

5. The Posterior Carpal Artery (Fig. 2-5)

It arises where the radial artery leaves the anatomical snuff box. It runs posteriorly and ulnar-wards to participate in the formation of the posterior carpal arch (superficial to the extensor retinaculum) by joining the posterior carpal branch of the ulnar artery.

6. The First Dorsal Metatarsal Artery (Fig. 2-3b)

It arises from the most terminal part of the radial artery at the dorsum of the hand and supplies the first dorsal interossei muscle. Branches of this artery spread over the radial side of the index finger and ulnar side of the thumb.
7. The Princeps Pollicis Artery (Fig. 2-5)

The terminal part of the radial artery penetrates the first intermetatarsal space from the dorsal aspect to appear on the palmar aspect in the same space, where, before its formation of the deep palmar arch, it gives origin to the princeps pollicis artery.

In effect, it arises at the commencement of the radial side of the deep palmar arch in the depth, near the palmar aspect of the proximal part of the first metacarpal. The artery divides into two branches which run on either side of the palmar aspect of the thumb, and supply it. Several septocutaneous perforators are given by the radial artery at regular intervals to supply the forearm skin. Latex and dye injection studies have revealed a maximum cluster of these to be in the central third of the forearm. However, from the point of view of survival of the flap in this region, plenty of them are present in the proximal third of the forearm as well.

**ULNAR ARTERY**

(Fig. 2-4b)

It takes origin in the cubital fossa at the level of the neck of the radius as the larger of the two terminal divisions of the brachial artery. It immediately takes a deeper and an ulnar direction, as compared to the radial artery, which continues in the same plane, straight in the line of the main trunk.

It lies initially on the brachialis and then on the flexor digitorum profundus under cover of the flexor digitorum superficialis. The median nerve crosses the artery superficial to it, in the proximal part of the course of the artery. In the distal half of the forearm, the ulnar artery lies radial to the flexor carpi ulnaris and ulnar to the flexor digitorum superficialis (runs between the two tendons). At the wrist, the ulnar nerve is ulnar (medial) to the ulnar artery (Fig. 2-4b). It is accompanied by two venae comitantes along its entire course.

A short distance above the wrist, the artery becomes superficial to the tendon of flexor carpi ulnaris and flexor digitorum and after piercing the deep fascia it runs superficial to the flexor retinaculum. However, here ligamentous tissue covers it. At this site it is radial (lateral) to the pisiform bone. After about a centimetre, it runs on the flexor retinaculum where it divides into a
deep and a superficial branch (Fig. 2-4b). The deep branch goes deeper and pierces the retinaculum to run deep to it and forms the deep palmar arch, while the superficial branch remains as the direct continuation of the artery and forms the superficial palmar arch (Fig. 2-4b).

**THE ARTERY GIVES THE FOLLOWING BRANCHES.**

1. **The Ulnar Recurrent Artery (Fig. 2-2, 4b)**
   It arises from the ulnar side of the artery and takes its direction upwards, towards the elbow. It divides into an anterior and a posterior branch, which participates in the formation of a network around the elbow by anastomosing with the inferior and superior ulnar collateral arteries, respectively (Fig. 2-4b).

2. **The Common Interosseous Artery (Fig. 2-4b)**
   It arises a little distal to the recurrent ulnar artery at the level of the tuberosity of the radius. Immediately, it divides into anterior and posterior branches.

   The anterior interosseous artery runs on the anterior surface of the interosseous membrane between fibres of origin of the flexor digitorum profundus and flexor pollicis longus muscles. At the upper border of the pronator quadratus muscle, it pierces the interosseous membrane to reach the posterior surface and participates in the formation of the posterior carpal arch (Fig. 2-5).

   It gives several muscular branches to the flexor muscles of the forearm, a nutrient branch to the radius and ulna and the median artery that accompanies the median nerve.

   The posterior interosseous artery pierces the interosseous fascia, soon after its origin, and appears on the posterior surface of the membrane just distal to the supinator muscle. It then runs between the deep and the superficial muscles on the extensor surface of
the forearm and reaches the wrist, where it participates in the formation of the posterior carpal arch which lies superficial to the extensor retinaculum (Fig. 2-5, 6, 7).

It also gives several muscular branches, but to the extensor muscles of the forearm other than an interosseous recurrent artery, which ascends upwards to the elbow under cover of the anconeus muscle.

3. Muscular Branches
Several muscular branches arise from the ulnar artery and supply the surrounding muscles in the forearm.

4. The Anterior Carpal Branch (Fig. 2-5)
It arises just above the level of the head of the ulna and runs distally and radially to reach the anterior surface of the carpal bone to participate in the formation of the anterior
carpal arch by joining the anterior carpal branch of the radial artery (Fig. 2-5).

5. The Posterior Carpal Branch (Fig. 2-5)
It arises at the same level as the anterior carpal branch, but then it passes to the back, passing under the tendon of the flexor carpi ulnaris muscle, where it participates in the formation of the posterior carpal arch.

6. The Deep Branch (Fig. 2-5)
It is the terminal division of the ulnar artery and arises just distal to the pisiform bone, superficial to the flexor retinaculum and then runs between the flexor digitorum profundus and the abductor digiti minimi muscle to pass deeper to the flexor tendons of the fingers. By union with the terminal division of the radial artery it forms the deep palmar arch (Fig. 2-5).

VENOUS SYSTEM OF THE FOREARM

THE CEPHALIC VEIN
(Fig. 2-6, 8, 9)

It is the continuation of the first dorsal metacarpal vein, which lies directly over the first metacarpal on the dorsum of the hand. It crosses over the anatomical snuff box from the dorsal to the lateral and then volar aspect of the forearm, at the junction of lower and middle third. It then ascends up towards the cubital fossa keeping itself towards the radial border of the forearm. In the arm it runs in the lateral bicipital groove and then in the deltopectoral groove. It penetrates the deep fascia in the groove, and reaches the infraclavicular region, where it pierces the medial part of the clavipectoral fascia and drains into the axillary vein (Fig. 2-8).
MEDIAN CUBITAL VEIN
(Fig. 2-8, 9)

This is a rather large communicating channel between the cephalic and the basilic vein in front of the elbow.

It begins from the cephalic vein, about 3 cm below the joint crease line of the elbow, travels obliquely from the lateral to the medial side to connect with the basilic vein, 3 cm above the medial epicondyle.

It receives few tributaries from the veins in front of the forearm in its short course (Fig. 2-9).

elbow, where it is joined by the median cubital vein. The calibre of the vein after this course is increased markedly and then onwards in the arm it runs in the medial bicipital groove (Fig. 2-8). At the level of distal and middle third of the arm it pierces the deep fascia and ascends further medial to the brachial artery before becoming the axillary vein at the lower border of the teres major muscle (Fig. 2-8).
CUTANEOUS NERVES OF THE FOREARM

1. Medial Cutaneous Nerve of the Forearm (Fig. 2-10a, b) (Medial antebrachial nerve) (C8, T1)

It is thicker than the lateral cutaneous nerve of the forearm and is a branch from the medial cord of the brachial plexus. It pierces the deep fascia in close relation to the basilic vein in the middle of the arm to surface in the subcutaneous tissue and runs downwards. Before reaching the elbow crease, it divides into anterior and posterior branches, which descend along the medial side of the forearm to the wrist. The anterior branch crosses the median cubital vein in the cubital fossa either in front of or behind it. It supplies the volar skin of the forearm between the cephalic and the basilic vein (Fig. 2-9).

2. Lateral Cutaneous Nerve of the Forearm (Fig. 2-10b)

It is the direct continuation of the musculocutaneous nerve (which is a branch from the lateral cord of the brachial plexus). The musculocutaneous nerve, having taken origin, takes a lateral course and pierces the coracobrachialis muscle just below the pectoralis minor muscle. It supplies the muscle and then descends obliquely downwards between the biceps and the brachialis, where it supplies both these muscles. It travels under the biceps muscle until it reaches the elbow crease line where lateral to the tendon of biceps it pierces the deep fascia to surface up into the subcutaneous tissue, where it is termed lateral cutaneous nerve of the forearm.

At the commencement, at or above the elbow crease line, it is behind the cephalic vein. It soon divides into anterior and posterior branches. Both these branches run to the lateral side of the forearm up to the wrist. They supply skin on the lateral side of the forearm, both on volar and dorsal aspects.

RADIAL NERVE
(Fig. 2-2, 3, 4, 6)

It is the termination of the posterior cord and is the thickest branch of the brachial plexus. In the arm it has a spiral course; from anterior to posterior and from posterior to anterior aspect in the forearm.

It descends behind the third part of the
axillary artery and then behind the brachial artery before leaving the front of the arm, by passing through two heads of the biceps muscle, to reach the radial groove in the middle third of the humerus, posteriorly.

It has to pierce the lateral intermuscular septum on the lateral side of the limb at the junction of the middle and lower third of the arm to pass into the anterior compartment of the arm. Here it lies deeply between the brachialis and brachioradialis.

In front of the lateral epicondyle of the humerus, it descends to the forearm under cover of the brachioradialis, where it divides into a deep (motor) and a superficial (sensory) branch. The deep branch runs in front of the lateral part of the head of the radius. It gives branches to the extensor carpi radialis brevis and enters into the supinator muscle to supply it. It then traverses the muscle, and after passing the muscle, it appears on the back of the forearm as the posterior interosseous nerve.

The superior branch descends in front of the lateral part of the elbow, under cover of the brachioradialis muscle. In the middle third of the forearm, it runs close to the lateral side of the radial artery. In the distal third of the forearm, it leaves the artery and takes a more posterio-lateral course to travel in the direction of the radial side of the dorsum of the hand. In the distal third of the forearm, it runs on the posterior edge of the tendon of brachioradialis and pierces the deep fascia to run superficially in the subcutaneous tissue crossing over the tendons of abductor pollicis longus and extensor pollicis brevis. Proximal to or over this crossing, the nerve divides into two or more branches that run towards the base of the index finger, the first web space and the thumb.
CHAPTER 3
RADIAL FOREARM FLAP

SURGICAL ANATOMY AND CONCEPT

The radial forearm flap is a fasciocutaneous island flap, raised from the forearm, based on the septocutaneous perforators of the radial artery. It has been raised either on the antegrade or on retrograde flow. A long pedicle is available on the retrograde flow and it is therefore preferred (Fig. 3-1a, b, c).

Two arteries that almost run parallel in the limb, namely the radial and the ulnar arteries, supply the forearm. They also supply the hand. In the palm, at the level of the distal and proximal palmar crease, they both unite to form two 'U' loops known as superficial and deep palmar arches respectively.

This communication between the two arteries is the basis for the radial and the ulnar forearm flaps, since circulation through them does not occlude even if one of them is ligated along its course. Through the 'U' loop, the blood from the other artery enters into the ligated vessel in a retrograde direction, maintaining the blood supply to the area of supply of the ligated vessel (Fig. 3-1a, b, c).

Plastic surgeons have taken advantage of this 'U' loop, both in the upper and the lower extremities.

It is now possible to use the entire territory of skin, supplied by either of these arteries, by raising them as distally or proximally based fasciocutaneous island flaps.

The radial forearm flap is a type 'C' fasciocutaneous flap of Cormack and Lamberty. It is supplied by the perforators of the radial artery and drained by its venae comitantes (deep venous system), and by the cephalic vein (superficial venous system).

The radial artery runs in the depth of the fascial septum that lies between brachioradialis and flexor carpi radialis. Perforators that supply the flap take origin from the artery in the depth of the septum and run between the two layers of the septa to emerge superficially onto the deep fascia and supply the skin of the forearm.

DESIGN AND MARKINGS
(Fig. 3-2, 3, 4)

A pattern of the defect is prepared and marked on the non-dominant proximal forearm
in a manner that at least 5 cm of vessels are available near the wrist. If the cephalic vein can be included with the radial vascular bundle, it provides added safety to the flap. This safety precaution is more meaningful when a large flap is raised.

The skin of the distal fourth of the forearm should be left intact so that postoperatively, tendons remain covered with normal skin, and do not get exposed. The ulnar side skin is non-hairy in males. In females, most of the forearm has insignificant hair growth. Commonly, non-hairy skin is required for facial and head and neck reconstruction. In these cases, skin from the ulnar side of the forearm is selected for flap elevation.

Depending upon the requirements of the defect, several types of tissue could be included with the flap such as a piece of radius bone, palmaris longus tendon, brachioradialis muscle with or without its tendon and the sensory branch of the radial nerve (Fig. 3-6) making it a compound flap. It is raised, as a neurosensory flap by using the anterior antebrachial nerve, (medial cutaneous nerve of the forearm) that supplies the skin of this flap.

The course of the radial artery on the forearm is marked. The site of the radial pulse is marked. The tendon of biceps at the flexor joint crease of the elbow joint is palpated and marked. A line joining these two points will mark the course of the radial artery. Under a venous tourniquet, the cephalic venous network can also be drawn.

We elevate all flaps over the extremities under a tourniquet. It is of great use in this flap in particular, since very fine and delicate dissection is required and that cannot be undertaken with precision without it.

**FLAP ELEVATION**

(Fig. 3-2, 3, 4, 5, 6)

Flap elevation commences proximally on the radial side of the flap marking, where a well defined plane of dissection lies under the deep fascia and over the flexor muscle bellies. Deep fascia in this area contains relatively less septas between the muscle bellies than on the ulnar side. In this plane, the dissection proceeds towards the course of the radial artery that has been marked on the skin in the middle of the flap, longitudinally. As with all other fascio-cutaneous flaps, deep fascia is stitched to the dermis immediately after its division. At this stage, no attempt is made to reach right up to the depth of the septum containing the radial vascular bundle.

A similar incision is made on the ulnar side and the deep fascia is stitched to the dermis. Here the deep fascia is very thick and near the origin of the flexor muscle bellies it is aponeurotic, where muscles take origin from the deep fascia. Here it is attached to the muscles. Additionally, on this side there are several septas that run between the muscle bellies, and firmly attach the deep fascia with them. Therefore, separation of the deep fascia from the muscles is difficult on this side and requires more care and attention. The aponeurotic part is separated by sharp surgical dissection and the septae are divided carefully.

The skin incision is now made for the dissection and isolation of the radial vascular stalk of the flap. The aim is to isolate the radial artery together with its venae comitant

If the cephalic vein is to be included with the vascular stalk, then a skin incision between the
cephalic vein and the radial artery is made with advantage. Skin and subcutaneous tissue are retracted away from the line of the skin incision and the deep fascia over the radial artery is exposed. A strip of deep fascia, over the vessels, in its entire length about 2 cm in width, is included while isolating the vessels. All branches coming out from the artery and all the venous tributaries joining their venae comitantes are either coagulated using a bipolar coagulator or ligated, about a centimetre away from their site of origin, to avoid any damage to the main trunk. Any fibro-fatty and loose areolar tissue present around the vessel are included. At no stage are the main vessels touched by any instruments, to avoid any kind of spasm or trauma. The fibrous septae enveloping the tendons next to the vessels such as flexor carpi radialis, brachioradialis and palmaris longus, are cut open longitudinally and septal tissues are included with the vessels.

Vascular dissection, which proceeds from the distal to the proximal, gradually reaches the septum, running between the muscle bellies of the brachioradialis and flexor carpi radialis, with the radial artery in its depth. At places, this septum may be very weak, flimsy or even absent.
The septum is approached from either side by retraction of the muscle bellies by using the teeth end of the Lanes retractor to visualise areas in the depth of the muscle bellies. Several veins will require coagulation in the depth. Finally, the point of bifurcation of the brachial artery into ulnar and radial artery, opposite the neck of the radius, surrounded by some fibro-fatty tissue, is reached. While the radial artery remains comparatively on the surface and remains straight in line as a direct continuation of the brachial artery, the ulnar artery will be seen dipping deep and going medially.
Just distal to this bifurcation, the recurrent radial collateral artery, accompanied by its venae comitantes, will be seen taking origin from the lateral side of the radial artery. Ligation of the radial vascular bundle distal to the recurrent radial collateral arteries is recommended since it will spare the supply of these vessels.

The sensory branch of the radial nerve needs to be separated now from the radial vessels. The nerve is dissected and isolated at one point and is retracted by a nerve hook. Now the scissors is run longitudinally over the nerve, cutting gently all the loose attachments of the nerve to the vessels, making sure that the scissors is close to the nerve and away from the artery.

Deeper separation of the vessels requires careful and gentle coagulation of branches and tributaries over the distal 3 cm of the radius, where the vessels run directly over the bone. Here, the branches of the radial artery like anterior and posterior carpal arteries, superficial palmar artery and the branches to the periosteum may be avulsed, if care is not taken during this separation. However, it is essential that the vessels are separated from the bone right up to the wrist crease, otherwise it will become a cause for kinking of the vessels after the flap inset.

TOPOGRAPHY OF RADIAL FOREARM FLAP
(Fig. 3-5a, b, c)
Similarly, the radial vascular bundle runs intimately attached to the deep surface of the brachioradialis tendon in its entire length. Running a knife longitudinally, close to the tendon, in a manner that it strips off even the paratenon of the tendon, can alone separate the vessels from the tendon. This is an absolutely essential step. It is therefore vital that skin flaps are left intact in the distal fourth of the forearm so that this bare tendon has a healthy skin cover and presents no problems later. It is also important that while isolating the septum, care is taken that the muscle belly of the brachioradialis does not inadvertently get isolated circumferentially, which at times is possible if precautions are not taken. In such an event the blood supply to the belly will be cut off significantly and the muscle may suffer ischaemic necrosis of some of its fibres.

By now there are no attachments left, except the radial vascular stalk at the radial side of the wrist crease. Tagging stitches between dermis and deep fascia applied at the beginning of the flap elevation are removed so that the full and original size of the skin opens up. The flap is placed back in position and a sheet of split thickness skin graft is wrapped around the vascular stalk. It is held in position by a few catgut stitches. After covering the flap with several layers of saline gauze, a tight bandage is applied over the entire forearm. The tourniquet is now released and the limb is kept elevated for 10 minutes, for the reactive hyperaemia to settle down. It should be possible to raise this flap within one tourniquet time of 90 minutes, after some practice. However, large and difficult flaps may require reapplication of the tourniquet, in which case we leave a breathing space of about 20 minutes.

The bandage is now opened, and haemostasis is performed meticulously. The donor area needs greater attention than usual. The tendons are bare at places and the muscle bellies lie flayed apart. Muscle bellies of brachioradialis and flexor carpi radialis are approximated together without undue tension with the help of a few vicryl stitches. Fibres of the pronator quadratus are used to envelop some of the bare tendons by applying vicryl stitches to the muscle fibres, in a way that they surround the tendons all around. As many tendons as possible are covered by muscle fibres in this manner. The skin flaps which have been left intact on the distal third or fourth of the forearm are approximated and the skin incision is closed.

This covers up most of the tendons, except the very proximal part of the brachioradialis tendon which may still be bare. Part of it can be covered by the muscle fibres of
the brachioradialis. After completing the haemostasis, a medium thickness sheet of split thickness skin graft is stitched over the donor bed of the flap. The limb is dressed over a layer of sofratoole. A loose dressing over the elbow joint is mandatory, especially in cases where the elbow has to be flexed for positioning, since flexion will further tighten the bandage causing great harm to the limb and to the flap. Invariably, it has to be flexed for head and neck defects. A circumferential tightness in this region may jeopardise the entire procedure by causing venous problems in the flap through external compression.

**POSITIONING THE LIMB**
(for Head & Neck reconstruction)
(Fig. 3-7)

The upper limb is highly flexible, mobile and portable. To be true, the hand can reach any part of the body except only a very small area on the back. However, the surgeon has to use only the most comfortable position, and therefore it is planned and discussed with the patient in advance, preoperatively. According to this planning, the pattern of the flap on the forearm has to be marked and cut.

Commonly, we have been using one of the four positions, A, B, C, D, as shown in Fig. 3-7 for head and neck reconstructions and found them very useful and comfortable for most of the patients.

While positioning the limb, the following points are made a special note of, and the surgeon should ask himself the following questions:

1. Will it be most comfortable?
2. Will the immobilisation be easy?
3. Will the immobilisation be stable?
4. Will there be any kinks, tensions or twists on the extracorporeal vascular stalk?
5. Will the donor area of the flap on the forearm be pressed against any part of the body?
6. Will the forearm be free from all around, so that pressure necrosis of tissues will be avoided and graft take is assured?
7. Will it be easy to dress the patient postoperatively?
8. Can the patient eat and see comfortably without being hindered by the immobilised limb?

**IMMOBILISATION**
(Fig. 3-7, 8)

Most stable immobilisations are obtained by using Plaster of Paris fixation. It is implemented in the following manner. For head and neck reconstruction, first of all, we
apply a Plaster of Paris head cap. Then a kind of wristlet is applied onto the hand using a Plaster of Paris bandage that goes more around the palm and less around the wrist as shown in Fig. 3-8b. Now these two (POP head cap and wristlet) are fixed together, once again by using Plaster of Paris. If the immobilisation is good, healing will progress trouble-free. If the pedicle is allowed to move too often, healing will be slow. Sometimes, the immobilisation may have to be revised after a few days – as and when it is found to be ineffective.

Other methods of immobilisation are by using elastopect bandages. These are lightweight and stick well to the skin. If no skin reaction takes place, they are equally effective. In our hands, we find them not so very stable and they require frequent changes since the weight of the limb drags down the interface and loosens the fixation.

In the lower limb, at times, external fixation devices are very useful for immobilisation. However, as a routine, we still prefer Plaster of Paris fixation, which after some practice can as well be made a light-weight affair.

**EXCISION OF THE EXTRACORPOREAL VASCULAR STALK**

Vessels could be excised any time after 10 days. We apply a weak plastic clamp on the vascular stalk (Fig. 3-9), on the 7th day, after removal of skin stitches of the flap inset.

**This clamp is fabricated in the following manner:**

(Fig. 3-9)

Two sheets about 2 cm wide and 10 cm long are cut out of a 2 mm thick PVC sheet. 4 mm diameter holes are drilled at either end. Screws (or nut & bolt) of 3 mm calibre and 4 cm length are passed through the holes, for approximation of two plates of the clamp.

The vessels are covered by a gauze piece and a weak clamp is applied over it on the seventh day. If nothing untoward happens to the flap, the screw is tightened about 3 threads, the same evening. The next morning, it is further tightened and so on until on the 10th day the vessels are so very compressed that they turn black because of necrosis at the site of
clamping. On the 10th day, in the dressing room, 1/0 silk ligatures are applied on either side of this black necrotic zone, and a knife is run through the necrotic area of this defunct umbilical cord. The limb is separated after removal of all the fixation bands. This procedure does not require any kind of anaesthesia. Flap revision at the site of entry and exit of vessels (donor wrist and the recipient site) is performed later, whenever theatre time is available, under local anaesthesia.

**COMPRESSION**

In all Asian patients, even if they are of fair complexion, some kind of compression for the next 3 months is a great must. It is applied by using compression garments in the form of elastic face masks, elastic garments, elastic head bands, gloves or even crepe bandages. This compression has to be continued for a minimum of 3 months or for the period that is tolerated by the patient. This is absolutely essential to improve upon the flap's contour, colour and texture match. At the end of this period, not only does the flap take up the desired contour, but the colour is also fairly acceptable.

**POSTOPERATIVE CARE OF THE DONOR LIMB**

Active and gradual passive exercises are instituted to the elbow joint, thumb, fingers and the wrist after two weeks of the first stage of the operation. It is expected that the graft over the forearm has taken and has healed well by this time.

Compression in the form of a crepe bandage that includes the entire forearm, elbow joint, wrist and palm, begins from now onwards to be continued for three months.

Power in the limb, which is initially weak, slowly recovers to reach its full strength in 3 months' time. Compression of grafted areas is a routine in Asian patients to avoid graft contraction, suture line hypertrophy and for turning the grafted area soft and supple, in a short period.

**DESIGNING AND TAILORING RADIAL FOREARM FLAP FOR DIFFICULT RECONSTRUCTIONS**

We will discuss designs for the following reconstructions:
1. Scalp and calvarial defects
2. Forehead
3. Nose
4. Maxilla
5. Oromandibular defect
6. Palatal defect
7. Hemifacial reconstruction
8. Cheek contour defects
9. Neck
10. Oesophagus
11. Penis
12. Resurfacing and reconstruction in the Upper Extremity
   * Tripod hand
   * Thumb and first web space
   * Index and middle finger
   * Index finger
   * Hand resurfacing
   * Defects around the Elbow

**DESIGN FOR SCALP AND CALVARIAL DEFECTS**

Calvarial defects of extensive nature are commonly seen following high voltage electric burns. We have rarely seen these following cancer extirpation. If the defect is so big that the residual scalp is not enough then tissues have to be imported. When the defect is not
only extensive but even the dura has to be removed requiring duraplasty, immediate flap coverage is called for. In such a situation, a radial forearm flap provides a ready solution.

Since the vascular pedicle can be planned anywhere in relation to the defect, planning is not very difficult. The forearm is kept across the vault as anteriorly or as posteriorly as desired. All positions are comfortable. However, the position is planned such that the forearm does not sit across the suture line. The donor area on the forearm should not be pressed against the rest of the cranium, otherwise graft loss or even necrosis of some of the muscle fibres of the flexor muscles can take place (Fig. 3-10).

CLINICAL EXAMPLES
Case 1 (Fig. 3-10)

An 11-year-old girl sustained a high voltage electric burn over the temporo-parietal region of the scalp in March 1986, and was admitted in poor general condition. After initial resuscitation she was treated by conservative dressings. It took 4 weeks for the necrotic scalp to separate, at the end of which underlying dead and necrotic calvarium measuring about 10 cm in diameter was exposed, over the vault of the skull. The scalp was lost in a diameter of about 15 cm. The necrotic calvarium was removed and the underneath dura was skin grafted. Once the grafts healed she was discharged.
She was readmitted 3 months later for definitive reconstruction. The split thickness skin graft over the dura was delicately separated and excised. The surrounding bone edges were freshened. The calvarial defect was reconstructed by a methyl methacrylate plate fabricated on the operation table. The entire plate and the surrounding raw area was covered by a distally based extracorporeal radial forearm flap, of 15 cm x 15 cm size, taken from the left forearm, on a 5 cm long vascular pedicle. Immobilisation was performed by a Plaster of Paris head cap and a wristlet.

The flap healed well in 10 days’ time, although reactionary fluid collected between the plate and the flap after a week. This was aspirated under aseptic condition. About 20 ml of this
fluid was aspirated on alternate days for the next 10 days. It gradually reduced in amount and finally stopped.

Immobilisation was removed on the 21st day, and the vessels were excised and limbs separated. Both the ends of the pedicle were revised. She was seen two years after reconstruction to be enjoying perfectly normal health.

**Case 2 (Fig. 3-11)**

A 30-year-old male patient sustained a high voltage electric burn of the scalp on 14th August, 1986. He was brought to us 2 weeks after the burn on 27th August, 1986, with a loosely attached necrotic scalp over the necrotic calvarium, in the frontal, occipital and parietal regions and right over the sagittal sinus in the mid line over the vault of the skull. The necrotic scalp was excised in the dressing room. A dry and brown bone underneath was visible (Fig. 3-11e). Tangential X-rays confirmed the necrosis.

Six weeks after the burn, the necrotic calvarium was removed and this created a bone defect of 17 cm x 8 cm. The dura was exposed in a large area and a lot of foul smelling discharge (thick, yellow pus) was present between the bone and the dura. Over the sagittal sinus, the dura was friable and was threatening to burst. Immediate flap cover was mandatory.

A radial forearm flap based distally, of 20 cm x 10 cm size, was borrowed from the left forearm and transferred to the defect extracorporeally. On the 19th day (25.11.1987), the vascular pedicle was excised and both the ends were revised. A week later, all wounds healed well and the patient was discharged.

He was readmitted 6 months later and on the 1st of May, 1987, cranioplasty was performed using the 7th and 8th ribs of about 20 cm length.
The ribs were split longitudinally into four pieces each and fixed at either end, onto the slots created for them, and were held in position by vicryl stitches to the surrounding periosteum and other soft tissues.

An 'H' shaped incision over the flap was used for the exposure which divided the flap into four smaller flaps keeping them attached to the
f - Late postoperative result after bone grafting

i - Radial forearm flap (proximally based) stitched in position (notice the forearm across the forehead).

g - Postoperative picture (6 months after the flap transfer, just before cranioplasty).

j - X-ray 6 months after cranioplasty using split ribs.

h - Six months postoperative result.

k - Donor area on forearm one year after surgery.
periphery (Fig. 3-11f). Follow up at 6 months (Fig. 3-11i, j, k) revealed that the ribs provided a good support as felt on palpation, being rigid, although they were not very clearly delineated on X-rays (Fig. 3-11f, j).

**DESIGN FOR TOTAL FOREHEAD RECONSTRUCTION**
(Fig. 3-12a, b, c)

The most common victims of this personality demolishing deformity are young girls, who have lost their entire forehead, at times along with both the eyebrows following avulsion of the scalp. A total reconstruction alone provides total rehabilitation of the patient. Nothing less should be attempted.

A full forehead is 20 cm in length and 8 cm in width in an average adult. The pattern that is required is shown (Fig. 3-12).

Positioning of the limb is a little difficult. As the pedicle can only enter from the side of the forehead near the temporal region, the forearm has to be kept across and over the vault, just behind the upper (cranial) suture line of the flap. In this position, the limb must be immobilised only by elastoplast fixation, since a Plaster of Paris head cap which is commonly used for head and neck fixation should not be applied, since it will press on the suture line of the freshly transferred flap (Position A).

The other alternative is to use the ipsilateral limb and fix the wrist to the ipsilateral temporal region and fixing the spread-out palm and fingers over the temporoparietal area of the scalp.

**CLINICAL EXAMPLES**

**Case 1** (Fig. 3-13)

A 55-year-old male patient was presented to us in March 1988, with a squamous cell carcinoma in the mid-line of the forehead, close to the eyebrows (Fig. 3-13a). The lesion was excised and covered by rotation of the residual forehead from both the sides into the mid-line.
defect. Although resection lines were clear histologically, the wound near the glabellar region never healed. A biopsy taken from this site in May 1988 revealed squamous cell carcinoma. Radiotherapy was instituted this time and 5000 rads were delivered in 16 sittings.

In August 1988 he came back to us with an ulcer of about 8 cm x 8 cm size, in the glabellar region extending up to the root of the nose (Fig. 3-13c). Additionally, he had 2 satellite nodules about a centimetre in size, in the right supraorbital area of the forehead. On 19th August, 1988, the tumour was excised along with the entire forehead. The frontal bone and the frontal sinuses were involved. Excision included both the tables of frontal bone about 5 cm x 10 cm in size (Fig. 3-13c), which exposed the dura in this area and a flap cover became mandatory. A distally based extracorporeal radial forearm flap, of 17 cm x 8 cm size, on a 5 cm long vascular pedicle taken from the left forearm, was used to cover this defect. The cephalic vein was included in the vascular pedicle. The vessels were excised in 3 weeks’ time and the limb was separated.

Once again in October 1988, he came back, this time with secondaries in the right parotid gland. Total parotidectomy was performed this time. The facial nerve was found to be involved for a length of about 5 cm, that had to be excised and replaced by microneural interfascicular sural nerve graft. Recurrence in the right preauricular region was noted in November 1988 and this time, before the patient could be taken for surgery, the tumour grew fast and destroyed a lot of adjacent areas.

In February 1989, he had a large growth sitting over the parotid and mastoid region, destroying half of the pinna. A C.T. scan revealed involvement of the base of the skull lateral to the carotid foramina, mastoid air cells, foramina oval, foramina lacerum, lateral pterygoid plate, zygomatic arch, temporomandibular joint and the upper part of the body of the mandible.

This extensive lesion was excised as well. Excision included complete external ear, skin in front and behind the ear, skin from the temporal region (12 cm x 18 cm), mastoid air cells, the base of the skull, lateral to the carotid foramina canal, including foramina ovale and spinosum.
zygomatic arch, temporomandibular joint along with segmental mandibulectomy, all the pterygoid muscle mass, masseter and temporalis muscle, sternomastoid muscle and the submandibular glands. Resurfacing of this defect was performed by an extended pectoralis major muscle, transferred as an extracorporeal flap to increase its arc of rotation and to let it reach up to the temporal region without tension (Fig. 3-13g). Three weeks later, the pedicle was excised. However, when all looked well healed, he developed serum hepatitis and grew very weak at this stage. The patient was discharged from the hospital in a very weak and frail state. I doubt if he survived much longer.

Case 2 (Fig. 3-14)

An 11-year-old fair and beautiful girl sustained complete avulsion of the scalp while she was working in the fields. Avulsion included loss of both the eyebrows and a part of both
upper lids, complete forehead and total scalp. An area about 2 cm in width of a hair bearing segment of skin in the nape of the neck was spared. She was brought to us without any scalp.

**RECONSTRUCTION OF TOTAL FOREHEAD**

Fig. 3-14a, b, c, d, e, f

- **a** - Post-traumatic scarring of total forehead following scalp avulsion injury
- **b** - Pre-operative view of the scalp
- **c** - Appearance of the flap on the 8th day
- **d** - Totally scarred scalp and forehead following scalp avulsion
- **e** - Appearance of the flap 2 years after reconstruction, showing a delighted patient
- **f** - Complete flap inset covering the total forehead (vessels wrapped with skin graft)
which could have been replanted and therefore nothing more than split thickness skin grafting could be offered at this stage.

To halt the disintegrating psyche of this female child, forehead reconstruction was undertaken 3 months later so that after wearing a wig she may look almost normal. Since a long flap was required, some skin from the distal arm had to be borrowed. Therefore, an extension of the radial forearm flap over the distal third of the arm was delayed on the 19th of January, 1990. The part to be delayed was incised down to deep fascia and the skin along with the deep fascia was raised up to the elbow joint crease line, and sutured back. Her complete forehead was resurfaced by a distally based extended radial forearm flap of 10 cm x 22 cm size, on a 5 cm long vascular pedicle, transferred extracorporeally on 2nd February, 1990 (two weeks after the delay procedure) (Fig. 3-14f).

The transfer was uneventful and the complete flap survived without any trouble. After clamping the vessels for 3 days (from the 7th to the 10th day), the extracorporeal vessels were excised on 15th February, 1990, and the limb separated. The donor area on the forearm by now had healed completely. Compression garments on the forehead and on the forearm were instituted and continued for 3 months. Since she now had plenty of soft and vascular tissue over the eyebrow region, free hair transplantation was undertaken next to reconstruct the eyebrows. The little hair bearing skin left in the nape of the neck was used for this purpose. Some hair grafts did not survive.

Two years later when she was seen, she looked a very happy child with no psychosocial barriers in her mind.

**DESIGN FOR NOSE**

(Fig. 3-15)

An extracorporeal radial forearm flap is indicated only for total nasal reconstruction, since smaller defects can be reconstructed very well by a mid-line forehead flap, and hardly ever is there a need for a distant tissue transfer. Total loss of nose, when calculated in terms of skin cover and lining, requires a fairly large-sized skin flap which could easily be underestimated.

The skin pattern of a normal adult nose, taken as an average of several measurements, has a length of 8 cm (from the root of the nose to the base of the columnella) and a width of 8 cm from the base of one alae to the other across the tip of the nose (Fig. 3-15).

The nasal lining (mucosa) is smaller in dimension all around – about 6 cm in length and 6 cm in width.

The pattern of the tip, alae and the columnella has a very irregular but specific shape that must be cut with care, otherwise the most important part of the nose will not achieve the most desired shape.
The defect of the lining measures 6 cm x 6 cm (Fig. 3-16). The two skin patterns (for the cover and for the lining) have to be harvested as two lobes of a single flap, with a de-epithelised segment in between. They have to be folded upon themselves in a manner that the raw surfaces of both face each other.

Therefore, we design a bilobed radial forearm flap as shown in Fig. 3-18.

The vascular pedicle enters the flap at the root of the nose. Not a great length of vascular pedicle is required since the wrist has to lie over the middle of the forehead and the forearm across it.

That much of skin is available easily on the proximal half of the forearm.

Skeletal support to keep the shape of the nose as prominently as planned has to be provided at the time of flap transfer. An iliac crest bone graft or a rib graft will do the job well. Ribs are easier to shape, while the iliac crest, if curved as thin as the ribs, will lose strength. We prefer rib grafts.

It is a complex affair to create a nasal skeleton from the ribs, and several points need special attention. The following must be kept in mind (Fig. 3-16).

1. The columellar strut that supports the tip of the nose is the most important part, and therefore, must be strong enough to provide continued support, even after some bone resorption. Some resorption of the bone graft will invariably take place, since it is not going to be under any stress or force. The bone graft should be long enough from the tip of the nose to the anterior nasal spine.

2. The dorsum and the lateral walls of the skeleton should be straight and smooth to give a uniform shape.

3. The fabricated angle between the bones of two lateral walls should be maintained in the desired position, firmly.

Skeletal fixation at the anterior nasal spine and at the nasion could be performed by interosseous wiring or by vicryl stitches (Fig. 3-16).

**Fabrication of Nasal Skeletal Framework from Ribs** (Fig. 3-16a, b, c)

- **Rib**
- **Split rib**
- **Triangular stopper (bone)**
- **Vinyl stitch**
- **Columellar strut**
- **Fabricated nasal framework**

**Position of Imobilisation** (Fig. 3-17)

The forearm fixed across the forehead is quite comfortable. In 3 weeks’ time, the nasal inset is well healed. The vessels are excised at this stage and ends are revised at the root of the nose and at the wrist. The shape of the nostrils
could be further improved by using acrylic nostril conformers, made to size and shape, for three months.

**CLINICAL EXAMPLE**
(Fig. 3-18)

A 25-year-old male patient was presented to us in December, 1989, with a large cavernous haemangioma completely involving the right maxilla, right cheek, upper lip, nose and the palate (hard and soft), a month after getting married.

The possibility of the selective embolization was excluded owing to the presence of multiple sources of feeding vessels to this tumour. Therefore, there was no other alternative than to surgically excise the lesion and get on with the reconstruction. ENT surgeons excised the lesion which included total nose, right cheek, right maxilla, complete upper lip, complete hard and soft palate on the right side and a part of the lateral pharyngeal wall in the region of the tonsillar pillars. About 20 units of blood transfusion was required during this surgery. A persistent effort and struggle saved the patient and the ENT surgeon, but has put the reconstructive surgeon in trouble, since reconstruction of this defect appeared a nightmare to me.

After repeated counselling and extensive thinking it was decided to reconstruct it using a combination of extracorporeal radial forearm flap and extended pectoralis major myocutaneous flap. Required patterns for the lining and for the cover for nose, cheek and upper lip were cut and put together as shown in Fig. 3-18n, o. Reconstruction of the maxillary cavity, hard and soft palate was planned by an extended pectoralis major musculocutaneous flap. However, since reconstruction of several organs and parts was planned in a single operation, for this most extensive defect, we decided to split the procedure into two by prefabricating the entire nose on the forearm and to transfer it to the face, once it had healed well.

**PREFABRICATION OF NOSE ON FOREARM**

On 24th August, 1990, eight months after surgical extirpation, we performed prefabrication of the nose on the forearm. The pattern for lining and cover of the nose (together with the skin requirement for the rest of the facial defect, Fig. 3-18i, j, k), was kept and marked on the left forearm in such a manner that non-hairy ulnar side skin is from one side of the septum of the radial forearm flap, and is available for nasal lining and as much as possible for nasal cover. Skeletal support had to be provided at this very sitting, otherwise the reconstructed nose would not hold its shape and would sit over the forearm, only as a blob of tissue.
PREFABRICATED NASAL RECONSTRUCTION USING EXTRACORPOREAL RADIAL FOREARM FLAP

Fig. 3-18a, b, c, d, e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u

a - Preoperative view following excision of cavernous hemangioma of right maxilla, cheek and nose.

b - Two years late follow-up seen from the right side of the face, profile view, showing acceptable appearance.

c - Two years after the reconstruction seen from the left side of the face.

d - One year after the tissue transfer. Several readjustments followed this appearance seen from the front.

e - Once the raw areas had healed and the infection settled the reconstruction was begun. This is the preoperative view just before the commencement of reconstruction.

f - Tissue requirement is assessed and drawn on a piece of mackintosh.
Using the 6th and 7th ribs, the nasal skeleton was fabricated as shown in Fig. 3-15.

Under a tourniquet, a distally based flap was raised only as far as the septum, without dissecting the radial vascular bundle at all, at this stage. The skeletal infrastructure fabricated out of the ribs was wrapped all around by the flap, creating a nose of perfect shape and size. All depressions including nostrils were packed

g - A transparent polythene sheet is very handy in such three dimensional reconstructions for assessing the size and shape of the defect that is used for planning the desired flap size, shape and location.

i - The pattern is then transferred on a piece of mackintosh that will be sterilized to be used during surgery.

j - Checking the mackintosh pattern on the forearm, calculating the length and the direction of the radial vessels that are required.

k - Prefabrication of the nose is then completed on the forearm. Only one side of the septum of the flap is used for this purpose. The donor area on the forearm is skin grafted. This is a view taken on the operation table, while finishing the prefabrication of the nose.

h - Cutting a paper pattern according to the drawing marked on the polythene sheet. The paper pattern is folded in a three dimensional manner and checked on the defect preoperatively to see whether it gives the desired shape to be reconstructed.

l - Three weeks after complete healing, the prefabricated nose is kept in a kind of mould by packing it from inside and outside with Vaseline gauze pieces to maintain and mould the shape as desired.
m - Total fabricated nose along with the rest of the flap for the cheek defect (from the other side of the septum) is raised on a distal radial vascular bundle. Notice the original mackintosh pattern still in use on the operation table. The forearm was skin grafted.

q - Two weeks after the flaps' transfer. Flap is totally viable and skin graft over the radial vessels has taken.

n & o - Extended pectoralis major myocutaneous flap has been raised to be used for palatal and cheek lining of the defect.

r - Vessels were excised after three weeks and a well healed flap is seen after 2 months.

p - All flaps (prefabricated nose on a radial flap and extended pectoralis major myocutaneous flap) were then stitched in position keeping the wrist on the forehead and vessels in the midline.

by wet saline cotton. A negative suction drain was left in between the two layers of the flap to maintain the shape of the nose. The donor area of the flap was skin grafted by a tie-over dressing. The nose was left to heal and settle before its transfer on the face. Four weeks later, it healed completely and had taken a good shape (on the forearm) and was ready for the transfer. The healed nose along with the rest of the radial forearm flap, according to the earlier
planned design, was then raised on a distal vascular pedicle by one team. The second team in the meantime had raised the extended pectoralis major myocutaneous flap. This flap was so designed that the distal extended part of the flap, which is basically a fasciocutaneous extension and is therefore thinner than the rest of the flap, is used for the palatal oral lining and the rest of the flap forms the palatal nasal lining and fills the maxillary cavity. This was accomplished by folding the flap upon itself, keeping the fold posteriorly towards the pharynx. The free skin edge was available anteriorly for stitching with the radial forearm flap, forming the upper lip (Fig. 3-18p).

The transfer of this (Fig. 3-18m) baffling tissue pattern and stitching all bits and pieces in place, as if a jigsaw puzzle, was not easy. The forearm was kept across the forehead so that the radial vascular bundle entered the flap from the root of the nose. All intraoral stitching was performed with vicryl stitches.

The transfer fell into trouble when the extended part of the pectoralis major did not survive. It necrosed and had to be excised. However, since the pectoralis major muscle which filled the cavity over the maxillary region survived and epithelialized, most of the reconstruction could be salvaged. Realising that more tissue would be required, an arm tube was prepared in the meantime and was used.

Three weeks later, on 23rd November, we excised the extracorporeal vessels and separated the limb. By this time the cheek and the nose had been reconstructed and had taken some shape, but not the upper lip. This was because the upper lip lining created by the radial forearm flap hung and remained displaced in the absence of the palatal lining (which had necrosed).

After several revisions, adjustments and finally bone grafting to provide him with an alveolar arch and the maxillary prominence, he looked socially acceptable. Restoration of speech and deglutition was a far greater asset to this patient than his appearance (Fig. 3-18t).
CLINICAL EXAMPLE
(Fig. 3-19)

A 22-year-old female suffered extensive and severe burns of the upper half of her body in March 1989 following an epileptic attack while cooking. The most severe (third and fourth degree) burns were sustained in the head and neck region. After three months of treatment in the village she was brought to us severely disfigured, scarred and with exposed cranial and facial bones, surrounded by dirty granulating wounds (Fig. 3-19a, b, c).

After initial skin grafting the granulating raw areas for quick and initial healing, definitive reconstruction of her forehead and

EXTRACORPOREAL RADIAL FOREARM FLAP FOR RECONSTRUCTION OF TOTAL FOREHEAD AND TOTAL NOSE
Fig. 3-19a, b, c, d, e, f, g, h, i, j, k,

b - The burn has disfigured the whole face. The frontal and left temporal bone had remained exposed for the past 2 months. The left eye has been lost and there is severe ectropion of both the lids of the left eye.

c - After an initial attempt to heal the burn wounds by burr holes and skin grafting.
sculpt was performed, by using a radial forearm flap (15 cm x 20 cm) from one forearm, and total nasal reconstruction by the radial forearm flap from the other forearm. This difficult reconstruction was completed practically in two stages and she was fully rehabilitated to move in society unhindered (Fig. 3-19j, k).

d - Multiple burr holes have been made in the exposed frontal and temporal bones.

e - A sickle shaped flap (3 cm x 18 cm) based on the right temporal artery has been transferred to reconstruct the anterior hairline.

f - A bilobed radial forearm flap from the left forearm has been used. Lobe B for the nose did not survive. Lobe A used for the forehead has survived completely.

g - Total nasal reconstruction has been undertaken from the right radial forearm flaps.
h - Severe burn cicatrisation is evident. Total forehead, nose and the left eye has been lost completely. Full face is severely scarred.

j - Very oedematous looking nose 6 weeks after reconstruction.

i - Appearance soon after the skin grafting on the raw areas on the face and scalp.

k - Flaps have been brought to their respective places and need readjustment to provide the desired shape to the reconstructed organs. At the end of several reconstructions she looked like this. A lot more final work was planned but could not be undertaken since the author moved out to a different hospital.
DESIGNS FOR MAXILLA

The maxilla occupies that central force on the facial skeleton that its presence and function is vital for the functional integrity of the skeleton that surrounds it, and remains supported by it. These include the mandible, zygoma, orbital bones and nasal bones.

Aesthetically, maxillary loss at times is acceptable and one may not bother about reconstruction at all. But functionally, loss of the palate, lateral nasal wall and orbital floor (that supports and keeps the eyeball in position), is a great handicap to the patient and needs reconstruction. An intelligent patient in the Western world may manage with an obturator that fills the entire cavity and also provides a palate, but the innocent and simple Asian villagers are at a loss, since they cannot manage with obturators. Reconstruction of the palate and the orbital floor support is a must in these patients.

Post-maxillectomy patients have defects of the soft and hard palate (inability of speech and of chewing well), a contour defect of the cheek, an everted lower eyelid (ectropion), causing epiphora, and a defect in the lateral nasal wall. Designing and planning of such extensive defects is difficult but not impossible.

The topography of the defects of the lining will reveal that, basically, there are two areas that require lining and they are the palate and the lateral nasal wall. There are two areas that require skeletal support and they are the orbital floor and the alveolar arch. Additionally, there is a cavity to fill in (maxillary sinus). Therefore, a three dimensional appreciation of the defect and designing and planning in accordance is called for.

Since palatal and nasal lining defects are in continuity, if a bilobed radial forearm flap could be so designed that each lobe could be used for the palatal and nasal walls, that should serve the purpose. One of these flaps will be sitting horizontally (for the palate) and the other will be sitting relatively vertically (for the lateral nasal wall defects). The cavity has to be filled with a muscle and the skeletal loss requires bony support.

The next question is about the entrance or the exit of the vascular stalk into or from this intraoral location. This too requires great thought and planning. This has to be collaborated with the posture that has to be adopted by the upper extremity after immobilisation. The position has to be comfortable. With these predetermined criteria about the requirements of the defect to be met, we approach the problem in the following manner.

Starting the planning in reverse, we keep the upper limb in various possible positions, as shown in Fig. 3-7a, b, c, d and assess the patient's comfort, and balance it with the stability of fixation. A forearm placed across the forehead is generally most comfortable and usually agreed to by the patient. Fixation, too, is easy and stable. If the wrist could be kept close to the glabellar region, then the port of entry of the vessels into the cheek could be anywhere below the medial canthus of the eye, by the side of the nose, and medial to the cheek flap.

Designing a bilobed radial forearm flap and planning its location on the forearm such that it may survive completely and in a trouble-free manner, is performed next. If both lobes are raised over the radial artery axis, there are no chances of trouble of any kind. The flap is designed as shown in Fig. 3-24.
FLAP ELEVATION

A skin island is planned on the proximal forearm. The distal forearm is used to harvest a good length of vascular pedicle. A minimum of 10 cm length of vessels can be easily obtained. The proximal-most lobe of the flap (Lobe B) is used to reconstruct the palate and its most proximal border is to be stitched to the midline of the palatal defect. The maxillary cavity is to be filled with the brachioradialis muscle belly which is to be raised with the flap, keeping its blood supply intact. This is made possible by leaving the septum and the septocutaneous perforators still attached to the muscle belly on the side of the septum. On the medial aspect of the belly no attempt is made to separate the septum from the muscle since blood supply to the muscle will then be damaged.

This vascularized muscle plays two roles. One, it helps greatly the survival of bone grafts that are to be used for the orbital floor and the alveolar rim. And two, by filling the cavity of the maxillary sinus, it treats the contour defect of the face.

The defect is to be recreated by elevation of the cheek flap, through the old maxillectomy incision and freshening of the edges of the defect, for the flap inset. Insetting of the flap is most complex. Having placed the wrist on the forehead, the flap is delivered in the oral cavity, keeping the vessels near the root of the nose. Flap 'B' is stitched first. Stitching of the lobe 'B' begins by approximating the de-epithelialized edge of this flap to the palatal edge in the midline from the posterior to the anterior part of the palatal defect. If the anterior part is stitched first, posterior stitching will be difficult. Vicryl suture material is used for this purpose. Stitching is then completed in the retromolar region. Now working from posterior to anterior, the stitching of the free edge of the lobe B with the residual cheek mucosa is completed, in the area of the upper buccal gingival sulcus. Finally, the lobe 'A' of the flap is stitched all around to the lateral nasal wall defect, in a manner that the port of entry of the radial vascular stalk sits near the medial canthus of the eye (Fig. 3-20h).

Now the bone grafts are placed in position. In the absence of the maxillary tuberosity, after maxillectomy, we use the lower part of the zygomatic bone to buttress both the bone grafts; one for the orbital floor and the other for the alveolar arch (Fig. 3-20g).

The medial end of the bone graft for the alveolar arch is fixed to the normal alveolus in the midline alveolar defect. The medial end of the bone graft for the orbital floor is fixed to the residual bony skeleton of the medial side of the orbit (Fig. 3-20g).

The brachioradialis muscle is filled in the space between these two bone grafts, which is in effect the site for the maxillary sinus. The muscle is secured well around the alveolar bone graft by vicryl stitches. This has two purposes: one, it helps the survival of the bone graft, and two, it keeps the reconstructed palate (palatal lobe of the flap) in position and does not let it hang, since the muscle is attached to the cutaneous segment of the flap.

The cheek flap that was raised in the beginning through the old maxillectomy incision to recreate the maxillary defect is put back and is stitched in position. Since the maxillary region is now occupied and filled, it may sit under some tension.
The upper medial-most tip of the cheek flap which sits near the root of the nose (just below and medial to the medial canthus of the eye), is the site for the port of the vessels and cannot be stitched at this stage.

The limb is fixed in position (across the forehead). Vessels which have already been wrapped with split thickness skin graft are checked for tension and kinking, and the skin graft is properly spread over them and secured by a few catgut stitches, since it usually wrinkles and gets displaced while the flap inset is being given.

Ten days later, the extracorporeal vessels are excised and the flap inset that has been left in during the first stage at the site of the port for vessels is now completed. Similar revision of the port is performed on the wrist. Care of the donor forearm is the same as described earlier.

**CLINICAL EXAMPLES**

**Case 1 (Fig. 3-20)**

A 55-year-old male was presented to an E.N.T. surgeon with carcinoma of the right maxilla. After preoperative radiotherapy (5200 rads), a total maxillectomy was performed which included the floor of the orbit and the right side of the soft and hard palate. Excision also included some of the involved skin of the right cheek. Reconstruction was performed by the E.N.T. surgeon, only for the loss of cheek skin using a deltopectoral flap. The undersurface of the flap and the rest of the cavity was skin grafted. After healing, an obturator was provided for the palatal defect and the patient was discharged.

One year later, the patient was presented to us, unhappy, with a marked contour defect of the cheek (Fig. 3-20a), epiphora from the left eye and with inability to speak without an obturator. He wanted a reconstruction of his palatal defect and of the maxilla. He was free of the tumour.

The maxillary and palatal defects and that of the orbital floor were recreated by exposing them through the old incision. Reconstruction of the hard and the soft palate in continuity with the lateral pharyngeal wall of the nasopharynx and that of the lateral nasal wall was required. After taking a pattern very carefully for lining, a distally based bilobed radial forearm flap of 6 cm x 8 cm size (of each lobe) was planned. The vascular pedicle was planned to emerge from the upper medial side of the cheek flap. One lobe was planned to reconstruct the palatal defect while the other was meant for the defect of the lateral nasal wall in continuity with the nasopharynx. The flap was raised on the left forearm under tourniquet isolating a distal vascular pedicle of about 8 cm length (Fig. 3-20e). The brachioradialis muscle was included with the flap, preserving its perforators. The vascular pedicle was wrapped in a sheet of split thickness skin graft, to avoid vessel spasm and drying during surgery. The donor area of the flap was skin grafted.

A temporary skeletal spacer was fabricated out of methyl methacrylate in two pieces. One was for the orbital floor including the infraorbital margin and the other, to reconstruct the maxillary prominence and the upper alveolar arch. The three points of fixation used for these pieces were the malar prominence, right nasal bone and the midline of the alveolar arch.

For transferring the flap intraorally, the left forearm was placed across the forehead,
EXTRACORPOREAL RADIAL FOREARM FLAP FOR THE RECONSTRUCTION OF MAXILLA

Fig. 3-20a, b, c, d, e, f

a - Contour defect of the face with a palatal defect following right maxillectomy

b - Late postoperative result.

c - Bilobed radial forearm flap, used for palatal reconstruction. One lobe of the flap that was used for palatal reconstruction is seen from intraoral view.

d - Late postoperative appearance of the donor forearm.

e - Schematic drawing of the bilobed radial forearm flap.

f - The trachioradialis muscle has been included in the flap. (Schematic drawing to show the flap with the muscle)
EXTRACORPOREAL RADIAL FOREARM FLAP FOR THE RECONSTRUCTION OF MAXILLA

Fig. 3-20g, h, i, j, k, l, m

j - Radial forearm fascia-fat flap with a pilot island of skin in the centre is marked on the right forearm based distally.

k - Radial forearm fascia-fat flap based distally is raised.

l - Undersurface of the radial forearm fascia-fat flap.

m - Appearance of the donor right forearm three months after harvesting the fascia-fat flap.
EXTRACORPOREAL RADIAL FOREARM FLAP FOR THE RECONSTRUCTION OF MAXILLA

Fig. 3-20 n, o, p, q

n - Preoperative contour defect after right maxillectomy, when palatal reconstruction has been completed.

p - The defect of skin deficiency over the cheek is recreated.

o - Four weeks postoperative result.

q - Skin is undermined all around the defect and filled with gauze pieces to make the initial assessment of the bulk required and to be filled with radial forearm fascia-fat flap.
EXTRACORPORAL RADIAL FOREARM FLAP FOR THE RECONSTRUCTION OF MAXILLA

Fig. 3-20r, s, t

r - Radial forearm fascia-fat flap from the left forearm is stitched in position.

s - Flap seen from the undersurface.

t - Vein port is placed in the right preauricular region and the limb is kept across the chest.
so as to pass the vascular pedicle into the oral cavity under the upper medial part of the cheek flap. The acrylic spacers were fixed in position by thin dental wires. Immobilisation of the forearm was provided simply by elastoplast fixation, after making sure that the vascular pedicle was totally relaxed and lay without any twist or kink, covered with a sheet of split thickness skin graft.

Postoperative management included provision for a rubber wedge between the molar teeth on the normal side, during the healing period, to avoid trauma to the flap. The postoperative period was uneventful and in 3 weeks’ time, all wounds healed. The vascular pedicle was excised on the 21st day and the ends revised. A week later, the patient was discharged.

A month later, he was readmitted and the acrylic spacers were removed and replaced with rib grafts from the 7th rib, which were introduced into the space provided by the spacer. The patient was discharged ten days after bone grafting. At the time of discharge, the patient had normal speech without any obstructor. There was no epiphora since the eversion of the lid has been corrected (Fig. 3-20b).

Six months later, the patient returned with some depression and the contour defect of the cheek, but with normal speech and deglutition (Fig. 3-20h). For purely aesthetic reasons, it was decided that a radial forearm fascia-fat flap from the other forearm be used to cover this contour defect and some skin could also be added at the centre of the defect. This skin can be used as a pilot to monitor the survival of the flap (Fig. 3-20). It would further help the lower eyelid which still had some pulling effect of the scarred and the deficient skin. The flap survived completely and the contour defect was corrected (Fig. 3-20f). Since he did not return for late follow-up, it is expected that he led a happy and normal life.

Case 2 (Fig. 3-20l)

A 45-year-old male was presented to us at Mafrak hospital in Abu Dhabi, U.A.E. with a post cancrum oris deformity of the upper lip, the right cheek and the right angle of the mouth. He was unable to open the mouth completely, which resulted in feeding difficulties.

The disfigurement was exaggerated when he tried to open his mouth; he had suffered from cancrum oris in his childhood.

He managed to live with this difficult face for all those years leading up to the surgery, in a country like the United Arab Emirates, until he came to us at Mafrak Hospital in 1996.

As a first step towards reconstruction, the defect had to be recreated. This was done by excising the thick fibrous plate at the base of the right alae of the nostril responsible for fixing the tissue in an abnormal position (Fig. 3-20g). He had a shortage of lining and of the cover of part of his upper lip, and the right side of the cheek, including some of the vermillion. The defect was reconstructed using a heart-shaped radial forearm alternate free flap of 8 cm x 8 cm (Fig. 3-20le, f) from the left forearm. The limb was immobilised by placing the left hand on the right shoulder, by fixing it with elastoplast for 10 days (Fig. 3-20lh).

The forearm was then separated with minor readjustments. Three months later, defatting and readjustment of the flap were carried out on this very irregular problem. He regained fairly normal features at rest and on opening his mouth. Feeding difficulties were emolliated.

SUGGESTED FURTHER READING:


(Cont’d after ‘References’ at end of book)
ALTERNATIVE FREE RADIAL FOREARM FLAP USED FOR POST CANCERUM ORIS DEFECT
CHEEK & LIPS Fig. 3-20a, b, c, d

a - Post cancerum oris deformity at right angle of the mouth.

b - Exaggerated disfigurement on opening the mouth.

c - Postoperative result while face is at rest.

d - Postoperative result showing full opening of mouth is possible without much disfigurement.

Dr. Anshul and Dr. Ashok Govila
ALTERNATIVE FREE RADIAL FOREARM FLAP USED FOR POST CANCARUM ORIS DEFECT

CHEEK & LIPS Fig. 3-201e, f, g, h

e - Heart shaped radial forearm flap marked over left forearm on a non-hair bearing segment with a 10 cm vascular pedicle

f - A distally based radial forearm flap is raised as marked

g - Defect was recreated. Note mucosal and skin deficiency in the nasolabial fold region.

h - Flap inset was possible to almost 100%. On the first postoperative day, the patient is sitting in the ward. These flaps behave like free flaps showing gross oedema.
DESIGN FOR PALATAL DEFECTS

In Asian countries, it is not uncommon to see a few patients in a year with a very wide cleft of lip and palate, who are presented as fully grown adult patients, in the age group of 20-35 years. Many times, nothing has been done. Sometimes, the lip has been repaired, leaving the palate unrepaired. Some of these patients have such wide clefts that there are hardly any palatal shelves on either side of the cleft that could be used for the closure of such defects.

There is yet another group of patients who require palatal reconstruction and they are the post-maxillectomy ones. Many surgeons opt to leave these defects without reconstruction and advise an obturator to block the cavity. That is not a very satisfactory answer to the problem. Some patients from this group, who cannot live life with an obturator, come for reconstruction.

Intraoral sources cannot provide enough tissue for a large intraoral defect. Tissue has to be borrowed from a distant location. The extracorporeal radial forearm alternative free flap is handy and is available immediately for this difficult problem. The palatal defect requires an oral and a nasal lining. There could be two basic designs of radial forearm flap for this purpose – either a single lobe or a bilobed flap.
DESIGN FOR A
WIDE CLEFT PALATE DEFECT

A. Bilobed flap  B. Single lobe flap

A. Bilobed Flap
(Fig. 3-22)

In this plan, the edges of the cleft of the palatal defect are freshened and the gap between the two edges is planned to be filled with two lobes of the radial forearm (bilobed flap - one lobe for the oral and the other lobe for the nasal lining). Both the lobes are in the shape of long narrow ellipses, which sit longitudinally and directly cover the radial artery.

The length and the width of these lobes of the flap are the same as that of the palatal defect. Both are elliptical in shape. There is a de-epithelized segment, about 1 cm in distance, between the two flaps. The length of the vascular pedicle required is a little longer than in other situations. The limb is placed across the forehead, with the wrist in the midline, and the pedicle is made to travel by the side of the nose (on the cleft lip side) to enter the oral cavity through the cleft lip. This distance is about 10 to 14 cm (Fig. 3-22).

If need be, the design could be changed and the lobes are planned side by side, on either side of the septum. Two flaps are once again separated by a de-epithelized segment placed longitudinally (Fig. 3-22).

However, two flaps in the small oral cavity get crowded up and may cause respiratory difficulties in the initial postoperative period. It is better to manage these patients initially for a period of 48 hours in the ICU, and shift them out only when they are well settled. To obviate this problem, the radial forearm fascial flap (alone) can be used and both surfaces (oral and nasal) can then either be skin grafted or left to epithelise. This will occupy less bulk in the oral cavity (Fig. 3-22).

B. Single Lobe Design
(Fig. 3-23)

The oral mucoperiosteum of the remaining palatal shelves, if at all there are any, is hinged on the free border of the cleft of the palate by giving an incision all around the alveolar border of the palate, and two flaps from both the sides are then brought in the midline of the palatal cleft. These two flaps are stitched together in the midline. This leaves a raw surface on the entire oral side of the palate, the central part of which has been resurfaced by the mucoperiosteal flaps from the oral mucoperiosteum.
This raw area over the oral side of the palate is then covered by a single lobe radial forearm flap (Fig. 3-23) of similar dimensions.

![Diagram of radial forearm flap](image)

**CLINICAL EXAMPLE**
(Fig. 3-24)

A 59-year-old male patient with recurrent carcinoma of the base of the tongue after surgery and radiotherapy (recurrence at the retromolar trigone very close to the mandible) underwent wide excision which included left sided segmental mandibulectomy, removal of two-thirds of the tongue, part of the lateral pharyngeal wall and part of the soft palate and retromolar trigone (Fig. 3-24a).

Primary reconstruction of this extensive totally intraoral defect was performed using an extracorporeal distally based radial forearm flap from the right limb. The flap measured 10 cm x 10 cm and the pedicle length was about 10 cm (Fig. 3-24c). The mandibular defect was stabilised with a "K" wire spacer. The donor area of the flap was skin grafted. Vessels were wrapped in a sheet of split skin graft.

Flap transfer in this case was performed by bringing the forearm across the chest so as to place the right hand on the left shoulder, with the vascular pedicle remaining externally. The limb was immobilised by elastoaplast fixation (Fig. 3-24e). Post-operatively, there was loss of the anterior third of the flap, following severe infection and cellulitis. This was debrided under general anaesthetic, and fortunately, there was enough flap left to cover the raw area thus created. Four weeks later, the vessels were excised and the limb separated.

At the time of discharge 6 weeks later, the patient could swallow a liquid and semi-solid diet without trouble, but had some speech difficulties which improved remarkably over the next 6 months.

**SUGGESTED FURTHER READING:**
a - The intraoral defect is seen following hemiglossectomy and segmental mandibulectomy for carcinomas of the tongue extending onto the retromolar region, posterior tonsillar pillars and part of the soft palate. The endotracheal tube could be seen very close to the vocal cords.

b - Reconstruction basing radial forearm flap is in progress. Posterior stitching of the flap has been completed.

c - A distally based radial forearm flap of 10 cm x 12 cm on 15 cm long radial vessels has been raised.

d - At the completion of surgery, the vascular pedicle could be seen to have been brought out from the submandibular suture line, keeping the forearm across the chest.

e - Quite a comfortable patient is seen in the ward keeping the limb across the chest. Vessels wrapped in a sheet of skin graft are seen hanging in the submandibular region.

f - Intraoral view 6 months postoperatively. The flap could barely be distinguished from the oral mucosa.
DESIGN FOR OROMANDIBULAR RECONSTRUCTIONS

Oromandibular defects are generally caused following cancer extirpation with the most common defects being the loss of cheek and skin over the mandible region, loss of oral mucosa (lining) and loss of part of the mandible. Extracorporeal tissue transfer is indicated when regional myocutaneous and fasciocutaneous flaps have failed, or has been used earlier or when a free tissue transfer has suffered total disaster. Primary use of this technique and the flap is indicated when the defect has extended beyond the oromandibular region such as behind the retromolar trigone, lateral and posterior pharyngeal wall, and into the larynx, because regional flaps such as pectoralis major myocutaneous flaps will be too bulky and obstructive while a deltopectoral flap will not reach these regions. A radial forearm flap is thin and can be tailored to fit these irregular shapes and areas.

If the requirement is only for the lining (oral mucosa), or only for a cover (skin), then a simple radial forearm flap, cut to size, is good enough. But for defects consisting of lining and cover both, a bilobed flap has to be designed: one lobe for the lining and the other for the cover. The intervening area has to be de-epithelialised. The lobes are so planned that the hairless ulnar side is used for the oral lining mucosa, and the rest of the forearm, which may or may not be hairy, is used for the skin cover.

The pedicle is so planned that it has its port of entry in the submandibular region.

The limb is immobilised across the chest by keeping the hand over the opposite shoulder region. The contralateral limb is used for this purpose.

CLINICAL EXAMPLE

(Oromandibular defect)
(Fig. 3-25, 26)

A 50-year-old man was presented to us with a squamous cell carcinoma of the right cheek, which had invaded and destroyed the right maxilla, alveolus, hard palate, upper lip alat and the septum of the nose. A combined approach with surgery and radiotherapy was decided. Following a radical dose of radiotherapy, the residual growth was widely excised by another member of our team. Two years later, when he was recurrence-free (Fig. 3-26a), we undertook the reconstruction using an extracorporeal radial forearm flap (AFF). The various components of tissue loss in this defect from several parts that included the upper lip, hard palate, nose and cheek lining and cover, were

EXTRACORPOREAL RADIAL FOREARM FLAP FOR ORO-MANDIBULAR DEFECTS
(Fig. 3-26)

Volar aspect skin surface available on the forearm

Skin cover

Hairless ulnar aspect

Lining mucosa

Position of immobilisation

Extracorporeal vascular pedicle
measured and a pattern was drawn and cut out (Fig. 3-26b). In four weeks' time, it was a well healed reconstruction. Minor flap adjustments were undertaken later. One year later (Fig. 3-26c, d), when he was examined in the clinic, he had satisfactory function of speech and deglutition, and a reasonable appearance.

**EXTRACORPOREAL RADIAL FOREARM FLAP FOR OROMANDIBULAR DEFECTS**

Fig 3-26a, b, c, d

- **a** - Defect following excision of squamous cell carcinoma cheek extending onto the palate, nose and the upper lip. Free from recurrence after one year of excision and radiotherapy.

- **b** - Position of the pattern is checked over the forearm for the feasibility of safe flap raising and its comfortable and safe transfer.

- **c** - Late postoperative result showing good functional reconstruction of palate; cheek, upper and lower lip including the right oral commissure.

- **d** - Early postoperative view before readjustment of the flap.

**RADIAL FOREARM FASCIAL AND FASCLIA-FAT FLAP FOR CHEEK CONTOUR DEFECTS**

This is yet another dimension to the idea of (AFF) extracorporeal tissue transfer. The idea is to transfer vascularised fat and fascia from the forearm to the face but with minimal scarring over the forearm. This is of great benefit to young girls, where forearm scarring may be aesthetically unacceptable. Fat and fascia are filled under the skin of the face at the site of hemifacial atrophy or any other type of contour defect on the face. The skin over the forearm remains intact and, therefore, only a linear scar of the skin incision is all that is left on the donor forearm.

Hemifacial atrophy is one of those diseases which have persistently puzzled plastic
surgeons and defied their methods of reconstruction. Synthetic materials are many for filling smaller defects, but for extensive defects, none are satisfactory. The weight of the material itself drags it down and the cheek is always hanging with the weight of the material. Replacement of lost tissues by biological tissues is the only permanent answer. Conventional fat grafts, dermofat grafts and dermal grafts eventually leave lumps and bumps scattered over the treated area, because of uneven atrophy of the transferred tissue. Free vascularized tissue transfer at present is the best option so far, but the facility for such methods (microsurgical) is not available universally. Therefore, the extracorporeal method of vascularized fat and fascia transfer is a logical extension of the idea of extracorporeal radial forearm flap (AFF). We have used it successfully and with great gratification.

**DESIGN AND PLANNING**

An assessment of the thickness of fat present over the forearm is made preoperatively by pinching the fat under the skin between the fingertips. In girls (females), a larger amount of fat is available from a smaller area, while in boys (males), a smaller amount of fat is present; therefore, a larger surface area of fascia and fat may have to be borrowed. The extent of the contour defect of hemifacial atrophy will decide how much fat and fascia will be enough to correct it.

**FLAP ELEVATION**

Through a ‘Y’ shaped incision over the forearm, a distally based flap consisting of fat and fascia is harvested. The technique of flap elevation is very much like the radial forearm flap, except for a few differences. The flap is so raised that half of the thickness of fat is left with the skin on the forearm and the other half remains attached to the deep fascia that is raised as a fascia-fat flap. Since the procedure entails extensive undermining of medial and lateral skin flaps, (beyond the medial and the lateral border of the forearm), the skin flaps may suffer marginal necrosis; therefore, enough fat for the survival of the skin is left attached. However, in a fat female, a lot of it could still be harvested.

**TRANSFER**

A preauricular or submandibular incision is made in cases of hemifacial atrophy. In other cases, it is made according to the site of the contour defect. The skin too has atrophied in these patients, and therefore, it is separated from the atrophied muscles and other tissues with great care. The skin is undermined all around about a centimetre beyond the contour defect.

The limb is brought to the defect and a preliminary assessment of contour correction is made after filling the flap under the skin, which has been undermined. An excessive flap size can now be trimmed after delivering it out. Tagging vicryl stitches in the flap are now taken. A straight, long needle, which is used for skin marking in conventional plastic surgery units, is used for this purpose. The thread is made to pass from the skin around the contour defect to be filled into the cavity that is to be filled and then out through the submandibular incision. Now the bite is taken on that part of the flap that is supposed to fill that area of the contour defect. Finally, the thread is passed in from the submandibular skin incision to the cavity and then taken out, about a centimetre
away from the original needle puncture on the skin. These stitches will be finally tightened over a small bolster, but at this stage, the thread is left long, until all the stitches have been passed. Now one by one, these stitches are tightened on a bolster in such a manner that they do not cause skin necrosis at the site of their application. The skin incision is now closed. There should be some amount of tension over the cheek skin and on the suture line. The extracorporeal vessels are wrapped in a sheet of split thickness skin graft and the limb is immobilized in the most comfortable position.

The flap is left to heal for 3 weeks so as to develop a good vascular pick-up before excising the extracorporeal vessels. The limb is separated and both the ends of the pedicle are revised.

Compression over the forearm and over the cheek begins soon thereafter by using crepe bandages initially, which are later replaced by pressure garments. This is continued until a perfect contour match is achieved. This may take about 3-6 months, when compression is discontinued.

CLINICAL EXAMPLES

Case 1 (Fig. 3-27)

A 22-year-old girl was presented to us in December 1989, with a burnt-out hemifacial atrophy of the right side of the face, mainly involving the cheek inferior to the zygomatic arch and infraorbital rim (Fig. 3-27a). We had not yet discovered the fascia-fat flap then. Synthetic materials, therefore, were used to fill the right side of her face, but with unsatisfactory results (Fig. 3-27b, c).

She was then shown the slides of our cases who underwent resurfacing of their faces following extensive burns and where we had used large radial forearm flaps. The possibility of using fat and fascia to avoid scarring over the forearm was discussed with her and she gladly consented. She became our first patient who underwent the radial forearm ‘fascia-fat flap’ procedure in March 1991.

A fascia-fat flap of 15 cm x 10 cm based distally on an 8 cm long vascular pedicle was raised through a 'Y' shaped incision over the forearm (Fig. 3-27d, e). The long limb of 'Y' was drawn over the radial artery. The incision opened up two skin flaps from the forearm, like opening a book, based on either border of the forearm. When the extreme radial border of the fat and fascia complex was reached, the deep fascia was incised and was raised medially toward the septum and over the brachioradialis muscle. A similar procedure was performed from the ulnar border of the planned flap. Finally, the most proximal dissection and then the isolation of the vascular pedicle were undertaken. The flap was now ready for the transfer (Fig. 3-27e). The tourniquet was released and haemostasis was performed. It was easy to approximate skin flaps and close the donor area since a good amount of tissue had been removed from under the skin.

The vascular pedicle was wrapped in a sheet of split thickness skin graft and then the limb along with the flap was taken to the face where the flap was filled in the cavity created for it (Fig. 3-27h). The flap was held in position by tagging bolster stitches around the contour defect. It was left to heal for 3 weeks (Fig. 3-27g) and then the extracorporeal vessels were excised and the limb separated. Compression garments were instituted for 6 months, at the end of which a very satisfactory result was achieved.
EXTRACORPOREAL RADIAL FOREARM FASCIA-FAT FLAP FOR THE RESTORATION OF CONTOUR DEFECTS OF THE FACE

Fig. 3-27a, b, c, d, e, f, g

a. Hemifacial atrophy of the right side of the face

b. One year after filling the depression with synthetic material

c. Two years after removing the synthetic material and filling the defect with a fascia-fat flap, showing a reasonable correction and the ability of expression.

d. Radial 'fascia-fat flap' is seen from the deeper surface. A 'Y' shaped incision that was used for harvesting the flap has been closed comfortably.

e. Radial 'fascia-fat flap' is seen from the superficial surface.

f. Extracorporeal vessels seen hanging in the air on the 10th day

g. A plastic clamp as shown in Fig. 1 has been applied, which will be gradually tightened for the next three days.
A distally based radial forearm fascia-fat flap, measuring 15 cm x 10 cms, harvested through a ‘Y’ shaped incision on the left forearm, on a 10 cm long vascular pedicle (Fig. 3-28e, f), was transferred extracorporeally to fill this contour defect, through a submandibular incision. The position as shown in (Fig. 3-28h) was used for this purpose.

Extracorporeal vessels were excised on the 10th day and the limb was separated. Compression garments were instituted from the 15th day for 3 months. One year later, she was seen last (Fig. 3-28c, d) with a perfect contour match. The patient and her parents were as delighted as we ourselves were. She was happily married then.

**EXTRACORPOREAL FASCIA-FAT FLAP FOR THE RESTORATION OF CONTOUR DEFECTS OF THE FACE**

**Fig. 3-28a, b**

A 20-year-old girl, otherwise beautiful and fair complexioned, was presented to us with a localized but severe hemifacial atrophy of the left side of her face; her parents found it difficult to get her married. The disease lay dormant for the past 5 years. The burnt out pathology was localised between the nasolabial fold anteriorly and preauricular line posteriorly. Above, it extended up to the malar prominence and below, up to the mandibular border (Fig. 3-28a, b, c).
EXTRACORPOREAL FASCIA-FAT FLAP
FOR THE RESTORATION OF CONTOUR DEFECTS OF THE FACE
Fig. 3-28c, d, e, f, g, h

**c - Late postoperative result.**

**d - Two year postoperative result.**

**e - Radial forearm fascia-fat flap has been raised, based distally, as seen form the undersurface of the flap. The entire radial vascular bundle could be seen longitudinally across the flap.**

**f - The flap is seen from the superficial aspect. Vessels are wrapped in skin graft. A 'Y' shaped skin incision that was used for the exposure has been closed. The flap is stitched in position using bolster stitches.**

**g - Donor forearm seen 2 years after surgery. Scarring is acceptable to the patient and the surgeon.**

**h - Appearance on the operation table at the end of the flap transfer. The flap is stitched in position using bolster stitches to keep the flap spread up into the contour defect. Notice the position of immobilization. The forearm that is not seen in the picture is kept across the forehead.**
DESIGNS FOR EXTENSIVE FACIAL DEFECTS

Facial defects of an extensive nature that are not amenable to tissue expanders require distant tissue transfer. If microsurgical facilities are not available, an extracorporeal radial forearm flap is a viable proposition. The entire forearm skin could be raised without a delay. The skin of the distal third of the arm in continuity with the forearm flap can also be raised as a single flap, for extremely large defects, but the part over the arm requires a delay procedure.

The irregularity and sheer dimensions of such defects demand some special considerations during the planning of these patterns. Very irregular extensions of the flap, which are almost like pseudopodia, should be avoided in the first place, but if they are absolutely unavoidable, they are so planned that either they fall nearer to the vascular axis of the flap or they have a demonstrable perforator entering into them. Two or three lobular defects in close vicinity can either be converted into one defect or two. Alternatively, a single lobed flap can be planned and the intervening segment is de-epithelialised. Such extensions should never be planned to sit on the ulnar side of the proximal forearm, since the dominant supply of this area is from the ulnar artery. These small pedunculated extensions of the flap survive best when they are placed on the radial side. On this side, the flap could be marked even up to the extensor aspect, over the muscle bellies of the proximal third of the forearm. While planning the flap pattern and its location, the inset, the site of the vascular pedicle and the positioning of the limb, these considerations are borne in mind. Similarly, in extensive defects, such as for hemifacial coverage or for total facial coverage, unreliable areas of the flap must be delayed a week in advance. These areas include the proximal ulnar side of the forearm.

The delay is performed by incising the skin and the deep fascia, undermining the flap in a plane between the deep fascia and the muscle. The flap is then stitched back to its original position.

CLINICAL EXAMPLES

Case 1 (Fig. 3-29)

A 38-year-old man was presented with severe post-burn scarring and disfigurement of the face 11 months after trauma involving the entire lower face.

There was loss of part of the upper and lower lip and left oral commissure. Scarring extended to the upper third of the neck (Fig. 3-29a, b). After excision of all scar tissue, a defect covering all of the lower face below the malar prominences, measuring 20 cm x 25 cm, was created and was covered with an extracorporeal radial forearm flap of similar dimensions based distally (Fig. 3-29e, f, g). The proximal part of the flap lying on the distal arm was delayed a week in advance. Postoperatively, some congestion developed at the very distal end of the flap which finally settled. After 20 days, the vessels were excised. One year later, when he was last seen, there was a very satisfactory result (Fig. 3-29c, d).

SUGGESTED FURTHER READING:

EXTRACORPOREAL RADIAL FOREARM FLAP FOR EXTENSIVE FACIAL DEFECTS

Fig. 3-29a, b, c, d,

a & b - Post burn severe scarring, folliculitis and epithelial bridging of the lower half of the face including the perioral region, causing difficulty in opening the mouth, and is very disfiguring.

c & d - Late postoperative result after resurfacing the complete lower half of the face using an extracorporeal radial forearm flap.
Case 2 (Fig. 3-30)

A 25-year-old female was admitted 3 months after severe, very deep burns of the face caused by her husband who held her head forcibly in a cooking fire. Initial treatment was carried out at a village hospital before she was brought to us in April, 1985. She then had severe burn scarring involving the entire face, except the lower right cheek. An area of the frontal bone of about 10 cm x 12 cm was bare over the sagittal sinus and here the frontal sinus was exposed. There was severe ectropion, of variable degrees, of all the four lids (Fig. 3-30a). As a first step to save her vision, the eyelids were released and the skin was grafted. The bare frontal bone was chiselled and the skin grafted.

She was later taken for definitive reconstruction when the right side of her face was resurfaced by an extracorporeal radial forearm flap measuring 20 cm x 25 cm, and the nose and forehead were resurfaced by a pedicled arm flap measuring 9 cm x 20 cm.

When the pedicled arm flap was being prepared, her anterior hairline was reconstructed by a sickle flap from the scalp based on the posterior branch of the superficial temporal vessels. Division of the pedicles of the arm and extracorporeal forearm flaps was performed simultaneously on the 20th day. Post-operatively, her extracorporeal tissue transfer remained trouble-free but there was marginal necrosis for a centimetre in the arm pedicled flap. Some minor flap adjustments were made later, when reconstruction of the ear lobule was performed, using a post-auricular flap which was folded upon itself. She was finally restored to a level that was socially acceptable.
EXTRACORPOREAL RADIAL FOREARM FLAP FOR EXTENSIVE FACIAL DEFECTS.

Fig. 3-30a, b, c, d

- Severe post-burn scarring, distortion and disfigurement of the face following homicidal burns causing exposure of cranial bones and loss of facial skin and that of the scalp.

- Radial forearm flap (marked with circle) and pedicled arm flap (marked with rhomboid) have been transferred simultaneously.

- Late postoperative result. Some finer readjustments are going on and some more will be needed.

- Two years postoperative result.

Case 3 (Fig. 3-31)

A 16-year-old girl was presented to us with a giant hairy naevus involving the right upper quadrant of the face and scalp (Fig. 3-31 a, c). Excision of the whole of the naevus created a defect measuring 10 x 27 cm which was covered with an extracorporeal radial forearm flap of similar dimensions, after an initial delay over the distal arm (Fig. 3-31c, f). On the 20th day, the pedicle was divided. Initial hyperpigmentation which developed in the flap improved significantly over the next 6 months. A year after reconstruction, when she was last seen, she was absolutely delighted with the result, and so were we (Fig. 3-31b, d).
a & b - Giant hairy naevus on the face of a young girl, involving the upper half of the right cheek, upper half of the nose, right half of the forehead, all of the temporal region of the scalp, right upper eyelid and right eyebrow. It was impossible for the parents to get this girl married.

c & d - Postoperative result six months after the completion of resurfacing of the face. She got married later on and was lost from further follow-up.

e - Proximally based radial forearm flap has been given an inset over the cheek, temporal and forehead region.

f - Notice the immobilisation.
Case 4 (Fig. 3-32)

A 19-year-old boy sustained homicidal acid burns on his face on 1st January, 1989. He was treated by local doctors in Bihar, until he was presented to us 10 months later in October, 1989, with severe hemifacial disfigurement. He then had cicatrical ectropion of both right lids (lower lid ectropion was far more severe than that of the upper lid), extensive scarring on the right side of the face, the temporal region down to the submandibular region, including most of the nasal skin. This scarring extended into the neck, causing neck contracture, ectropion of the lower lid and severe pull on the lower third of the nose. Additionally, he had corneal opacity in the right eye and the right eyebrow was lost and replaced by scar tissue (Fig. 3-32b).

The ectropion of both lids was released and skin grafted on 27th October, 1989. At the same time the extended part of the expected radial forearm flap was delayed, over the extensor aspect of the forearm (Fig. 3-32h). The skin and the deep fascia of the extended part of the flap was incised and raised as a flap up to the radial and ulnar borders of the volar aspect of the forearm and sutured back.

A week later, on 3rd November, 1989, the entire disfiguring scarred area was excised and this opened up a rather large and irregular raw area on the face extending from the preauricular region to the midline on the nose and from the glabellar to the submandibular region (Fig. 3-32e, f). The defect, which measured 22 x 18 cm, was covered by a distally based extended (and delayed) radial forearm flap from the left forearm, on a 5 cm long vascular pedicle (Fig. 3-32i).

The pedicle included the cephalic vein, in addition to the radial artery and its venae comitantes, for added safety. The position used for immobilisation is shown (Fig. 3-32g).

The postoperative course was uneventful and on the 7th day, all the stitches were removed. A trial clamp was applied weakly on the 10th day which was gradually tightened for the next 4 days. The extracorporeal vascular pedicle was excised on the 15th day (on 17.11.1989), and that separated the limb. Both the ends of the pedicle were revised then. Compression garments were instituted a week later. They were continued for 3 months.

Two years later, when he was seen last, he enjoyed a normal life with an almost normal and radiant face. The flap appeared almost the same in colour and texture as the rest of the face (Fig. 3-32c, d). The donor forearm had full function and was acceptable aesthetically (Fig. 3-32j).

SUGGESTED FURTHER READING:

Rev Stomatol Chir Maxillofac. 2002 Apr;103(2):74-8. [Contribution of the semi-free radial forearm flap for head and neck reconstruction][Article in French]


EXTRACORPOREAL TISSUE TRANSFERS FOR EXTENSIVE FACIAL DEFECTS

Fig. 3-32a, b, c, d, e, f

a & b - Homicidal acid burn cicatrization of the face resulted in a very severe disfigurement of the right half of the face and neck, causing functional problems with the right eye, nose and oral commissure in addition to post-burn contracture of the neck.

c & d - Late postoperative result following resurfacing of the face with an extracorporeal radial forearm flap.

e - Scar tissue from the face and neck is excised completely.

f - Notice the defect is up to the middle of the neck and almost total nose.
EXTRACORPOREAL TISSUE TRANSFERS FOR EXTENSIVE FACIAL DEFECTS

Fig. 3:32g, h, i, j, k, l, m

g - A complete inset of the flap has been possible. The patient is sitting comfortably in the ward on the 9th day.

h - Radial forearm flap has been delayed over the extensor aspect of the forearm and distal arm.

i - Distally based radial forearm flap has been raised. Note the donor area extends over the distal arm.

j - Late postoperative result of the donor forearm. Full power and movement in making a fist.

k - Late postoperative result.

l - Completely rehabilitated patient.

m - Almost normal look – two years postoperative result.
DESIGN FOR NECK CONTRACTURE

Post-burn contracture of the neck is a common problem. Many times, additional problems are presented with it, such as scar hypertrophy on the face, chest and arm, or even bilateral axillary contractures in severe cases.

The common practice to release these contractures and skin graft the resultant areas does provide good functional results, but aesthetically, there is nothing positive about them. Moreover, compression collars are cumbersome and their prolonged use, at times, causes non-healing ulcers which are difficult to treat.

We presume that in good looking girls, and even boys, when the neck alone is so severely burned and contracted that, aesthetically it is an unacceptable result and personality disorders or difficulties may arise in getting them married, then a flap cover should be provided. All the scarred tissue should be removed and the radial forearm flap should be transferred extracorporeally. This provides skin almost as close to normal as the patient had before the burn. It not only provides brilliant functional results without any hassle of compression garments but is aesthetically so pleasing that at times it is hard to believe that the area was ever burned at all.

The flap requirement is mainly on the anterior half of the neck, since the posterior aspect and the nape of the neck are commonly spared. Half of the circumference of the neck (in a 40 cm collar size) comes to 20 cm, and the distance from the chin to the suprasternal notch is about 15 cm in a fully extended average adult neck. Since we know the forearm can provide a 25 cm x 25 cm flap, it is possible to plan a flap of 20 cm length and 15 cm width, placed longitudinally over the forearm. About 5 cm of vascular pedicle will be left on the distal forearm for the transfer.

A comfortable position is to fix the hand over the contralateral shoulder near the base of the neck. This position is not only comfortable to the patient but helps the venous drainage of the flap.

CLINICAL EXAMPLES
Case 1 (Fig. 3-33)

A 16-year-old girl sustained 40 percent second and third degree burns in March 1986, and was initially treated by dressings followed by split thickness grafting. It took about 3 months for the wounds to heal before she could be discharged.

She was presented to us a year later in March 1986, with a severe and disfiguring neck contracture (Fig. 3-33b, c). She had a fair and beautifully radiant face completely spared from the effects of the burn. She therefore used to hide her neck by wrapping a ‘chunni’ (a kind of garment used by girls in India) around it, and that is how she entered our clinic.

On 13th March, 1987, we excised all the hypertrophic and disfiguring scarring from the neck. This opened a large area from the chin to the sternum on the anterior aspect of the neck. The entire area was covered by an extracorporeal radial forearm flap based distally, of 20 cm x 14 cm size, from the left forearm, on a 10 cm vascular pedicle (Fig. 3-33b, f, g). The cephalic vein was included with the vascular pedicle. The limb was taken across the chest and the hand was immobilised over
the other shoulder by elastoplast fixation. In two weeks' time, healing was complete when the pedicle was excised and the limb was separated. Compression was instituted over the forearm and neck (neck collar) for the next 3 months.

A year later, when she came for a routine follow up, the surgeon was delighted with the result which was beyond his imagination, and so were the patient and her mother (Fig. 3-33b, d).

EXTRACORPOREAL RADIAL FOREARM FLAP FOR RESURFACING NECK DEFECTS.

Fig. 3-33a, b, c, d

a - Post-burn neck contracture seen from the side.

b - Late postoperative result.

c - Post-burn neck contracture seen from the front.

d - The area of hypertrophied and contracting scarring to be excised has been marked.
EXTRACORPOREAL RADIAL FOREARM FLAP FOR RESURFACING NECK DEFECTS.
Fig. 3-33e, f, g, h, i, j

e - The defect, after the excision of scar tissue, extends from under the chin to the manubrium sterni.

f - A distally based radial forearm flap of 18 cm x 13 cm has been raised.

Case 2 (Fig. 3-34)
Similar problem as in Case 1

DESIGN FOR OESOPHAGUS
(Fig. 3-35a, b, c)

In those cases where other methods of oesophageal reconstructions are either not possible or have failed, the extracorporeal method is applicable. Such situations arise when, following suicidal or accidental swallowing of concentrated acid, severe stricture of the oesophagus develops in a long segment in a young patient and which is not amenable to dilatations. The initial surgical procedure of
jejunal pull through and jejunoo-jejunal anastomosis has been attempted and has failed. In such a situation, free jejunum cannot be used since the abdomen is full of adhesions following an earlier laprotomy. So, the only solution in the given situation is the reconstruction of a skin tube using a radial forearm flap to be transferred extracorporeally. The method is best applicable for the upper third oesophageal reconstructions.

The design depends upon the barium X-ray findings, showing the length of the oesophageal segment that requires replacement. Depending upon the length required of the constricted oesophageal segment, the length of the radial forearm flap is marked on the forearm. The
EXTRACORPOREAL RADIAL FOREARM FLAP FOR OESOPHAEGAL RECONSTRUCTIONS
Design and position of immobilisation (Fig. 3-35a, b, c)

Flap tubed with skin surface inside
Position of immobilisation

width is so calculated that a lumen of 3 cm diameter could be created. This will require about a 10 cm width of flap, which on tubing can provide a 3 cm diameter tube. This skin pattern is borrowed from the proximal half of the forearm so that the distal half is available for the vascular stalk (Fig. 3-35a, b).

In a female patient, the entire forearm can be non-hairy, but in male patients, the surgeon should take more skin from the ulnar non-hairy side. Some males are extraordinarily hairy, in which case we shave off the epidermis and part of the dermis, down to the level of hair follicles from the forearm and apply a sheet of split thickness skin graft over it. Since the hair follicles have been removed, hair growth stops. About 3-6 months later, once the graft is soft and supple, a non-hair flap can be raised from the forearm. Through a manubrial split exposure, the upper normal segment of the oesophagus is approached and the defect is recreated. The narrow and scarred segment of the oesophagus is removed. If needed, this procedure could be performed by a cardiothoracic team.

For the transfer of a fabricated skin tube from the forearm, the limb is taken to the upper chest and the most proximal end of the skin tube is joined to the upper proximal normal end of the oesophagus using vicryl suture material (Fig. 3-35c). Now the other end of the skin tube is joined to the lower end (cardiac end) of the normal oesophagus, or to the jejunal loop that has been attempted earlier by a pull-through procedure. All sutures lines have to be water-tight. We use two layers of vicryl. If one is worried about the survival of the tissue that is being transferred, then only the upper end is joined while the lower end of the tube is brought out over the skin of the chest wall and stitched all around to the lower end of the skin incision that was used for the exposure. This wound will require great care to protect it from the oral and the pharyngeal mucosal secretions that will trickle down the reconstructed skin tube causing skin excoriation.

Several points are worth mentioning about the immobilisation of the limb, especially if the lower end has not been stitched:

1. Immobilisation should be firm, since the tissues under repair are quite delicate.

2. The pedicle should travel laterally and upwards, so that it is away from the oesophageal mucosal discharge. The discharge runs into the skin tube and onto the skin of the chest. In this area of the wound, the vascular stalk should not lie and the chest wall skin as well should be prevented from excoriation.
Excision of the extracorporeal vessels and limb separation are performed three weeks later. If the lower union has not been performed in the first sitting, then either it could be performed now or it could be deferred for a further 3 weeks when the reconstructed tube is well settled and excoriation of the chest wall skin has improved.

**DESIGN FOR PENILE RECONSTRUCTION**

(Fig. 3-36a, b)

Total loss of the penis, either following trauma or after surgical amputation for carcinoma in a young patient, requires reconstruction. Multistage reconstructive procedures are many. Single stage reconstruction is performed using free tissue transfer and almost single stage reconstruction is performed by the alternative free flap (extracorporeal radial forearm flap) procedure.

**SCHEMATIC DRAWING OF EXTRACORPOREAL RADIAL FOREARM FLAP FOR PENILE RECONSTRUCTION**

(Fig. 3-36a, b)

Reconstructive requirements are:

1. Skin cover - 15 cm length x 11 cm width.
2. Lining of urethra - 15 cm length x 3 cm width.
3. Skeletal support - 15 cm length x 1 cm thickness.

An 11 cm wide skin cover will provide an organ of 3.5 cm diameter. 3 cm width of skin used for reconstruction of the neourethra will create a urethra of 1 cm diameter. At least 1 cm width of skin has to be left de-epithelised between the cover and the lining segment. Therefore, breakdown figures of the total width of the flap that is required are as follows:

- **Cover**: 11 cm
- **Lining**: 3 cm
- **De-epithelised segment**: 1 cm
- **Total size**: 15 cm

In effect, a flap of 15 cm x 15 cm is required. The average length of the volar aspect of the forearm is 25 cm and the average maximum circumference of the proximal forearm is 25 cm.

Therefore, after harvesting a flap of 15 cm x 15 cm width, it is possible to preserve a 10 cm long vascular stalk and leave about 10 cm width of skin over the ulna (Fig. 3-36).

The medial antebrachial nerve (medial cutaneous nerve of the forearm) is used for sensations, which is connected to the pudendal nerve in the perineum.

Assessment of the amount of fat under the skin should be made preoperatively. If too much of fat can be pinched under the forearm skin, the width of the flap should be increased accordingly, otherwise the skin tube will be in tension, since no fat, except at the margins, could be removed at this stage. This is a clinical
judgement and no rule of thumb is applicable for this measurement.

**FABRICATION**  
(Fig. 3-36, 37, 38e, f, g, h, i)

Fabrication of the penis is performed as a bench surgery on the forearm itself after raising the flap. As a first step, the neourethra is reconstructed by closing the inner skin tube over a 14 French gauge silicon coated Foley’s catheter with the skin side in, using vicryl stitches. No tension at this suture line is permissible; if need be, a smaller catheter should be used, but the tension-free suture line must be created.

The bone graft which has been harvested from the fibula (15 cm long and 2 cm thick) using an oscillating or pneumatic saw, is split into two long pieces, each about a centimetre thick. These bone grafts are placed on either side of the neourethra and the rest of the skin is tubed over this, as a double layer closure. Prolene is used for the skin and vicryl for the deeper layers. The suture line for the cover as well should be tension free. It will be possible only if the forearm skin does not contain too much fat. The vascular pedicle is wrapped in a sheet of split thickness skin graft. The donor area of the forearm is skin grafted. Now the fabricated penis is ready for the transfer.

**TRANSFER**  
(Fig. 3-37, 38j)

While penile fabrication is undertaken by one team, the other has prepared the ground for penile implantation. The recipient site is prepared for receiving the penis by creating a raw area around the urethral meatus in the amputated stump of the penis by raising a triangular flap from the suprapubic region.

The urethral opening is cut obliquely so that anastomotic stricture is avoided. Spaces on either side of the urethra, over the corpora cavernosum over the pelvic rims, are created. The pudendal nerve is identified and dissected to receive the medial antebrachial nerve of the forearm. If the pudendal nerve cannot be identified, then the ilioinguinal nerve in the inguinal canal is looked for, and used for nerve co-optation.

The hand is brought to the ipsilateral groin and that brings the prefabricated penis into the penile region for implantation.

The raw proximal end of the fabricated penis is held in position by one silk stitch in the suprapubic region, and first of all, the nerve co-optation is performed under loupe magnification. Now the bone grafts are inserted.
into the pockets created for them. The skin is approximated over the ventral aspect of the penis, in the perineum. Dorsal penile skin closure has to be performed after joining the urethra.

Now the neourethra of the fabricated penis is united to the residual stump of the urethra by vicryl stitches after inserting the rest of the catheter into the bladder. If possible, a double layer closure is performed. Skin closure at the dorsal side of the root of the penis in the lower part of the suprapubic region is now completed and that finishes the implantation of the fabricated penis.

The palm is placed over the groin, over a cotton pad, and strapped in that position, which completes the immobilisation. No other immobilisation is required; uneventful healing should follow for the next 3 weeks, at the end of which the vessels are excised after their trial clamping for 2-3 days. The ends are revised on either side. The catheter is left for another 10 days, at the end of which it could be removed and the patient should pass urine from the tip of the reconstructed penis. The patient is advised to defer intercourse for another 6 weeks.

He is instructed about the technique of using the organ for sexual purposes. Since active erection and stability is not a possibility, the penis has to be passively stabilised by holding it by hand for penetration and further action. An active participation of the female from above and relatively passive participation by the male from below is required.

The care of the donor forearm is taken as usual by compression garments for 3 months.

**CLINICAL EXAMPLE**

(Fig. 3-38)

A 20-year-old engineer sustained traumatic loss of the complete penis along with both the testes and scrotum in November 1989, when his clothes (lungi) were accidentally entangled in the strap of an electric motor of a water pump in the fields, where he was working. His immediate treatment at Dibrugarh Medical College in Assam consisted of implantation of one of the testes in the right groin. He was then referred to us three months later for definitive reconstruction.

On examination (Fig. 3-38a, b), he had total loss of the penis. A small opening of the amputated urethra was visible in the pubic region through which an in-dwelling catheter had been left for urinary drainage. A tender swelling of the implanted testis in the right groin was palpable.

Definitive reconstruction was performed by prefabrication of the penis, that consisted of reconstruction of the neourethra, a bone graft as penile stiffener, and the creation of a penis of decent shape and size on the left forearm, using a distally based radial forearm flap.

A radial forearm flap was raised, of 11 cm x 18 cm dimensions (Fig. 3-38c, d), proximally up to the flexion crease line of the elbow joint and distally about 8 cm from the wrist so as to allow an 8 cm long vascular pedicle. The ulnar non hair-bearing side of the flap (3 cm x 18 cm) size was used for the fabrication of the neourethra. A skin strip next to it, about 1 cm in width, was de-epithelized, so as to allow stitching of both the tubes (tube inside the tube).
As a first step, de-epithelization of the required skin segment was performed and then only was the flap raised (Fig. 3-38). Now by tubing the flap with the skin side in, around a 14 gauge Foley’s catheter, the neourethra was created (Fig. 3-38h). The vascular pedicle consisted of the radial artery, its venae comitantes, and the cephalic vein, for a distance of about 8 cm at the wrist, right down to the joint crease. Proximally, the medial antebrachial nerve was dissected and harvested with the flap for a distance of about 8 cm.

15 cm of the 5th rib was then split into four pieces and was placed around the reconstructed neourethra (Fig. 3-38h). The outer skin segment was now tubed to give the penis its final shape (Fig. 3-38i), leaving a suction drain between the inner and the outer tubes. The vascular pedicle was now wrapped in a sheet of split thickness skin graft. The donor area of the flap was skin grafted. To avoid retraction of the fabricated penis during healing, its proximal end was held in position next to the elbow joint crease line by a silk stitch.

After three weeks, when the fabricated penis was well healed, its transfer to the pubic region was executed by bringing the wrist next to the groin. An inset of the most proximal part of the penis was given after creating a raw area in the lower part of the suprapubic region by raising a superiorly based triangular flap (Fig. 3-38j).

The neourethra was stitched to the amputated urethral stump. The medial antebrachial nerve which was earlier buried between the inner and the outer skin tubes was drawn out from its storehouse to be attached to the internal pudendal nerve. However, in this patient, the internal pudendal nerve could not be identified and therefore could not be used.

The bone grafts were placed in the pockets created for them over the pubic ramus. The triangular skin flap was stitched to the anterior aspect of the root of the fabricated penis.

In three weeks’ time, the inset healed completely and the extracorporeal vascular pedicle was excised on the 21st day. Except for a small suture line, dehiscence of the neourethra, no significant postoperative complication developed. However, it required quite a bit of surgical jugglery later to close this fistula.

Six months later, at the follow-up clinic, it was learned that he could manage to have sexual intercourse, but of course, the other partner was required to provide more active participation. It was however noted that he had fractured the bone graft in the process.

SUGGESTED FURTHER READING:


**PREFABRICATED PENILE RECONSTRUCTION BY EXTRACORPOREAL RADIAL FOREARM FLAP**

Fig. 3-38a, b, c, d, e, f

- **a** - Posttraumatic amputation of total penis and avulsion of both testes.

- **b** - Posttraumatic amputation of total penis and avulsion of both testes. Catheter is seen coming out of the urethral stump.

- **c** - Two years postoperative result using extracorporeal radial forearm flap from the left forearm. Notice the scar of the left forearm is quite acceptable.

- **d** - Two years postoperative result using extracorporeal radial forearm flap from the left forearm. Notice the scar of the left forearm is quite acceptable.

- **e** - Design of the flap marked on the forearm.

- **f** - The flap has been raised and the neourethra constructed around a catheter that is seen passing through the neourethra.
PREFABRICATED PENILE RECONSTRUCTION BY EXTRACORPOREAL RADIAL FOREARM FLAP

Fig. 3-38g, h, i, j, k

j - Three weeks later inset of the prefabricated penis to the pubic region is given.

k - Two years postoperative picture of the donor forearm, acceptable aesthetically and fully functional.

h - Split rib grafts are placed on the undersurface of the flap around the neourethra and by the side of the radial vascular bundle.

RECONSTRUCTIONS IN THE UPPER EXTREMITY

DESIGN FOR TRIPOD HAND
(Fig. 3-39a, b)

Reconstruction of a tripod hand is required when trauma has created a metacarpal hand following amputation of all the fingers of the hand including the thumb. If complete thumb is absent as well, a metacarpal hand has no function at all.

Reconstruction of a radial and an ulnar component will provide pincer movement, and a weak grasp. An additional component between the two will provide grasp, and pinch (end to side and end to end). The third component is best placed at the site of the
middle finger. When three such components are reconstructed, it is known as a tripod hand.

Each component should be ideally mobile, sensitive and stable. Mobility without stability is ineffective while stability without mobility in one of the three components is unacceptable, since the other two mobile components can use the fixed component by pressing the objects against it. Sensitivity of those parts of the reconstructed tripod hand that come in contact while in use should be provided. These are commonly the tips of these components. Conventionally, in most plastic surgery units, these have been known as radial and ulnar ‘posts’.

The length of each such ‘post’ (component) is logically calculated from the observation that a thumb, which has a length up to the interphalangeal joint, is good enough for
function. That means a length of about 6 cm from the level of the palm is enough (when the reconstructed thumb is held perpendicular to the palm). The length of the other two posts is calculated, such that all three meet at the tips when closed together. In effect, the level of the metacarpal amputation will decide the length of the ulnar and the middle component. If the amputation is at the level of the metacarpal heads, much less than 6 cm length will be required of these two components to meet a 6 cm long thumb. The circumference of the thumb at the middle of the proximal phalanx is about 7 cm on average. The circumference of the rest of the posts can be calculated accordingly (Fig. 3-40).

Newer methods of reconstruction such as fasciocutaneous island flaps and free tissue transfer have added a new dimension of hope to such difficult problems.

**DESIGN AND PLANNING**
(Figs. 3-39, 40, 41, 42)

A distally based radial forearm island flap transferred with or without extracorporeal means can provide single stage reconstruction of a tripod hand.

The first web space, on average, is open to about 5 cm of skin width. In these reconstructions, a web space could be created more than 5 cm in width, to give effective grasp of larger objects to compensate for the loss of finger length (which provides grasp of large objects in a normal hand). A web space as wide as 7 cm should be aimed for. Adding all these skin patterns together, a 26 cm x 6 cm size skin flap is required for a single stage reconstruction of a tripod hand.

We know the average circumference of the proximal forearm is 25 cm. A flap as wide as 25 cm could therefore be raised. The length of the flap (6 cm) has to be placed longitudinally over the forearm so that after a 180 degree turn of the pedicle, the reconstructed posts sit in the desired direction longitudinally over the hand (Fig. 3-39a, b, 40). Since the length of the flap required is not much, a long vascular pedicle could be secured so as to attain maximum reach of the flap to the hand.

In cases of mid palm amputations, palmar loss needs reconstruction and therefore additional flap length is required accordingly. The vascular pedicle in these cases may not be long enough. If so, then the flap could be transferred extracorporeally by taking the vessels directly across the palm, and by flexing the wrist. This manoeuvre saves about 3 cm of vessel length. The vessels are wrapped in a sheet of split thickness skin graft to be sacrificed 4 weeks later.
CLINICAL EXAMPLE
(Fig. 3-41)

An 18-year-old boy sustained a crush avulsion of his right hand in a zinc sheet-making machine. All four fingers passed between two rollers (inter-roller distance was 1 cm) and were crushed beyond salvation (Fig. 3-41a, b). To salvage the skeleton and provide primary reconstruction, the loose and fragmented bone pieces were stabilised by interosseous wiring. The whole of the bony complex was then covered with a radial forearm flap of 20 cm x 14 cm on a retrograde flow (Fig. 3-41c).

The shortest distance for the flap to reach the fingers was across the palm. And there is never enough space under the palmar skin to be used as a tunnel, for the vascular pedicle to be accommodated without causing trouble. The pedicle was kept extracorporeally and was wrapped in a sheet of split-thickness skin graft (Fig. 3-41j). The postoperative course was uneventful, and the flap healed well in 3 weeks’ time, when the extracorporeal vessels were excised. Separation of the fingers was later undertaken in stages, and three good fingers could be created. The patient finally had reasonable pinch (Fig. 3-41k) and grasp in the reconstructed hand.

EXTRACORPOREAL RADIAL FOREARM FLAP FOR RECONSTRUCTION OF TRIPOD HAND
Fig. 3-41a, b, c, d, e, f, g, h, i, j, k

c - Schematic drawing to show the planning bones were assembled by pinning and were covered by a vascularized radial forearm flap, which had to be swung to 180 degrees to reach the fingers.

d - Flap swung to 180 degrees to reach the fingers placing the vessels across the palm, wrapped in skin graft.

a & b - Crush avulsion injury of right hand in a young male patient.
e - A large, distally based flap in the process of being raised on a 12 cm long radial vascular pedicle.

f - The extensor limit of the flap is seen as the lines of incision are drawn.

g - Flap swung to 180 degrees to reach the fingers placing the vessels across the palm, wrapped in skin graft.

h - Three weeks postoperative appearance of the flap, vessels and the donor forearm.

i - Appearance of the hand and that of the flap on the fifth day from the dorsal aspect.

j - Appearance of the vessels and the skin graft from the palmar aspect, on the fifth day.

k - Late postoperative result showing the ability to write.
SYMBIOTIC TISSUE TRANSFER
FOR RECONSTRUCTION OF
A TRIPOD HAND
(Fig. 3-42, 43, 44)

The concept of ‘symbiosis’ in reconstructive surgery was introduced by the author in 1991, and was used for a single stage reconstruction of a tripod hand following transmetacarpal amputation of the right hand in an 11-year-old child.

The term ‘symbiosis’ has been defined as “The biological association of two individuals depending on the advantages derived from the relationship”. It can also be defined as a “simultaneous transfer of two composite blocks of tissue in such a manner that both help each other for their survival” (Fig. 3-42). It was evolved and practised by the author since 1991, but was published much later.

The concept has helped to produce a three component hand (tripod hand), which is a three dimensional organ (three fingers), in a single operation (single stage procedure).

TECHNIQUE

A radial forearm flap that was transferred partially as extracorporeal was
used for reconstruction of the thumb. The terminal end of the vessels (radial artery and its venae comitantes) of the reconstructed thumb were used to supply and drain a composite second toe and the wrap-around great toe free transfer. The first tissue block (thumb) not only supplied arterial blood to the second tissue block, the great and the second toe, but also ascertained venous drainage to help the survival of the second tissue block. In return (to complete the theory of ‘symbiosis’) the second tissue block created a through-and-through venous drainage in the first tissue block and thereby it helped the first tissue block (Fig. 3-42, 44).

CLINICAL EXAMPLE
(Fig. 3-44)

A 13-year-old boy sustained a transmetacarpal amputation and lost all the fingers of the right hand including the thumb, while working on an electrical hay chopper (Fig. 3-44a, b).

On 5th February, 1991, the great toe skin-nail wrap around the flap and the complete adjacent second toe were harvested from the right foot, based on the dorsalis pedis artery, the great saphenous vein and the common plantar digital nerve (Fig. 3-44e, g). Simultaneously, the other team raised a distally based radial forearm flap, measuring 10 cm x 5 cm (Fig. 3-44f).

The distally based radial forearm flap was so designed that the radial artery travelled longitudinally through the centre of the flap. The radial artery and its venae comitantes were additionally dissected, isolated and procured, proximal to the flap, for a distance of about 8 cm so as to provide extra length of these vessels for anastomosis. The medial antebrachial nerve was harvested proximally to a similar distance.

Assembly of the two composite tissue blocks began by osteosynthesis of the bone grafts for the thumb and wrap-around transfer for the digit fixed on the fourth metacarpal (Fig. 3-44g, j, l). The second metacarpal from the same hand, which was lying superfluous, was utilised as a bone graft. Additionally, it had the effect of deepening the first web.

The radial flap was swung to 180 degrees to reach and cover the bone graft for the thumb. The flap was wrapped around the bone graft. The terminal end of the radial vascular bundle, which was harvested for extra length from the proximal forearm, was brought over the dorsum of the hand for anastomosis. The medial antebrachial nerve was however left on the palmar side for co-optation with the common digital nerve of the thumb. The great toe segmental skin-nail flap was wrapped around the bone graft for the third digit of the tripod hand. Interosseous wiring and the ‘K’ wire fixations were used for osteosynthesis. The second toe was now fixed to the fifth metacarpal and the joint capsule was repaired. The extensor tendon of the second toe was then connected to the extensor tendon of the little finger (Fig. 3-44j, l).

Microvascular anastomosis was now performed, over the dorsum of the hand between the terminal end of the radial artery and the dorsalis pedis artery (end to end). The great saphenous vein was anastomosed, end to end, to one of the venae comitantes of the radial artery (Fig. 3-43b). A sheet of split thickness skin graft covered the vascular pedicle that was lying exposed.

The postoperative course was uneventful, except for marginal loss of the pulp of the wrap-around transfer. All healed well in 2 weeks’ time. No donor area morbidity was observed at one year (Fig. 3-44n).
Nerve co-optation for the thumb and two digits was performed three months later, along with the flexor tendon repair. 'K' wires were removed 3 weeks later. Good bony union was visible at 8 weeks.

Physiotherapy before the tendon repair was instituted in the form of passive mobilisation of the joints of 2nd toe transfer and after the repair in the form of active physiotherapy.

Nine months later, in the review clinic, he was found to have satisfactory pinch (Fig. 3-44c) and grasp (Fig. 3-44d) in the reconstructed hand. He also, by this time, recovered fairly satisfactory sensations in the transferred toes.
**SYMBIOTIC TISSUE TRANSFER FOR SINGLE STAGE RECONSTRUCTION OF TRIPOD HAND**

**Fig. 3-44e, f, g, h**

**e** - Partial great toe and total second toe harvested to be used for symbiotic tissue transfer.

**f** - A distally based radial forearm flap while being raised. Notice the length of the vessels proximal to the flap that are being harvested with some extra perivascular fat so that they could be skin grafted without getting exposed to trauma.

**g** - Tissue harvested and the donor area on the foot closed.

**h** - Donor foot after the closure of the wound. The medial skin toe flag is used to cover the bare bone end of the great toe. The rest of the raw area on the great toe is skin grafted.
SYMBIOTIC TISSUE TRANSFER FOR SINGLE STAGE RECONSTRUCTION OF TRIPOD HAND

Fig. 3-44i, j, k, l, m, n

**Tissue After The Assembly**

1. Schematic drawing of the plan of tissue assembly.
   - A = Anastomosis, R = Radial component (thumb),
   - G = Reconstructed finger using great toe,
   - S = Reconstructed fifth finger using second toe

**Plan For Tissue Assembly**

2. Schematic drawing of the plan and the stages of tissue assembly.

**j** - Tissue assembly completed according to the plan shown in Fig. 1 and a thumb and two digits have been reconstructed seen from the Palmar aspect.

**l** - Immediate postoperative result seen from dorsal aspect, the raw area left is of the fat around the vessels that were skin grafted.

**m** - Donor foot from the plantar aspect - rather a large first web space, but still useful to wear Hawai chappals (slippers).

**n** - One year postoperative donor foot can take full weight and has identical web spaces on both sides to be useful to wear slippers in the village surroundings.
DESIGN FOR THUMB RECONSTRUCTION

Reconstruction of the thumb requires a sensate flap of 9 cm x 9 cm size covering a bone graft of 1 cm x 5 cm size. The radial forearm flap readily provides this with or without including the radius as a vascularized bone graft. The medial antebrachial nerve is used to provide sensations. The pedicle could be buried or transferred extracorporeally according to the situation.

The radius (1/3 to 1/2 of its circumference) is harvested from an area where fibres of the flexor hallucis longus take origin. This area is caudal to the insertion of the pronator teres muscle and that is used as a landmark for identification.
**CLINICAL EXAMPLES**

**Case 1** (Fig. 3-47a, b, c, d)

A 40-year-old male farmer sustained bilateral amputation of the thumb while working on a hay chopper (Toka machine) in the fields. The right thumb was amputated just proximal to the metacarpophalangeal joint (Fig. 3-47a, c), and the left at the MCP joint level. A distally based radial forearm flap was used to reconstruct the right thumb (Fig. 3-47a, b, c, d) using an iliac crest bone graft for skeletal support. The flap healed in 3 weeks’ time and a satisfactory pinch (Fig. 3-47lb) and grasp (Fig. 3-47ld) was restored.
Case 2 (Fig. 3-47Ila, b, c)

This 40-year-old man lost his right thumb in an industrial accident two years prior to our first consultation. Reconstruction of the thumb was undertaken using a radial forearm flap with a design shown in Fig. 3-47Ila, b, on a 12 cm long vascular pedicle. The pedicle was buried in a partially open tunnel, which means it was not kept completely extracorporeal and only the outer exposed surface (not the whole surface of the pedicle) was skin grafted.

Bone grafting was planned as a second stage procedure to be done once the flap survived in toto and healed well. At this stage, only an acrylic spacer that was prefabricated to the shape of the distal phalanx was kept in place of the bone graft as a temporary spacer.

The flap healed well, and after three months, the spacer was replaced by an iliac crest bone graft. The patient regained end to side pinch, the ability to write, and to grasp and hold objects.

RESURFACING THE FIRST WEB SPACE AND THUMB
(Fig. 3-45, 46, 48)

The first web space appears small, but its total loss requires a fairly large amount of skin for reconstruction. Loss of the web space in conjunction with the thumb or index finger requires additionally much larger skin flaps for reconstruction.

A diamond-shaped flap, with a 6 cm diagonal, is required for the web space. A functional thumb has to be at least 6 cm long from the metacarpophalangeal joint. The circumferential skin requirement is 7 to 8 cm. The thumb and web space patterns have to be joined in continuity. The pattern for such a flap is shown in Fig. 3-46.
CLINICAL EXAMPLE
(Fig. 3-48)

A 20-year-old man, while working on a printing press, sustained a crush injury of the right thumb, index finger, and first web space, and was presented to us 18 months after the trauma (Fig. 3-48a). Reconstruction required resurfacing of part of the dorsum of the hand, the thumb, and the first web space.

It was performed using a radial forearm flap of 12 cm x 14 cm, of a neurosensory nature (Fig. 3-48d, h). An iliac crest bone graft provided skeletal support for the thumb. The postoperative course was uneventful, and a satisfactory pinch and grasp was recovered in the hand 3 months after the reconstruction (Fig. 3-48b, c).

EXTRACORPOREAL RADIAL FOREARM FLAP FOR THUMB AND FIRST WEB SPACE RECONSTRUCTION
Fig. 3-48a, b, c, d

- Posttraumatic loss of the thumb, index, middle and distal part of the ring finger along with contracture of the first web space following a printing press injury.
- Late postoperative result showing pinch and the ability to write.
- Late postoperative result showing grasp.
- Preoperative planning: expected size and shape of the flap is marked over the forearm in accordance with the length of the vessels required. (The size of the defect that will be recreated is anticipated and marked on the contralateral hand.)

Dr. Anshul and Dr. Ashok Govila
EXTRACORPOREAL RADIAL FOREARM FLAP FOR THUMB AND FIRST WEB SPACE RECONSTRUCTION.

Fig. 3-48e, f, g, h, i, j

e - All the scar tissue is excised and the first web space is recreated.

h - Flap seen from the dorsal aspect on completion of surgery to have reconstructed the thumb and the first web space.

f - A lint cloth is cut to the size of the defect.

i - Appearance of the flap on the 5th day, dorsal aspect.

g - A skin incision is made to cut out the island. The flap is swung to 160 degrees and stitched in position.

j - Appearance of the flap on the 5th day, volar aspect.
EXTRACORPOREAL RADIAL FOREARM FLAP FOR THUMB AND FIRST WEB SPACE RECONSTRUCTION.

Fig. 3-48k, l, m, n, o

k - Appearance of thumb on the operation table seen from the volar aspect.

l - Two weeks postoperative result showing grasp and a healed flap, and the donor forearm.

m - Two weeks postoperative result of reconstructed thumb and the donor forearm.

n - Two years postoperative result showing grasp.

o - Two years postoperative result showing pinch and the ability to write.
SALVAGE REPLANTATION

CLINICAL EXAMPLE
(Fig. 3-49)

A 21-year-old male patient sustained amputation of the index finger on 21st March 1987 at 3 p.m., following a road-side accident. His index finger was caught by some moving object and was forcibly pulled out of the patient's hand, causing avulsion of the index finger and the flexor tendons (profundus and sublimis). The tendons were avulsed right up to the flexor muscle bellies (Fig. 3-49a, b). He was brought to us 24 hours later, along with an unpreserved amputated index finger (at the level of the middle of the proximal phalanx).

This individual finger injury had no indication for immediate or late reconstruction but he was a skilled and educated man, working as a stenographer, and insisted on a replantation, if possible, by some means.

A ‘salvage replantation’, if this is a proper term, was performed 30 hours after the trauma in a very unconventional manner. It is hard to coin a term for this procedure, therefore we have called it ‘salvage replantation’. Until a better term is coined, we shall keep it in our descriptions.

The amputated index finger was skeletonized in a manner that skin, nail, fat and fibro-fatty septae from the finger were removed. All the joints, tendons (flexor and extensor), fibrous flexor sheath, ligaments and the joint capsule were left intact (Fig. 3-49c). The preserved skeleton and the soft tissue over it were reattached by interosseous wiring. Extensor tendon repair was performed. Flexor tendon repair between the profundus of the amputated finger and the profundus (end to side) of the middle finger in the palm was performed. The entire skeletal framework was then covered all around by a radial forearm flap of 7 cm x 7 cm size, borrowed from the proximal forearm, on a 10 cm long vascular pedicle (Fig. 3-49d). The vascular pedicle was taken across the dorsum of the hand in a partially exposed manner. The outer surface of the vessels was skin grafted. The deeper surface was left in contact with the bed created for it on the dorsum of the hand.

This vascularized tissue transfer added vascularity to the bony, cartilaginous and ligamentous structures of the amputated finger that has been used in effect like a composite graft. A Technichium-99 scan performed 72 hours after the reconstruction depicted uptake, in the reattached skeleton, proving its vascularity and survival.

The postoperative course was uneventful and the complete flap and the finger survived. Immobilisation by a thin plaster finger slab was initially instituted for 6 weeks when healing at the site of bony fixation was faintly visible on X-rays. In another 4 week period, the bony union was complete and, gradually, active and passive physiotherapy to the proximal interphalangeal joint and the distal interphalangeal joint was instituted. Movement in both these joints could be regained, but only up to 30 degrees. Since the metacarpophalangeal joint was mobile anyway, the function to this finger was restored significantly and the patient went back to his work (Fig. 3-49f, g).
'Salvage replantation' of index finger using extracorporeal radial forearm flap

Fig. 3-49a, b, c

a - Avulsion injury of the right index finger following forceful traction on a machine, in a young skilled worker, who desperately needs the index finger for this job.

b - Amputated right index finger following avulsion by a machine.

c - Skeletonized index finger - all soft tissue up to the level of tendons, joint and ligaments were removed surgically. It was established in position and wrapped in a radial forearm flap.
'Salvage replantation' of index finger using extracorporeal radial forearm flap.

Fig. 3-49d, e, f, g, h

**d** - A distally based radial forearm flap on 12 cm long vessels was raised.

**e** - Two months later, the bony union is visible. Fixation is well maintained.

**f** - Three months postoperative result showing the ability to write.

**g** - Three months postoperative result showing grasp.

**h** - Three months postoperative result.
RADIAL FOREARM FASCIA–FAT FLAP FOR RESURFACING HAND DEFECTS

The extensive and deep soft tissue defects of the hand are treated by free tissue transfer in a microsurgical unit. Conventional plastic surgery units have to transfer distant flaps through staged procedures. A distally based radial forearm flap is a good choice for such units. However, in young female patients it may leave a scarred and grafted donor area. In such patients, a fascia-fat flap, which leaves no grafted area on the forearm, is a viable proposition.

We have used as large as 15 cm x 20 cm size fascia-fat flaps and as small as 10 cm x 10 cm size flaps for a variety of problems including ear reconstruction and for filling contour defects of the face.

CLINICAL EXAMPLE
(Fig. 3-50)

A 26-year-old female, a known epileptic patient, sustained fourth degree burns of the right hand following an epileptic attack in March 1989. Treatment at the village hospital consisted of dressings. Seven months later in November 1989, she was brought to us when she had already developed syngactyly of all the four fingers, extensive and severe scarring of the entire dorsal aspect of the hand, with an area of ulceration (5cm x 9 cm) and exposed middle and proximal phalanx of the index finger (Fig. 3-50a). On the 10th of November, 1989 all the hypertrophic scar and unstable area (10 cm x 20 cm) was excised and covered by a similar sized distally based fascia-fat radial forearm flap. The vascular pedicle and the flap were covered by a split thickness skin graft. After one supplementary grafting, the entire area healed in the next 4 weeks’ time (Fig. 3-50b, c). The fingers were later separated, and a useful function was regained. As a bonus, the forearm remained relatively unscarred (Fig. 3-50d).

RADIAL FOREARM FASCIA–FAT FLAP FOR RESURFACING THE HAND

a - Epileptic burn of right hand exposing most of the bones and joints on the dorsal aspect of index and middle fingers.
b - Two months postoperative result using radial forearm fascia-fat flap. Fingers were separated later.
c - Radial forearm fascia-fat flap was used to cover the entire dorsal aspect of the hand, after creating a surgical syngactyly. A thin sheet of split thickness skin graft covered the flap. It looks swollen and oedematous, very much like a free flap, even at 4 weeks.
RADIAL FOREARM FLAP FOR DEFECTS AROUND THE ELBOW

Defects around the elbow requiring flap coverage up to 20 cm x 15 cm are best treated by a proximally based radial forearm flap with or without keeping the pedicle extracorporeally. The limb need not be attached anywhere for transfer, and there is no risk of total failure as with free flaps.

CLINICAL EXAMPLE
(Fig. 3-51)

A 25-year-old male patient was presented to us one month after sustaining electrical burns over the medial side of the left elbow (Fig. 3-51). He was presented with necrotic medial epicondyle of the humerus along with the muscles attached to it. The elbow joint was exposed and surrounding this slough there was a granulating wound of about 10 cm x 15 cm size. The ulnar nerve had been sloughed off earlier.

After excision of all necrotic muscles and the medial epicondyle, the ulnar nerve defect (10 cm) was bridged by a microneural interfascicular sural nerve graft. The wound was then covered by an 18 cm x 10 cm radial forearm flap. The vascular pedicle was skin grafted. In two weeks' time, the flap and its donor area healed (Fig. 3-51b, c, d). Gradual active and passive physiotherapy resulted in complete extension (Fig. 3-51c) and flexion (Fig. 3-51d) of the elbow joint in 6 weeks' time. When the patient was seen 2 years later, he had full function of the elbow joint and there were no sensory or motor signs of ulnar nerve loss.
ULNAR FOREARM FLAP

The ulnar side of the forearm skin is relatively hairless and thin. A limited amount of skin, as an island fasciocutaneous flap, could be raised, based proximally or distally, if the radial artery and the palmar arches are intact. It is raised on the same principle as the radial forearm flap.

ANATOMY
(Fig. 4-1, 2)

The flap is supplied by the perforators of the ulnar artery and is drained by its venae comitantes. Additionally, it is drained by the basilic vein, which runs in the lateral part of the flap. The medial cutaneous nerve of the forearm that runs along with the basilic vein, when included with the flap, adds a neurosensory potential to the flap.

Part of the ulna could be harvested with the flap, to provide skeletal support and to create an oseofasciocutaneous flap. The flexor carpi ulnaris could also be raised with...
the flap to be transferred as an active motor unit transfer. In this case, the motor nerve to the muscle is harvested by splitting it off from the ulnar nerve.

It is much smaller in size than the radial forearm flap. The boundaries of this flap on the ulnar side include the palpable edge of the ulna and on the radial side a line drawn on the hairless and hairy part of the skin of the forearm. The proximal limit is marked by a line drawn between the two epicondyles. The distal limit depends upon the requirement of the defect.

**ARTERIAL ANATOMY**
(Fig. 2-2, 2-3a, b, 2-4b, 2-5)

The ulnar artery is a continuation of the brachial artery, arising at the bifurcation of the brachial artery into radial and ulnar artery in the cubital fossa at the level of the coronoid process of the ulnar approximately at the level of the head of the radius. Soon after its origin, the ulnar artery dips deep and medially (unwards) to run near the medial border of the forearm in the plane between flexor digitorum superficialis and flexor carpi ulnaris. In this plane, the artery runs towards the wrist and in the distal third of the forearm, the tendons of flexor digitorum superficialis are radial to it while the tendon of flexor carpi ulnaris is ulnar to it (perforators from the artery to the skin surface superficially between these two muscle bellies via a flimsy septum). The ulnar nerve and two venae comitantes run with the ulnar artery in its entire course. The basilic vein that begins at the dorsal aspect of the proximal part of the dorsum of the hand gradually ascends towards the wrist and in the proximal forearm it moves to the volar aspect of the forearm to run over its medial border.

There are two major branches that arise from the artery within the first inch of its origin and they should, if possible, be saved and preserved while raising this flap. They are the ulnar recurrent artery and the common interosseous artery. The ulnar recurrent artery arises from the medial side of the ulnar artery, while the common interosseous artery arises from the radial side to run towards the midline of the forearm. It divides into the anterior and posterior interosseous arteries soon after its origin to run over the anterior and posterior aspects of the interosseous membrane.

Additionally, there are several muscular branches that arise from the artery all along its course and supply the adjacent muscles in the forearm.

**FLAP ELEVATION**
(Fig. 4-3b, c, d, e, f)

Having marked the vascular axis (ulnar artery) of the flap, the desired skin pattern is placed over the forearm in a manner that at least 6 cm of vascular pedicle is available, and the vessels run in the centre of the flap.

Under a venous tourniquet, the course of the basilic vein is marked. The vein can easily be included in the flap and will always help the venous drainage, especially in distally based island flaps.

The skin pattern is marked (Fig. 4-3c, d) and cut all around, down to the deep fascia, which is stitched to the skin by catgut stitches. While cutting the skin, an attempt is made not to touch or distract the skin of the flap. If need be, the skin surrounding the flap could be distracted.
The vascular pedicle is dissected through a straight-line incision over the artery in the distal forearm. The basilic vein that appears soon after the skin incision is traced distally. The ulnar vascular bundle along with the ulnar nerve is identified close to the wrist, lying between the flexor carpi ulnaris medially and tendons of the flexor digitorum superficialis radially. It is now traced proximally towards the distal limit of the skin flap.

Dissection of the skin island is carried from the medial and lateral aspects towards the septum that needs to be created by preserving all the fibro-fatty tissue between the muscle bellies of flexor carpi ulnaris and flexor digitorum superficialis, that contains perforators to the skin from the artery.

The dissection of the vessels, once again from the distal to the proximal, but this time under the skin flap, to create the septum, begins by retracting the muscle bellies apart. Muscular perforators that may be seen supplying the muscles around the artery, medially, laterally, and posteriorly, are coagulated. The vessels are gradually separated from all around, keeping the septum and the skin island in continuity with the artery (Fig. 4-3c). Both venae comitantes are included with the vascular pedicle by keeping the dissection around them. The ulnar nerve is separated from the artery all along its course. Once the dissection reaches the most proximal limit of the flap, the ulnar artery along with its veins is ligated distal to its two main branches, that is the common interosseous artery and the ulnar recurrent artery.

Now the flap is attached only to its vascular pedicle, that has been dissected up to the wrist joint crease.

As with the other extracorporeal flaps, the pedicle is now wrapped in a sheet of split thickness skin graft and held in position by a few catgut stitches (Fig. 4-3b, f).

**IMMOBILISATION**

(Fig. 3-7)

The limb is now taken to the defect and kept in the most convenient position that has already been rehearsed and discussed with the patients before surgery (Fig. 3-7). While the assistant holds the limb, the inset to the flap is given, commonly on head and neck defects, which is almost 100 percent. The only area where the inset cannot be completed is the area of entry of the vessels in the flap.

The limb is now fixed in this position by elastoplast fixation. Alternatively, a Plaster of Paris head cap is used, which is attached to the Plaster of Paris cast over the palm and wrist, keeping the thumb and fingers open for active mobilisation. Plaster of Paris fixation is better and more secure.

**FLAP DETACHMENT**

On the 7th day, a weak plastic clamp, designed for this purpose, is applied to the vessels that are hanging outside the body (that is why the term ‘extracorporeal’ is used). It is tightened every day, until the 10th day after the first inset. On the 10th day, the clamp is removed and two thick silk ligatures are tightened on either side of the compressed zone of the vessels, and a knife is run dividing the vessels at the zone of necrosis, and the limb is separated. This is performed in the dressing room without any kind of local or general anaesthesia. Either end of the vessels (at the recipient area and at the wrist) are revised, under local anaesthesia, on the next operation day.
Active and passive physiotherapy to the hand is now instituted. It takes 6 weeks to regain full power and movement on all the joints of the hand and the elbow joint.

**COMPRESSION**

Compression over the transferred flap and on the donor area on the forearm is an integral part of the overall management of the patient. This is highly applicable to all Orientals for several reasons. One, the suture line of the flap either tends to hypertrophy or stretch. Sometimes, it may even end up in an inverted depressed scar. All these are avoided by using compression garments that are really tight. Two, excessive bulk in the flap gradually disappears and a nice contour and shape is taken by the transferred flap. Three, it prevents graft contraction and allows early softening of the grafted area, on the donor forearm. Final colour and appearance is also better with compression than without.

**DESIGNING OF THE ULNAR FOREARM FLAP**

Compared to the radial forearm flap, it is a much smaller flap in dimension. There are constraints with regard to its size. Variations in designing that go with the radial forearm flap are not possible with this flap. It is about 10 cm x 10 cm in size, and is useful for the defects within this size, when tissue expanders are not available or are not economical.

**CLINICAL EXAMPLE**

(Fig. 4-3a, b, c, d, e, f)

A 20-year-old young man was presented to us following an industrial accident when he lost the skin and tendons over the extensor aspect of the right index finger, exposing PIP and MP joints (Fig. 4-3a). A flap cover was mandatory. The extracorporeal ulnar forearm flap was transferred to cover the defect. Since the vascular pedicle was fairly long, 15 cm in this situation (Fig. 4-3c), we decided not to bury the vessels in a subcutaneous tunnel where they may find some compression and compromised conditions. Instead, the vessels were kept extracorporeally. Except for some superficial necrosis, the flap survived and served the purpose.
b - Ulnar forearm flap in position. Notice the length of the vascular pedicle that has been wrapped with skin graft.

c - Preoperative planning of the flap.

d - Flap markings during surgery.

e - Flap raised. Notice the long vascular pedicle.

b1 - Resurfacing the defect using ulnar forearm flap transferred extracorporeally, across the dorsum of the hand.

f - After the debridement, the ulnar forearm flap has been raised and the vessels to the flap are wrapped in a sheet of skin graft. Notice the reach of the flap up to the recipient area.
CHAPTER 5
FLAPS IN THE LEG

FLAPS IN THE LEG

Using the radial and ulnar forearm flaps, we have managed to cover defects from the head and neck down to the knee joint. Defects below the knee joints are very well covered by island flaps like the anterior tibial flap, posterior tibial flap, peroneal flap, sural artery flap and dorsalis pedis flap from the contralateral limb, transferred extracorporeally, when the required amount of tissues are not available on the traumatised limb.

The following flaps will therefore be discussed:
1. Anterior tibial flap
2. Dorsalis pedis flap
3. Posterior tibial flap
4. Peroneal flap
5. Sural artery flap

It would not be out of place if anatomical arrangements of the leg in general are described here before individual flaps are dealt with.

SURGICAL ANATOMY
OF THE LEG

The leg has been divided into three osteofascial compartments by two bones and two fascial septae of deep fascia, that attach at one end to the bone and at the other to the deep fascia. These are the anterior, posterior and the lateral (peroneal) compartments (Fig. 5-1).

The anterior compartment contains (Fig. 5-1):
1. Tibialis anterior muscle
2. Extensor hallucis longus muscle
3. Extensor digitorum longus muscle

The lateral (peroneal) compartment contains only two (not three) muscles (Fig. 5-1). They are:
1. Peroneus longus
2. Peroneus brevis

The posterior compartment contains (Fig. 5-1):
1. Tibialis posterior muscle
2. Flexor hallucis longus muscle
3. Flexor digitorum longus muscle
4. Soleus muscle
5. Gastrocnemius muscle
6. Plantaris tendon.

The posterior compartment is subdivided into three such compartments by two strong fascial septae. The anterior of these two septae separates the tibialis posterior muscle from the rest of the muscles in the posterior leg. In effect, the tibialis posterior muscle is placed in a very tight, osteofascial envelope being surrounded by bones on either side, interosseous membrane anteriorly and a fascial septum posteriorly.

The posterior of these two septae separates the flexors of the toes and the great toe and from the soleus and gastrocnemius muscles (Fig. 5-1).

1. The posterior septum also envelops the posterior tibial vessels and thus separates these vessels from the soleus and gastrocnemius muscles.

2. The tibial nerve accompanies the posterior tibial vessels.
3. The anterior tibial vessels are accompanied by the deep peroneal nerve and run close to the lateral surface of the tibialis anterior muscle in the anterior compartment on the anterior surface of the interosseous membrane.

4. The superficial peroneal nerve in company with the peroneal artery runs close to the medial surface of the fibula.

The anatomy of the following structures should be known to a plastic surgeon.

The leg has three main arteries, namely:
1. Anterior tibial artery (continues as dorsalis pedis artery in the foot)
2. Posterior tibial artery
3. Peroneal artery

The leg has two main superficial veins, namely:
1. Great saphenous vein
2. Short saphenous vein

The leg has five main nerves, namely:
1. Tibial nerve
2. Deep peroneal nerve
3. Superficial peroneal nerve
4. Saphenous nerve
5. Sural nerve
ARTERIES OF THE LEG

ANTERIOR TIBIAL ARTERY

(Fig. 5-2, 3)

The popliteal artery divides into anterior and posterior tibial arteries at the distal border of the popliteus muscle (at the lower end of the popliteal fossa, Fig. 5-3). The posterior tibial artery, the larger of the two, is straight in line with the main trunk while the anterior tibial artery arises as a side branch and takes a lateral direction.

Having taken origin roughly opposite the tibial tuberosity, the anterior tibial artery leaves the posterior aspect of the leg to appear anteriorly, through a hiatus in the uppermost part of the interosseous membrane (Fig. 5-2).

On the skin surface, its course could be marked in the following manner: A point is marked midway between the tibial tuberosity and the head of the fibula. Another point is marked midway between the medial and lateral malleoli. Connecting both these points with a line marks the course of the vessel in the leg.

While entering from the posterior to the anterior aspect of the leg, it is close to the medial surface of the neck of the fibula. It then runs on the anterior surface of the interosseous membrane, lateral to the tibialis anterior muscle. The extensor digitorum longus is lateral to the vessel in the upper part and medial to the vessel in the lower part of the leg (Fig. 5-2).

The deep peroneal nerve, throughout its course, accompanies the artery.

It gives several unnamed branches to the muscles around it, roughly 20-30 in number, all along its course. Several of these branches travel towards the skin either through the muscle fibres of the tibialis anterior muscle or
through the anterior peroneal septum that separates the tibialis anterior from the peroneal muscles.

Skin on the anterio-lateral aspect of the upper and middle third of the leg is supplied by these branches. At the level of the ankle joint, it terminates and its continuation in the foot is termed as the dorsalis pedis artery.

**DORSALIS PEDIS ARTERY**

It is the continuation of the anterior tibial artery, beginning at the level of the ankle joint and terminating at the most proximal part of the first interosseous space.

The deep peroneal nerve, which runs with the anterior tibial artery, continues to run with this artery.

At its termination, it forms an arcade, which is vertically placed in the most proximal part of the first inter metatarsal space of the foot. This arcade is created by the formation of a ‘U’ loop between the dorsalis pedis artery from the dorsum and the lateral plantar artery from the plantar aspect of the foot. It is this arcade that gives origin to the first dorsal and the first plantar metatarsal artery. This arcade has not been named by the anatomists or the surgeons.

In the foot, the artery runs directly over the periosteum of the small bones of the foot.

From the proximal to the distal, it runs over the distal part of the talus, navicular and medial cuneiform bones, before dipping into the first interosseous space. Throughout its course, the artery is lateral to the tendon of extensor hallucis longus. However, the distal part of the tendon is relatively anterior to the artery.

The muscle belly of extensor hallucis brevis, which is palpable on the lateral side of the proximal part of the dorsum of the foot, just below the lateral malleolus, lies between some of the branches (lateral tarsal branch) of the dorsalis pedis artery and the skin.

**POSTERIOR TIBIAL ARTERY**

This is the larger of the two terminal divisions of the popliteal artery; in fact, it is the direct continuation of the main trunk and runs as a straight line downwards. It begins at the distal border of the popliteus muscle and ends between the lower part of the medial condyle and tendoachillies by dividing into medial and lateral plantar arteries (Fig. 5-3).

Soon after its origin, it takes a little deep course and runs in company with the tibial nerve, in the septum that separates the tibialis posterior muscle from the rest of the muscles in the calf.

The artery descends on the posterior surface of the leg, posterior to the tibialis posterior muscle and anterior to the soleus muscle. The flexor digitorum longus is posterior-lateral to the artery.

At the level of the medial malleolus, the artery is separated from the posterior surface of the medial malleolus by the tendon of the tibialis posterior and flexor digitorum longus muscle (Fig. 5-3). Here it lies on the deep layer of the flexor retinaculum, which separates the artery from the muscle fibres of the belly of the flexor hallucis longus. The muscle fibres of the belly of flexor hallucis longus reach almost as low as tendoachillies.
The artery gives the following branches (Fig. 5-3):

- **Peroneal artery** (largest branch)
- **Circumflex fibular artery**
- **Nutrient artery** (of tibia, fairly large in size)
- **Muscular branches at every 2 cm**
- **Medial calcanean branches**

**PERONEAL ARTERY**

(Fig. 5-3)

It is the largest branch of the posterior tibial artery about 2-4 mm in diameter and arises from about 2 cm below the commencement of the posterior tibial artery. It then runs obliquely downwards and laterally under cover of the soleus, to reach the posterior-medial surface of the fibula, where it runs anterior to the flexor hallucis longus and posterior to the tibialis posterior muscle, between the two layers of septum. Sometimes, it may run within the muscle belly of the flexor hallucis longus.

It passes medial to the peroneal tendons at the level of the ankle joint before ending in a bunch of lateral calcanean branches.

Along its course, it gives the following branches:

1. **Nutrient artery to the fibula**
   (in the middle third of the bone)
2. **Cutaneous perforating branches**
   (2-6 in number)
3. **Lateral malleolar branches**
4. **The communicating branch**
   (to communicate with a branch from the posterior tibial artery)
5. **Calcaneal branches**

The cutaneous perforating branches (2-6 in number) travel in the posterior peroneal septum to come to the surface and supply the skin over the central third of the fibula. Some of these branches also reach the skin through the muscle fibres of the flexor hallucis longus and the soleus muscles.
VEINS IN THE LEG

GREAT SAPHEROUS VEIN
(Fig. 5-4, 5, 6)

This is the longest vein in the body. It is formed on the medial side of the foot by the union of the medial end of the dorsal venous arch on the dorsum of the foot and the medial digital vein of the great toe. It ascends in front of the medial malleolus and then runs upwards along the medial border of the tibia. At the level just below the knee, it takes a posterior course to run posterior to the condyles of the knee joint. Here it is covered by a sleeve of fascia that separates it from the rest of the superficial veins in the leg. It then passes upwards, taking an anterior-lateral course over the thigh to reach the saphenous opening, where it pierces the cruriform fascia and the femoral sheath to terminate in the femoral vein.
It not only receives several contributions from superficial veins but also from the deep veins in the leg that reach it by piercing the deep fascia. The vein is full of valves and, therefore, it is not preferred by the plastic surgeons as a vein graft. Its counterpart, the short saphenous vein, which is valveless, is preferred as a vein graft.

**SMALL SAPHENOUS VEIN**
(Fig. 5-5)

It is formed on the lateral side of the foot by the union of the lateral end of the dorsal venous arch and the lateral dorsal digital vein of the little toe. It runs posteriorly below the lateral malleolus and then follows the curve of
medial malleolus to reach behind it. At this level, it runs between the medial malleolus and tendoachilles, in close proximity to the sural nerve. In fact, both are adherent to each other and have to be separated for harvesting them as a graft.

It ascends upwards to reach the midline of the leg at the middle of the leg and continues a straight course upwards up to the lower end of the popliteal fossa where it pierces the popliteal fascia to terminate in the popliteal vein.

Two saphenous veins are connected together by several connecting veins of large calibre. The small saphenous vein has much fewer valves, better wall thickness and smoother intima and, therefore, is preferred over the great saphenous vein as a vein graft by plastic and microvascular surgeons.

NERVES IN THE LEG

The following nerves will be detailed for our purpose:

1. Tibial nerve
2. Deep peroneal nerve
3. Superficial peroneal nerve
4. Saphenous nerve
5. Sural nerve

TIBIAL NERVE
(L4, 005; SI, 2, 3)

The sciatic nerve divides into tibial and common peroneal nerves at the level of mid-thigh. The proximity of the sciatic nerve to the femur is the cause of 'sleeping foot'. The tibial nerve is the larger of the two. It runs down in the middle of the popliteal fossa in close proximity to the popliteal vessels, crossing from lateral to medial, as it descends.

It supplies muscular branches to the gastrocnemius, soleus, popliteus and plantaris muscles.

The sural nerve is the largest cutaneous branch of this nerve, which arises around the middle of the popliteal fossa.

DEEP PERONEAL NERVE
(L4, 5; SI, 2)

The common peroneal nerve is the smaller of the two divisions of the sciatic nerve and takes origin at the level of mid-thigh. It divides into the deep and superficial peroneal nerves, at the lateral side of the neck of the fibula, where it could be rolled under the fingertips.

The deep peroneal nerve runs around the neck of the fibula, and takes an anterior course to follow the anterior tibial artery over the anterior surface of the interosseous membrane. It crosses the ankle midway between the malleoli, close to the tibia and talus, being crossed by the tendon of the extensor hallucis longus. Here, the nerve ends by dividing into two terminal branches, namely the medial and the lateral.

In the leg, it supplies all the four muscles of the anterior compartment.

The medial branch continues over the dorsum, under the tendons of extensor hallucis brevis. The dorsalis pedis artery runs between the nerve and the extensor hallucis longus. In the first intermetatarsal space, it dips deep to the deep fascia where it divides into two and supplies adjacent sides of the great and second toes and the skin of the first web space.
The lateral branch turns abruptly laterally, under cover of the extensor digitorum brevis, and terminates as a ganglionic enlargement. Several small twigs arise from this enlargement and supply the extensor digitorum brevis muscle, and all the small joints around.

**SUPERFICIAL PERONEAL NERVE**

(L4, 5; S1)

At the lateral surface of the neck of the fibula, the common peroneal nerve divides into the superficial and deep peroneal nerves. The superficial peroneal nerve descends down, in the muscle bellies of the peroneal compartment, until it reaches the junction of the middle and the lower third of the leg, where it pierces the deep fascia and becomes superficial. Soon thereafter it divides into the medial and lateral branches. Each branch further divides into two, over the dorsum of the foot. All these (four) nerve twigs run deep to the dorsal venous arch. Together, they supply the skin of the entire dorsum of the foot, but not the first web space, which is supplied by the deep peroneal nerve.

**SURAL NERVE**

(S1, 2)

It is the longest branch of the tibial nerve. This cutaneous branch arises in the middle of the popliteal fossa and descends in the midline of the leg, between the two heads of the gastrocnemius. In the middle of the leg, it pierces the deep fascia to run in the subcutaneous tissue, in company with the sural artery and short saphenous vein. From here it takes a gradual but steady lateral course downward to reach behind the lateral malleolus. At this point, the nerve lies between the lateral malleolus and tendoachilles. For harvesting it as a nerve graft, it is this area where dissection is performed to locate the short saphenous vein which is easily identified. The sural nerve and the vein are so closely stuck together that they are sometimes mistaken as one structure.

The nerve supplies the skin of the lower part of the posterior-lateral aspect of the leg, the lateral border of the foot and the adjoining part of the dorsum and the lateral side of the little toe.

**SAPHENOUS NERVE**

(L3, 4)

The longest branch of the femoral nerve, it arises about 2 cm below the inguinal ligament and descends along with the femoral artery in the adductor canal. At the lower end of the canal it leaves it by passing behind the lower edge of its fibrous roof, and then lies directly under the sartorius muscle. A little above the knee, it comes to surface, by passing between the tendon of gracilis and the posterior border of the sartorius muscle. It then lies posterio-medial to the knee, where it pierces the deep fascia to run in the subcutaneous fat, and here onwards, it runs in company with the great saphenous vein. In the leg, it runs over the medial border of the tibia and then obliquely forwards across the distal third of the tibia. Still in company with the vein, it crosses in front of the medial malleolus to reach the medial border of the foot, where it terminates.

It supplies the skin of the medial side of the leg and foot.
CHAPTER 6
ANTERIOR TIBIAL FLAP & DORSALIS PEDIS FLAP

ANTERIOR TIBIAL FLAP

The skin of the antero-lateral side of the leg is supplied by the anterior tibial artery by the septocutaneous perforator that runs in a relatively well defined septum between the tibialis anterior muscle medially and extensor digitorum longus (above) and extensor hallucis longus (below) laterally. Plastic surgeons have named several of these, and not the anatomist.

The skin as an island flap based on these perforators can be raised up to as large a size as 8 cm x 20 cm, on an antegrade or a retrograde flow.

ANATOMY OF PERFORATORS

The arterial anatomy of the anterior tibial artery has been described earlier (pg 115). Several muscular, musculocutaneous and septocutaneous (fasciocutaneous) branches (perforators) are given by the anterior tibial artery to supply tissues around it. The branches of our interest are the septocutaneous ones. Some of them travel between the tibia and tibialis anterior muscle, others between the anterior and the lateral compartment of the leg through the anterior peroneal septum, and still others through the space among the muscles of the anterior compartment itself. A well defined septum and space exists lateral to the tibialis anterior muscle, which separates it from all other muscles of this compartment (extensor digitorum longus superiorly and extensor hallucis longus inferiorly). The anatomy of this region has been studied by several plastic surgeons, including ourselves.

From these studies, one can conclude that there are at least 3 septocutaneous perforators in the upper third, 7 in the middle third, and 3 in the lower third of the leg.

Also, three of them which are fairly large (over 1 mm diameter) have been named by some but we will not put any tag on them (to avoid confusion), and only mention that a large septocutaneous perforator exists (at every 7 cm distance starting from the tibial tuberosity from above downwards).

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SCHEMATIC DRAWING AND MARKINGS OF ANTERIOR TIBIAL FLAP

(Fig. 6-1)

- Septum
- Tibialis anterior
- Extensor hallucis longus
- Extensor digitorum longus M.
- Anterior peroneal septum

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**DESIGN & MARKINGS**
(Fig. 6-2)

At the junction of the upper to the middle third and between the middle and the lower thirds of the leg, a larger septocutaneous branch supplies this flap. These have been named, but in a confusing manner, so it will be easier to call them a superior and an inferior branch.

**FLAP ELEVATION**

**Antegrade Flap**

It is a very reliable flap and a fairly large-sized one. It is useful for the defects around the knee. The skin of the upper two-thirds of the leg could be utilised in this manner. The flap is raised, as marked from distal to proximal. The skin and deep fascia is divided at the distal marking and here the space between the tibialis anterior and extensor hallucis longus is opened and the muscles are retracted. All muscular and septocutaneous perforators that are encountered in the initial dissection are preserved. In the depth, the anterior tibial artery, its two venae comitantes and the deep peroneal nerve that run together are seen running over the anterior surface of the interosseous membrane. All branches going posteriorly into the membrane and those going into the muscles are gently coagulated, but the septocutaneous perforators are preserved. Two well-defined large perforators, as mentioned earlier, will be seen at the levels of 7 cm and 14 cm from the tibial tuberosity in adults, and these are preserved. The anterior tibial vascular bundle is double ligated, in the depth, at the most distal limit of the flap, between the muscles. The dissection that creates and elevates the septum along with anterior tibial vessels that have been ligated proceeds proximally. Depending upon the plan and the design of the requirement, the skin over the proximal end is incised, creating an island flap, or if desired, it

There are two fixed points beyond which the flap cannot be raised and moved. Superiorly, on an antegrade flow up to the tibial tuberosity and inferiorly on a retrograde flow a point 5 cm above the lateral malleolus.

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**SCHEMATIC DRAWING AND MARKINGS OF ANTERIOR TIBIAL FLAP**
(Fig. 6-2)

- Tibia
- Gastrocnemius
- Tibialis anterior M.
- Proximal flap (retrograde)
- Extensor digitorum longus M.
- Distal flap (antegrade)
- Extensor hallucis longus M.
- Peroneus brevis tendon
- Surface marking of anterior tibial vessels
is left intact. The deep peroneal nerve is separated out and preserved from the anterior tibial vessels during dissection.

Extracorporeal transfer of this flap is possible for the defects of the other leg.

Retrograde Flap

It is not as reliable as the antegrade flap. Unless an island is created, it is not of much use since the arc of rotation is limited. When an island flap is raised, its reach increases tremendously and this flap could cover almost any area on the lower third of the leg and foot. However, its complete survival is doubtful. Marginal necrosis has been reported in many cases and we agree with this experience. This is because of insufficient venous drainage. The problem is overcome by venous anastomosis of one of its veins to the recipient veins.

The flap should not be pivoted 5 cm below the lateral malleolus, otherwise venous congestion may be marked and survival may be in jeopardy. However, a 20 cm long flap can be raised from the middle and upper thirds of the leg, but the width of the flap is limited to 8 cm.

Preoperatively, identification of major cutaneous perforators with the help of a Doppler probe is always of great help.

POSITIONS OF IMMOBILISATION

Positioning the Limb for Antegrade Flap
(Fig. 6-4)

For the defects of the contralateral limb and for using the flap extracorporeally, the limbs have to be crossed in a manner that both knees are close together and overlap each other. The donor limb is behind the recipient limb and the pedicle is not compressed by the weight of the other limb. The donor knee is kept straight and the recipient one is flexed (Fig. 6-4).

The other position that is also comfortable is when the donor knee is flexed anterior to the recipient knee (Fig. 6-4).

Positions for Retrograde Flap
(Fig. 6-5)

Using it as an extracorporeal flap for the contralateral limb, it has a great reach. In this respect, this flap is quite similar to a distally based radial forearm flap.
A comfortable position is achieved when both the limbs are kept parallel and straight. However, even when the limbs have to be crossed, they are tolerable. Care is taken that the crossover limb (Fig. 6-5) does not compress the vascular pedicle.

3. Simple elastoplast fixation with sponge padding is the most preferred method. It is lightweight and easy to manage but an intelligent patient is required to manage it without traumatising the pedicle.

**FLAP DETACHMENT**

Since overall healing is slow in lower limbs, we divide the pedicle in 3 weeks' time. The limbs are separated and both the ends of the vessels are revised.

**CLINICAL EXAMPLE**

(Fig. 6-6)

A 55-year-old male patient was presented to us with a wound over the tendoachilles region of about 15 cm x 10 cm size, in which the tendoachilles was bare in the centre of the wound for about 5 cm x 5 cm (Fig. 6-6a). A local transposition flap was attempted by some plastic surgeon that failed. The problem, therefore, was compounded.

**ANTERIOR TIBIAL FLAP - CLINICAL EXAMPLE Fig. 6-6a**

- Posttraumatic defect over tendoachilles region of 15 cm x 10 cm size in a 55-year-old man.

**IMMOBILISATION**

1. It is best performed by external pin fixation (Hoffman's Fixator). We use indigenously designed fixator frames based on a similar line of thinking.

2. Plaster cast fixation is equally effective, but is cumbersome. There are difficulties while using toilet facilities on the bed.
EXTRACORPOREAL ANTERIOR TIBIAL FLAP FOR RECONSTRUCTION OF TENDOACHILLES DEFECT Fig. 6-6b, c, d, e

b - A distally based anterior tibial flap of 15 cm x 10 cm has been raised on a 10 cm long vascular pedicle.

c - Flap has been transferred extracorporeally. An arrow has been marked over the vessels that has been wrapped in a sheet of split thickness skin graft.

d - Postoperative result is seen after the excision of the vessels.

e - A well healed flap after two months of surgery.
We covered this defect with a retrograde (distally based) anterior tibial flap of 15 cm x 10 cm size, on a 10 cm long vascular pedicle (Fig. 6-6b) from the same limb. The vascular pedicle was taken extracorporeally (Fig. 6-6c, d) to enhance the reach of the flap and to avoid postoperative venous congestion in the flap. We feel that whenever the vascular pedicle is buried in a blind tunnel, especially in those flaps where venous drainage is precarious anyway, then we are by choice lodging the pedicle in the ‘zone of compression’, and therefore, some venous compression does take place. This we always avoid. Three weeks later, the vessels were excised and ends revised.

Four weeks after the reconstruction, all the wounds healed well and partial weight bearing was allowed. In a period of the next 4 weeks, he was back to full weight bearing (Fig. 6-6e). One year later, he was seen last (Fig. 6-6f) to be walking normally without any supportive footwear.

**DORSALIS PEDIS FLAP**

This is an axial pattern fasciocutaneous flap raised from the dorsum of the foot. Some plastic surgeons, however, disagree about it being a fasciocutaneous flap. The flap consists of skin, subcutaneous tissue, deep fascia and the dorsalis pedis artery along with its branches, the tendon of extensor hallucis brevis, and some of its muscle fibres. If a neurosensory flap is raised, it also contains the superficial peroneal nerve.

**CLINICAL ASSESSMENT OF VESSELS IN THE LIMB**

The patency of the posterior tibial artery and the anterior tibial artery should be assessed by palpation beforehand. It is performed in the following manner:

1. Palpate the dorsalis pedis artery, with the posterior tibial artery occluded, by thumb compression, behind the medial malleous. If pulsations are present, then reverse flow in the dorsalis pedis artery is excluded.

2. Occlude the dorsalis pedis artery distally by a thumb and palpate it proximally. If pulsations are present, its proximal patency is proved.

3. Angiography should be performed if the above tests are inconclusive.

**DORSALIS PEDIS FLAP DESIGN**

(Fig. 6-7, 8)

A flap as large as 12 cm x 12 cm from the dorsum of the foot could be raised. Proximally, the flap is designed up to the ankle joint crease line and distally up to the heads of the metatarsals which are approximately at the level of the prominence of hallux valgus (undelayed flaps) and up to a centimetre proximal to the web space (delayed flaps). Medially and laterally, about 2.5 cm width of skin is left intact on the foot, measuring from the edge of the plantar surface that comes in contact with the ground.
A large sized flap will measure 12 cm x 12 cm. The distal 3 cm of such a flap must always be delayed. A flap of up to 10 cm x 10 cm can be raised without a delay procedure. In a full size flap, an attempt is made to include the first dorsal metatarsal artery in the flap.

The superficial peroneal nerve runs separately and is about 1.5 cm lateral to the dorsalis pedis vascular bundle; therefore, the neurosensory island flap has two fixed points of attachment. It has a longer reach laterally than medially.

For extracorporeal neurosensory transfer, a segment of the superficial peroneal nerve is dissected and divided. It is stored under one edge of the flap, to be co-opted with the recipient nerve (few fascicles of the sural nerve) of the other foot, at the second stage (separation of limbs and excision of the dorsalis pedis vessels).

A long length of vessels (anterior tibial artery and veins), up to 6-8 cm, should be dissected as a carrier segment, for extracorporeal transfer. In this case, the pivotal point of the flap will be in the distal third of the leg.

**MARKINGS**

*(Fig. 6-7, 8)*

The venous pattern of the foot, which includes the dorsal venous arch, commencement of the short saphenous vein laterally, and great saphenous vein medially, is marked by application of a venous tourniquet for a few minutes.

In a thin individual, the superficial peroneal nerve or its medial and lateral branches could be rolled under the fingertips and marked.

The course of the dorsalis pedis artery and the expected site of the first dorsal metatarsal artery are marked.

**Schematic Drawing of Dorsalis Pedis Artery**

*(Fig. 6-8)*

**FLAP ELEVATION**

*(Fig. 6-8)*

Elevation may begin from the medial or the lateral side, or from the distal limit of the flap. Distal to proximal dissection is followed in general.

Medial dissection is carried up to the paratenon of the extensor hallucis longus tendons. The plane superficial to the paratenon of the tendon is reached. Immediately lateral to it, and closely in contact with the bones of the foot, runs the dorsalis pedis vascular bundle. Therefore, immediately lateral to this tendon, the surgeon should dig deep and straight onto the bones and gently free the vessels from the bones underneath. This is the most vital part of flap dissection. If this precaution is not taken now, it will be soon
realised that the whole flap has been raised without including the artery. The artery has been left on its bed over the bones.

Lateral dissection gradually reaches the dorsalis pedis vessels taking the tendons of extensor hallucis brevis with the flap. If necessary, some of the muscle fibres of extensor hallucis brevis could be taken with the flap (since the belly lies between the branches of the artery and the skin).

A proximal incision is now made, taking care not to cut the superficial peroneal nerve. It is identified about a centimetre lateral to the dorsalis pedis vessels. When required (for a neurosensory flap) it is traced proximally. Now the flap is attached only by its vascular pedicle.

The following tissue planes are encountered during flap elevations:

Skin
Subcutaneous tissue with veins
Subcutaneous nerves
Deep fascia
Tendons and the muscle fibres of extensor digitorum brevis
Dorsalis pedis artery along with its venae comitantes.

**POSITIONS OF IMMOBILISATION**

The recipient foot is kept in front of the donor foot for the defects of the sole. Similarly, keeping the recipient leg in front of the donor limb is better for the defects of the lower third of the leg, although several other positions are possible. Care is taken that the weight of the receiving limb does not compress the pedicle on the donor foot.

**IMMOBILISATION**

Commonly, clasto plast fixation over the soft sponge padding is used, which is light in weight and easy to manage. A fixation at the level of the ankle and another at the level of the knee is required.

Occasionally, in unusually obese patients, this method may not be satisfactory. It is then better to use Hoffman's external fixator or Plaster of Paris fixation.

**FLAP DETACHMENT**

The reconstructive surgeon himself best determines the timing of the flap detachment, since no two patients behave similarly. However, general guidelines could be mentioned. If the flap inset is healing well all around in a trouble-free manner, then there is no reason why vessels should not be excised on the 10th day, after a 2-3 day period of trial clamping. But the judgement about sound healing has to be made. In case of doubt, it should be performed on the 15th day. When healing is poor, there is infection and suture line dehiscence or even marginal necrosis, in the case flap separation should be delayed for 3 weeks.

For detachment, the extracorporeal vessels are excised and their ends are revised. Fixator devices are removed and limbs are separated. For neurosensory flaps, this stage is the time for nerve co-optation between the donor and the recipient nerves, which is performed easily under magnification, once the limbs have been separated.

Walking on the reconstructed sole should return gradually. Total weight bearing should return only after 3 months of flap transfer.

**CLINICAL EXAMPLE**

(Fig. 6-10)

A 28-year-old farmer with a non-healing ulcer, surrounded by an unstable scar covering the entire heel (Fig. 6-10a) of the left foot, was presented to us in March, 1984. The ulcer was present for the past 12 years and multiple attempts at some other hospitals failed to cure the problem. He had a history of recurrent breakdown and because of this, for the past 12 years, he had been walking on crutches and had withdrawn from active work at his farm.

In March, 1984, we excised the entire unstable scar on the heel, including the non-healing ulcer, and covered it with a 10 cm x 8 cm size dorsalis pedis neurosensory island flap (Fig. 6-10b) from the contralateral foot. The ipsilateral dorsum of the foot was scarred and was not enough to cover the defect. At the time of flap elevation, about 3 cm of the
superficial peroneal nerve was dissected from the flap proximally in the leg and was stored under the flap inset to be utilised at the time of flap separation for sensory purposes. Gross postoperative oedema in the flap was noticed for the first 7 days after the transfer, but it settled gradually. Three weeks later, the thin vascular leash connecting the two feet was
excised and the feet were separated. Microneural repair between the superficial peroneal nerve and three fascicles (Fig. 6-10c, d) of the sural nerve was performed at this stage. The rest of the three fascicles in the sural nerve that were left intact preserved the sensations in the area of distribution of the recipient sural nerve (Nerve Sharing Technique) (Fig. 6-10c). The flap healed in 3 weeks’ time, uneventfully. Three months later (Fig. 6-10g), the patient was able to bear his full weight.

Six months later, he had sensations of touch, pain and pressure in the entire flap, and there was no loss of sensation in the distribution of the recipient sural nerve. At 3 years’ follow-up, he had sensations of touch, pain and temperature in the flap, and has suffered no breakdown in the last 3 years after reconstruction. He was back to hard work as a farmer and could walk long distances without trouble.

**EXTRACORPOREAL DORSALIS PEDIS FLAP FOR RECONSTRUCTION OF HEEL PAD**

Fig. 6-10e, f, g, h

- **e** - Neurosensory dorsalis pedis flap has been raised on a short vascular pedicle.
- **f** - Two weeks after the flap transfer, Flap in position, healing well, and the donor foot is almost healed.
- **g** - Three months postoperative result.
- **h** - Since the nerve sharing technique has been used, there is no sensory loss in the distribution of the sural nerve and a neurosensory dorsalis pedis flap has been provided without resorting to microsurgical means.
POSTERIOR TIBIAL ARTERY FLAP

The skin of the posterio-medial side of the leg is supplied by a set of septocutaneous perforators that lie about 3 cm posterior to the medial tibial border. About 4-6 such perforators arise from the posterior tibial artery and run in the septum that lies between the muscles, to eventually surface over the deep fascia to supply the skin. The skin of the lower two-thirds of the leg, which is supplied by these, can be raised as an island flap, safely up to a limited dimension (10 cm x 10 cm) and a larger flap, after a delay.

ANATOMY OF PERFORATORS
(Fig. 5-3, 5-5, 7-2)

The posterior tibial artery runs between the lower border of the popliteus muscle to the posterior surface of the medial condyle. The artery runs on the posterior surface of the leg, posterior to the tibialis posterior muscle and anterior to the soleus muscle. The flexor digitorum longus muscle is antero-lateral and the flexor hallucis longus muscle is

ANATOMICAL STRUCTURES POSTERIOR TO MEDIAL MALLEOLUS
(Fig. 7-1a)

TRANVERSE SECTION THROUGH THE MIDDLE OF THE LEG (Fig. 7-1b)
anterio-medial to the artery. The artery sends blood supply to the skin of the posterio-medial side of the leg, through a set of septocutaneous perforators (about 4-6 in number) other than its named branches that arise from the artery. They are located about 3 cm posterior to the posteriomedial border of the tibia. These perforators arise from the artery at an interval of about 5 cm, the most distal perforator being 5 cm proximal to the medial malleolus.

In the proximal third of the leg, these perforators run through the soleus muscle to reach the skin. Sometimes, even up to the mid leg, they run through this muscle. But distal to it, where the artery gets gradually nearer the skin, these perforators run in a flimsy septum that lies between the soleus, posteriorly, and the flexor digitorum longus, anteriorly.

It may be recalled for the benefit of surgeons that behind the medial malleolus, the set of structures that are traceable from anterior to posterior are the tibialis posterior tendon, flexor digitorum longus tendon, posterior tibial artery, tibial nerve, flexor hallucis muscle fibres and the tendoachilles (Fig. 7-1a).

In effect, it means that the artery behind the medial malleolus has two tendons anterior to it (close to the artery is flexor digitorum longus and further anterior is the tendon of tibialis posterior). Muscle fibres of the flexor hallucis longus are posterior to the artery.

**DESIGN AND MARKINGS**

(Fig. 7-2)

A safe flap is within a 10 cm dimension limit and is raised from the distal half of the posterio-medial surface of the leg.

Confirmation of proximal patency of the artery and the patency of the other vessels of the limb is mandatory and is performed on similar lines to that described for the anterior tibial artery flap.
A Doppler study can mark the series of perforators 3 cm posterior to the posteriomedial border of the tibia. A flap based on selected perforators is so designed that at least 6-8 cm of vascular pedicle is available for extracorporeal transfer. Therefore, at least 6 cm proximal to the medial malleolus, the distal limit of the flap should stop. According to the requirement, the flap is then marked.

The anterior limit of the flap is the posteriomedial border of the tibia. The posterior limit is up to the midline in the leg. Proximally, the flap is reliable up to the middle of the leg.

**FLAP ELEVATION**
(Fig. 7-1a, b, 7-3)

The flap is elevated under a tourniquet. The best way is to identify the posterior tibial artery early in the flap elevation process behind the medial malleolus. This identification is easy. The artery is to be found behind two tendons that run anterior to it. These are of the tibialis posterior, immediately next to the medial malleolus, and then behind it is the tendon of flexor digitorum longus. The posterior tibial artery, along with the tibial nerve, is found just behind this tendon. Posterior to the artery are the muscle fibres of the flexor hallucis longus.

Once the artery has been identified, it is traced proximally without separating it from its venae comitantes and without damaging its septocutaneous perforators. This is best done by keeping a distance from the vessel, by including some amount of fibro fatty tissue around the vessel and by including a cuff of some muscle fibres, where the vessels to the skin are running through the muscle fibres. The posterior tibial nerve is gradually separated from the artery and its venae comitantes.

The anterior skin incision of the flap is made after the vessel identification, down to the deep fascia, which is cut and stitched to the skin with catgut stitches. A similar skin incision is made all around, and the flap elevation is approached towards the posterior tibial vessels as an axis of the flap.

Proximal dissection of the vascular bundle will require anterior retraction of the muscle fibres of flexor digitorum longus and posterior retraction of the soleus muscle fibres. All the muscular branches running posteriorly are coagulated.

At the proximal-most limit of the flap, the posterior tibial artery is double ligated. The flap now has only the distal vascular
attachment, behind or near the medial malleolus. Saline gauzes are kept on the undersurface of the flap and over the donor area, and a tight dressing is applied, while the tourniquet is released. It is left elevated for 10 minutes for the reactive hyperaemia to subside. The dressing is now removed and further haemostasis is performed. The exposed vascular pedicle is wrapped in a sheet of split thickness skin graft soon after removal of the dressing to avoid any further vascular spasm. The graft is held in position by a few catgut stitches and the donor area is skin grafted by a tie-over dressing, to avoid compression of the residual superficial veins of the limb, and to avoid impeding the establishment of retrograde flow in the veins.

**POSITION OF IMMobilisation**

(Fig. 7-4, 7-5)

The basic principles of positioning the two limbs together remain the same for all other island cross limb extracorporeal flaps. They are that:

1. The most comfortable position is planned.

2. The extracorporeal pedicle should be free in the air and not against any kind of external compression, like the weight of the limb.

3. The extracorporeal pedicle should neither be too stretched nor too relaxed.

4. The position should be easily immobilised and maintained for 3 weeks.

A great benefit of this flap is that its pivot point is on the medial side of the ankle, near the medial malleolus. Because of this location, two limbs could be simply placed together, keeping them parallel and straight and immobilised for defects of the foot. However, for other defects, either of the knees has to be flexed so that the flap reaches the recipient area.

**IMMobilisation**

Once again, the methods of immobilisation remain the same. We use elastoplast fixation with sponge padding between the areas of contact of the two limbs. Plaster of Paris fixation is more effective and, therefore, healing of the flap is better. However, because of its weight, difficulty is faced by the patient in its management.
When available, and when the patient can afford it, external fixator devices provide a better kind of immobilisation.

**CLINICAL EXAMPLES**

**Case 1**
*(Retrograde flap)*

An 18-year-old male patient was referred by the orthopaedic unit 4 weeks after a crush injury to the right leg. He sustained a compound fracture of the distal third of the tibia, and soft tissue over and around the tibia was lost following debridment. Some more tissue turned necrotic gradually, over the next 4 weeks’ time.

On physical examination then, he had an exposed tibia for a length of about 12 cm along with the exposed fracture site. Unhealthy granulations and scar tissue for about 5 cm all around surrounded this.

Excision of all unhealthy tissue surrounding the bone created a raw area of about 18 cm x 9 cm (with a 12 cm x 5 cm segment of tibia), which was covered by a distally based extracorporeal posterior tibial island flap of similar dimensions.

A parallel limb position and plaster of Paris fixation was used for immobilisation.

The postoperative course was uneventful and the complete flap survived the transfer. On the 12th day, a trial clamp was applied weakly and it was tightened every day for the next 2-3 days, until on the 15th day, the vascular pedicle was excised and the limb was separated.

In 4 weeks’ time, the traumatised leg and the donor leg healed well. He was walking normally 6 months later, when the tibia was well united and the donor area well settled.

**Case 2**
*(Antegrade Flap)*

A 35-year-old male patient sustained a crush injury to his right lower limb. He fractured both the bones in his leg, and soft tissue, including the skin and muscles in the entire leg, were badly contused. His initial management by orthopaedic surgeons included debridment and external fixation of the tibia. A lot of tissues necrosed further, and after the second debridment, he had been referred to us.

On examination, he had an exposed tibia along with the fracture site, in a segment of about 12 cm x 6 cm. The surrounding skin and muscles were unhealthy, and covered with granulations and scar tissue. This together constituted almost the anterior half of the circumference of the middle and lower thirds of the leg.

A proximally based extracorporeal posterior tibial island flap measuring 20 cm x 10 cm was used to cover the defect following excision of all unhealthy scarred tissue from the leg.

A parallel limb position was used for immobilisation. The postoperative course was uneventful. Two weeks later, the vascular pedicle was excised, the ends were revised, and the limb was separated. In 4 weeks’ time, all wounds healed well, both on the recipient and the donor limb.
CHAPTER 8
PERONEAL ARTERY FLAP

PERONEAL ARTERY FLAP

This is a Fasciocutaneous Island Flap based on the peroneal artery, which supplies the skin of the middle and upper thirds of the lateral side of the leg, by means of 3-6 septocutaneous perforators. This could be either based on the antegrade or on the retrograde flow. Flaps on retrograde flows are very useful to solve difficult foot reconstructions. A flap up to 8 cm in width and 15 cm in length can be raised.

ANATOMY OF PERFORATORS
(Fig. 5-3, 8-2, 8-3)

The peroneal artery runs in close proximity to the posterio-medial surface of the fibula, where it runs between the flexor hallucis longus (posterior to the vessel) and the tibialis posterior muscle (anterior to the vessel), sitting on the posterior surface of the interosseous membrane.

The peroneal group of muscles is encased between two septa of deep fascia, namely the anterior septum and the posterior septum. They spread between the deep fascia and the fibula. The posterior septum separates the peroneal muscles from the posterior muscles of the leg. It is through this septum that about 2-6 septocutaneous perforators travel from the artery to the deep fascia and supply the skin. The maximum concentration of these is in the upper and middle thirds of the vessel. They are at a distance of 3-5 cm each. In the lower thirds as well, there are a few perforators, which are of comparatively small calibre. Therefore, an area about 10 cm from the fibular head and from the lateral malleolus should be left intact, and the skin segment between these two points should be raised as a flap.

At the level of the ankle joint, the artery runs medial to the peroneal tendons before ending as a bunch of calcaneal branches, below the lateral malleolus.

The artery is about 4 mm in diameter and gives the following branches:

**Medial branches** - to the muscles, interosseous membrane and the periosteum of the fibula.

**Lateral branches** - to the peroneal muscles and to the skin via septocutaneous perforators. There are about 10 such branches with an average diameter of 1.2 mm.

**A Nutrient Artery** - It is given off about 7 cm from the origin of the artery and runs in the muscle before piercing the nutrient foramina in the fibula in the centre of the bone on its posterio-medial surface.

**A Transverse Communicating Branch** - It is given off about 6 cm proximal to the lateral malleolus. It communicates with a branch from the posterior tibial artery.

**A Perforating Branch** - It arises above the lateral malleolus and after piercing the interosseous membrane runs anteriorly to communicate with the branch of the anterior tibial artery.
Lateral Malleolar Branches - These may communicate with the lateral tarsal branches of the dorsalis pedis artery.

Calcaneal Branches - The artery ends at the level of the ankle as a bunch of calcaneal branches that may communicate with the calcaneal branches of the posterior tibial artery.

**DESIGN AND MARKINGS**

(Fig. 8-1)

The head of the fibula and the lateral malleolus are marked, and a line connecting them is drawn. This is in effect the surface marking of the peroneal artery. A flap, on this axis, on its central third, up to 8 cm width and 15 cm length, could be drawn according to the requirements. The posterior peroneal septum is visible as a distinct depression in lean and muscular males, and in these cases, the flap should be centred over this septum.

The length of the pedicle is planned in advance, and positions of the limb after immobilisation are rehearsed. This preoperative drill will provide the surgeon with an approximate estimate of the length of the extracorporeal vessels. About 8 cm of length is satisfactory. The distal third of the leg is used with advantage to provide extra length to the extracorporeal vessels by raising a distally based flap from the central third of the leg.

**FLAP ELEVATION**

(Fig. 8-1, 2, 3)

The flap is raised under a tourniquet. Anterior and posterior skin incisions are made down to the deep fascia, which is stitched to the skin after being cut. Dissection proceeds...
towards the posterior peroneal septum, after the identification of underlying muscles.

In retrograde flaps, identification of peroneal vessels near the lower end of the fibula is easy, where it lies medial to the peroneal tendons. Once identified, the artery, along with its venae comitantes (one of them is larger than the artery) is traced proximally, taking care to coagulate all the muscular branches away from the main trunk. Vessels are dissected in the entire length by retraction of peroneal muscles anteriorly and the flexor hallucis longus and soleus muscles posteriorly. Septocutaneous perforators lying in the septum are well preserved. The skin island thus created is now attached to the vessels by the septum. The peroneal vascular bundle is double ligated proximally and the vessels are divided.

Immediately, the vessels in the vascular
pedicle are wrapped in a sheet of split thickness skin graft to avoid further spasm.

After cotton gauze padding, a tight dressing is applied and the tourniquet is released. The leg is kept elevated for 10 minutes, so that reactive hyperaemia settles down.

Now the dressing is removed and the flap is inspected; haemostasis is performed. The donor area is skin grafted.

**POSITION OF IMMOBILISATION**

(Fig. 8-4)

Since the vascular pedicle is located laterally near the lateral malleolus, usually, crossing of the limbs will be required, for interfacing the limbs and for insetting the flap.
SURAL ARTERY FLAP

This is a fasciocutaneous flap available over the posterior surface of the leg on an antegrade or retrograde vascular pedicle that could be as long as 15 cms.

Although the entire posterior surface of the upper two thirds of the leg could be raised, a 12 cm x 12 cm flap is most safe.

The flap has a robust circulation derived from the superficial sural artery and its veins, in addition to the perforators from the peroneal artery.

ANATOMY

The median superficial sural artery runs in conjunction with the medial sural nerve. The lesser saphenous vein, along with its two accompanying arteries, runs close to the sural artery in most of the lower third of the leg, except in the mid calf, where the sural nerve takes a more lateral course. All these vessels

ALTERNATIVE SURAL ARTERY FLAP FOR RECONSTRUCTION OF ANKLE DEFECT - CLINICAL EXAMPLE Fig. 9a, b, c, d

a - Showing circumferential jacket of cicatrice scar tissue right lower leg and ankle with non-healing ulcer of 18 years duration following coal tar burn in childhood.

b - Alternative free sural artery flap is marked on the contralateral limb

c - Six weeks postoperative result.

d - Six weeks postoperative result showing weight bearing

Dr. Anshul and Dr. Ashok Govila
together make the vascular axis of the sural artery flap. Additionally, a series of 4-5 perforators emerges to surface from the depth coming out of the peroneal artery, running in the crural septum, to add to the supply of the skin of the leg. These perforators are located between 5 cm and 15 cm distances from the lateral malleolus.

**MARKINGS**

The entire skin of the posterior surface of the calf is supplied by this vascular axis and can be raised as a fasciocutaneous flap based in either direction, depending on the location of the defect. A flap marked on the proximal third of the calf can reach up to the sole of the foot. A useful guideline is a 12 cm circumference over the calf.

**FLAP ELEVATION**

This begins by incising the flap all around, and fixing the deep fascia to the skin by vicryl stitches. The sural vascular axis is easy to identify in the midline of the calf running just on the undersurface of the deep fascia. As a first step, it is doubly ligated proximal or distal to the flap, depending on the required and planned movement of the flap. Dissection continues deep, to deep fascia, and the flap is lifted completely with the vessels. Dissection continues around the vessels,

**ALTERNATIVE SURAL ARTERY FLAP FOR RECONSTRUCTION OF ANKLE DEFECT - CLINICAL EXAMPLE Fig. 9e, f, g, h**

- **e** - Alternative free sural artery flap of 12 cm x 16 cm marked on the left leg.
- **f** - Sural artery flap raised on a 10 cm long vascular pedicle.
- **g** - Showing raw area over right leg following excision of all the soft tissue exposing the ankle joint.
- **h** - Sural artery flap inset given as an alternative free flap. Vascular pedicle has been skin grafted.
keeping a fringe of supporting deep fascia and fat for the desired length of the pedicle. After the release of the tourniquet, haemostasis is secured, and the vascular pedicle is then wrapped in a sheet of skin graft. The donor area of the flap is skin grafted with a tie-over dressing. Skin to deep fascia tagging stitches applied in the beginning around the margins of the flap are then removed. The flap is now ready for the transfer.

**CLINICAL EXAMPLE**

(Fig. 9a-i)

A 30-year-old male was presented to us at Mafraq hospital, Abu Dhabi, U.A.E. in 1999, having suffered a coal tar burn of the left lower-half of his leg at the age of 12 years, while working as a labourer on the road-side in Bangladesh, his home country. For 18 years, before he came to us, he had been suffering with a deformed foot that had a chronic ulcer on it, coupled with the inability to walk normally. On examination, he had a non-healing ulcer over the dorsal aspect of the ankle, about 10 cm x 10 cm in size, sitting over a thick cage of fibrous tissue encircling the entire circumference of the lower half of the leg (Fig. 9a, b). The ankle joint had severe fixed plantar flexion deformity (Fig. 9b).

We decided to circumferentially excise the fibrous cage and open up the ankylosed ankle joint to 90 degrees of the foot (and send the tissue for histopathology to exclude any Marjolin’s ulcer) (Fig. 9g). We planned to cover the exposed bones and joints with an alternate free sural artery flap of 12 cm x 15 cm from the contralateral leg, and skin graft the rest of the raw areas (Fig. 9e, f). The ipsilateral leg was not selected because it was not expected for any functioning perforators or even the patent sural artery in the midst of such a dense and thick layer of fibrous jacket encaging that limb. The ankle joint was to be fixed with thick ‘K’ wires.

The ECTT pedicle was skin grafted and 100% flap inset was given (Fig. 9h). The limbs were immobilised straight, using Plaster of Paris semi-cast fixation for 10 days (Fig. 9i). On the 15th day, the limbs were separated. Three weeks later, the ‘K’ wires were removed and partial weight bearing was permitted. Six weeks postoperatively, he regained his walk after 18 years of suffering (Fig. 9c, d). It is now four years since we operated, and he enjoys a normal walking life.
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GENERAL


ANATOMY


VASCULAR ANOMALIES


APPLIED ANATOMY


DESIGN AND ITS VARIATIONS


One-staged coverage and revascularisation of traumatised...


**BASIC CONCEPT**


**CONCEPT RECONFIRMATION**


**CONCEPT EXTENDED BEYOND**


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UPPER LIP RECONSTRUCTION

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ANTERIOR TIBIAL FLAP

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Dr. Anshul Gavila – Extending the Legacy

Doctor Anshul had the best of both worlds. Not only did he, as a child, witness the making of a plastic surgeon in his father, but in his process opted to become one himself.

His unusual intellect was nurtured at King Edward Medical College in Bombay, India, which was followed by extensive training at Sir. J.J. Hospital, also in Bombay, which helped him mature into a dynamic thinker in his area of specialization.

Time spent with great masters in the field like Dr. Fu Shen Wei in Taiwan refined his understanding of microvascular surgery and added substantially to his perspective of the subject.

Besides other important factors, a natural gift for literature and the fine arts set the foundation that helped him opt for plastic surgery as a vocation.

In his extensive repertoire of experiences, Dr. Anshul was commissioned to work at India’s Maharashtra Health Services for a year. He spent this year in the bowels of poverty; it was a great lesson in humility, and taught him to amalgamate modern medicine and modern surgery with the depth of rural India.

Dr. Anshul’s contribution to this book includes the unseen contributions of all his teachers. The book also draws on the teachings of the hardships of his professional life, making it a more holistic reference for other microvascular and reconstructive surgeons in years to come.
ALTERNATIVE FREE FLAPS
(Extracorporeal Tissue Transfer)

Govila & Govila