The Ertl Osteomyoplastic Transtibial Amputation Reconstruction
Description of Technique and Long Term Results

J.W.Ertl,MD,FACS, Hinsdale, IL,
J.P.Ertl,MD, Sacramento, CA,
W.J.Ertl,MD, New York, NY,
J. Stokosa,CPO, Okemos,MI.

Abstract

143 patients with 150 symptomatic transtibial amputated residual extremities were treated operatively by two surgeons experienced in osteomyoplastic reconstruction. Patients were reviewed an average of 9 years post-operatively, with a range of 2 to 15 years. The average age at reconstruction was 48.5 years. The primary amputations were performed as a result of trauma in 63%, vascular disease in 28%, infection in 7% and tumor in 2%. Patients were referred for a combination of residual extremity pain, soft tissue or bony instability, swelling, cutaneous prosthetic interface difficulties resulting in the inactive residual extremity syndrome. Surgical reconstruction was performed only after non-operative attempts had failed to improve upon their symptoms.

The long term results were determined by a 30 point clinical assessment score, integrating subjective and objective evaluation parameters, comparing pre- and post-operative symptoms. 138 patients were rated as good or excellent, 8 as fair and 4 as poor. The poor results were in vascular amputees with persistent post-operative residual extremity pain, even though improving in other parameters. The osteomyoplastic reconstruction technique provides a stable, durable and active residual extremity, with lasting improvement and high patient satisfaction.

Introduction

Lower extremity amputation is an ancient phenomenon which dates to pre-history and is one of the oldest surgical procedures described. Neolithic man is known to have survived traumatic, ritualistic, punitive and therapeutic amputation. Therapeutic amputation techniques have been described by Plato (385 B.C.) and Hippocrates.

The treatment of severe lower extremity trauma and peripheral vascular disease have made great advances in the modern surgical era. The advent of revascularization, internal fixation of fractures, microvascular techniques and free tissue transfer have become routine procedures which have favorably enhanced the patient's outcome. Failure of these techniques in the lower extremities may result in factors which will lead to amputation. The reality being that all efforts were pursued to salvage and maintain the extremity with amputation being the only alternative to return the patient to his family and an active lifestyle. Amputation is then viewed as a failure by both the surgeon and the patient, who then pictures himself as incomplete by societal standards. In many regions of the world these refined surgical techniques are unavailable, or even too costly, and amputation remains the primary form of treatment.

Amputation techniques have changed little over the years and are usually performed by the most junior member of the surgical team. In contrast, the prosthetic industry has made significant advances in accommodating the amputated extremity, at times attempting to improve on less than optimal surgical results. In spite of a well performed amputation and a well fitted prosthesis some patients have persistent symptoms of residual extremity pain, swelling, sense of instability and decreased length of prosthetic wear. These patients pose a challenging situation from a surgical reconstructive perspective. The effects of previous surgery, altered anatomy, muscle and bone atrophy, aerobic deconditioning and maintenance of residual limb length create additional difficulties when considering surgical reconstruction.

The purpose of this study is to describe our surgical technique and correct the misconceptions in the literature (Smith Bowker), as well as present our results over the past 15 years. Our experience with this procedure has been positive and offers the surgeon an option when presented with difficult surgical reconstructive amputee symptoms.

Materials & Methods

Between January 1980 and January 1995 two surgeons performed 171 transtibial osteomyoplastic lower extremity amputation reconstructions in 164 patients. There were 7 bilateral amputees treated in stages. 12 patients were deceased from unrelated causes and 9 patients were lost to follow-up. A total of 143 patients with 150 osteomyoplastic reconstructions, with a minimum 2 year follow-up, were available for review. The average follow-up was 9 years with a range from 2 to 15 years. There were 109 males and 41 females with an average age at reconstruction of 48.5 years, with a range of 12-88 years. There were 72 right and 78 left lower extremities involved. The initial causes of amputation were traumatic in 63.3% (95), peripheral vascular disease in 27.3% (41), infection 7.3% (11) and tumor in 2% (3). The average time to surgical reconstruction after primary amputation was 9.5 years, with a range of 2 months to 47 years. Surgical indications included a combination of residual extremity pain, bone and muscle atrophy, swelling, weakness, sense of instability, poor prosthetic fit with cutaneous breakdown resulting in decreased function. We have termed this symptom complex the "inactive residual extremity syndrome", as the residual extremity becomes a passive attachment for the prosthesis the tissues an inactive participant in ambulation.

The residual extremity was initially examined for knee flexion contracture, localization of pain, presence of exostosis, fibular mobility and general extremity condition. Knee flexion contractures were treated with aggressive physical therapy and stretching exercises prior to surgical intervention. Palpation of the residual extremity was performed for tenderness of bone or neuromatous origin. Superficial palpation of bony exostosis is easily identified. Fibular instability is evaluated by firmly grasping the fibula and checking mobility. With increased fibular mobility, there is increased localized soft tissue irritation and poor rotational control within the prosthesis.

Preoperative planning consisted of AP, lateral and internal and external oblique x-rays of the residual extremity. These were evaluated for extremity length, osteopenia and exostosis. Doppler vascular studies were obtained in those patients with a history of peripheral vascular disease or temperature intolerance.

In attempts to quantify our results a rating system was developed incorporating the patients most frequent complaints and symptoms. This scoring system was modeled after other rating systems (Hughes/Weber, Goldberg, Ertl). The resultant clinical score provided us with an objective means of assessing our results and patient improvements.

Pre-operative and post-operative residual extremity symptoms of pain, function, stability, swelling and length of prosthetic wear were obtained. Post-operatively all patients were seen and evaluated by one of the authors. Final evaluation consisted of a questionnaire regarding residual extremity pain, function, swelling with use, hours of prosthetic wear and subjective stability. Overall patient satisfaction was also requested. Roentgenographic evaluation was obtained to evaluate synostosis formation.
Roentgenographic review of synostosis (bridge) formation was evaluated on internal and external oblique views for percentage of bridge formation. The bridge formation was divided into 4 segments of 25% each. Points were awarded in the following manner: 5 for 100% completion, 4 for 75%, 3 for 50%, 2 for 25% and 1 for < 25%.
The evaluation criteria were integrated into a six category, 30 point clinical assessment score with each category worth 1 to 5 points (see chart). In this 30 point scoring system a point total of 25-30 was considered excellent, 20-24 good, 15-19 fair and <15 as poor or failure.

Clinical Assessment Score - Transtibial

1. Pain

a. no pain/ignores	5
b. slight pain/ no compromise in activities	4
c. mild pain with normal activity	3
d. pain with standing in prosthesis	2
e. pain w/o prosthesis	1

2. Function

a. unlimited walking ability	5
b. 6 - 12 blocks	4
c. 2 - 5 blocks	3
d. 1 - 2 blocks	2
e. indoors only or wheelchair assistance	1

3. Stability

a. no weakness/no limitations	5
b. difficulty with uneven terrain	4
c. difficulty with stairs/ inclines	3
d. extremity weakness	2

	e. thigh lacer/walking aids(cane/crutches)	1
4. Swelling of residual limb		
	a. none/minimal/no socket compromise	5
	b. with walking 6-12 blocks	4
	c. " walking 2-5 blocks	3
	d. " " 1-2 blocks	2
	e. with indoor walking	1
5. Hours of prosthetic wear		
	a. 14-18 hours	5
	b. 10-13+ "	4
	c. 6-9+ "	3
	d. 3-5+ "	2
	e. 1-2+ "	1
6. Radiographs		
	a. full synostosis	5
	b. up to 75%	4
	c. up to 50%	3
	d. up to 25%	2
	e. no synostosis	1

Grading	30 point
excellent	25-30 points
good	20-24
fair	15-19
poor	<15

Results - Transtibial

Overall: 143 patients with 150 osteomyoplastic residual extremity reconstructions with greater than 2 year and average 9 year follow-up were available for review.

The final overall results using the 30 point rating system demonstrated 110 (73.3%) excellent, 28 (18.7%) good, 8 (5.3%) fair and 4 (2.7%) poor. Overall patient satisfaction was 97.3%. These patients felt their final result improved the residual extremity function and quality of life stating they would repeat the surgery again. The 4 poor results occurred in patients with peripheral vascular disease. These patients were placed in this category as they continued to experience residual extremity pain in spite of improving in other parameters. In these 4 patients pain limited ambulatory ability and length of prosthetic wear resulting in a limited functional result and an overall poor rating.

The overall results using the 30 point clinical assessment score for all patients was 26.98 points. Post traumatic amputees demonstrated a mean score of 25.47 points and vascular amputees demonstrated a mean of 20.51 points. The results in each category were broken down and improvements levels expressed as point improvement.

Pain: All patients complained of preoperative residual extremity pain of varying degrees. The average pre- and postoperative score for pain were 1.57 and 4.13 respectively. The average decreases in pain was 2.41 points. A total of 139 patients obtained pain relief while four vascular patients showed no improvement.

Function: The average pre and postoperative scores were 2.45 and 4.55 points respectively, with an overall average improvement of 2.10 points. Those patients who participated in sports pre-operative returned to the same or higher level post-operatively. All patients showed at least 1 level of improvement in their functional abilities.

Subjective stability: Stability was expressed as residual extremity control, subjective strength and precieved proprioception. The average pre and postoperative operative scores were 2.20 and 4.28 points respectively. An average increase was 2.08 points. All patients achieved gains in this category.

Swelling: The average pre and post-operative score for swelling was 2.75 and 4.37 points respectively. The average decrease in swelling of the reconstructed extremity improved 1.62 points. A total of 131 of 150 extremities showed an improvement in their reconstructed extremities.

Length of prosthetic wear: The average pre and postoperative average total time of prosthetic wear was 9.15 hours/day and 14.50 hours/day respectively. The average increase in prosthetic wear was 5.35 hours/day. This correlated to an average pre and postoperative score of 2.75 and 4.51 points respectively.

Radiographs: Complete synostosis formation occurred in 141 (94%) limbs. Synostosis was completed at 6-8 weeks with progressive remodeling and ossification on successive x-rays. Complete ossification was seen on the average of 3 to 4 months postoperatively with maintenance of the tibiofibular relationship. Nine (6%) limbs demonstrated incomplete synostosis formation, 4 with 75% completion, 3 with 50% completion and 2 with 25% completion. One 25% completion occurred in a pvd patient who was graded as poor. The other 25% occurred in an individual who sustained a grade III open tibia fracture which underwent multiple attempts at limb salvage, free muscle transfer and STSG, eventually requiring amputation for persistent pain and infection.

Description of Procedure: Transtibial

The patient is informed of all possible surgical risks, complications. In very short residual extremities the possibility of knee disarticulation or above the knee level may be necessary. All attempts are made to maintain the knee and residual extremity length to spare the cost of increased energy expenditure. The patient is also informed of the possibility of bone graft harvest locally or from the iliac crest. A diagrammatic transverse section of the extremity is also of assistance in anatomic structure identification during surgery.

The extremity is prepared in standard fashion. A tourniquet is placed on the upper thigh and used as indicated. Discression is used in the vascular amputee. Occasionally a bump is placed under the affected hip to assist in limb rotation. The previous incision are identified and utilized. We have found no difference in the final result with AP, medial/lateral or oblique incisions.

The incision is made and dissection carried to the muscular layer. Frequently the residual extremity has no distal bony muscular coverage, the musculature having been poorly secured or allowed to retract at the time of initial amputation. In this case the dissection is carried proximal and the anterior, lateral and posterior musculature identified and isolated. Often a long posterior muscle flap has been used and secured anteriorly to bone. In this situation care should be taken not to transect the muscle belly and sacrifice muscle length. This could also lead to difficulty in neurovascular isolation as many times these structures are brought forward as well. The posterior flap is isolated and released from its anterior attachment, fascial scar attachment is maintained on all musculature for later myoplastic reconstruction.

The neurovascular structures are now identified, released from scar tissue and separately isolated. Depending on the amputation level the major neurovascular bundles are isolated, these include the tibial nerve, artery and vein, peroneal artery and vein, superficial peroneal nerve and deep peroneal nerve artery and vein (fig). This may be difficult as the neurovascular bundle has usually been ligated together and is embedded in scar. Palpation for a probable neuroma is performed to assist in neurovascular identification. The saphenous and sural and sural nerves should also be identified, however at times may be very difficult to find and a great deal of time should not be spent searching for them. Once identified the nerve, artery and vein should be isolated. Of importance is to separate the nerve and artery so the pulsations, of the artery do not constantly irritate or stimulate the nerve. The nerve is separated, distracted, transected as proximal as possible and allowed to retract into a soft tissue bed. The tourniquet may be released at this time to evaluate and gain control of any bleeding. On reconstruction the vascular structures are very friable and should be handled gently, for fear of tearing or proximal retraction. The artery and associated veins are separately ligated. Once control of the vascular structures has been obtained the tourniquet may be elevated again.

Attention is now directed towards the distal end of the tibia and fibula. The periosteum is incised anterior to posterior longitudinally on both bones. Utilizing a 45 degree angled chisel (not osteotome), an osteoperiosteal flap is elevated medially and laterally, maintaining the proximal attachments. Cortical fragments are left attached to the periosteum, this if facilitated by rotating the chisel 180 degrees to assist in cortical elevation. This procedure is also performed on the fibula. Occasionally it is necessary to split the fibula longitudinally creating medial and lateral osteoperiosteal cortical flaps. These flaps are sutured together in tube like fashion. The lateral tibia flap is sutured to the medial fibular flap creating a superior barrier. The medial tibial flap is sutured to the lateral fibular flap creating an inferior barrier. Progressive osteogenesis occurs with eventual bony bridging or synostosis formation and fibular stabilization.

In short or very short residual extremities, free osteoperiosteal grafts are harvested from the proximal tibia or iliac crest to maintain length. This may also be performed on any length of residual extremities. We have utilized free osteoperiosteal grafts in primary amputations harvested from the amputated extremity without difficulty and complete synostosis formation.

The previously mobilized muscles are brought distally covering the osteoperiosteal bridge and tibia forming the myoplasty. The myoplasty may be completed by suturing the posterior to the anterior and lateral muscles or in a pants over vest fashion securing the posterior muscle into the osteoperiosteal bridge. Distal bony coverage and padding are achieved in addition to placing the muscle under tension and reestablishing an insertion. Extremity length may also be gained with distal muscle coverage.

The skin is fashioned to the underlying myoplasty. Care is taken to reapproximate the flaps in a symmetric fashion not to leave dog ears or crevices allowing air leaks. A smooth contour allows for a better total contact socket fit with a cylindrical residual extremity contour as the goal. Penrose drains are placed through the incision prior to complete incisional closure.

Postoperatively the extremity is immobilized in an extension plaster splint which is removed in one week. A bulky soft tissue dressing is applied with an extended 4 or 6 inch ace bandage. Sutures are removed between 2 and 3 weeks depending on wound healing. Temporary total contact end bearing prosthetic fitting is coordinated with the patients CPO and completed between 4 and 8 weeks. Physical therapy is instituted for transfers, aerobic training and upper body strengthening.

Discussion

The Ertl osteomyoplastic lower extremity amputation procedure was first applied in post World War I Hungary and initially described in 1939 by Professor Janos v. Ertl, MD, whose experience was based on treating over 13,000 amputees. The principles of the surgical technique were not only limited to the amputation field but had their origins in the field of reconstructive surgery. The procedure arose from the observation of the regenerative potential of the periosteum in bony injuries of the mandible and skull from frequent trench warfare injuries in World war I. Through these observations arose the utilization of the Ertl osteoperiosteal graft for bone defects in the skull, mandible, long bones, hand and spine in addition to amputations.

The application of the osteoperiosteal graft in amputation surgery has a similar history as did internal fixation in Switzerland. In post war Hungary a large portion of the population had lost their lower limbs to trauma. These injuries limited the manpower for the countrys rebuilding efforts. The government challenged surgeons to assist in returning these people to the active work force, as the prosthetic industry was not as advanced. The osteoperiosteal graft was applied in association with myoplasty, neurovascular isolation, smooth skin closure. This provided the patient with a cylindrical residual extremity creating a durable end bearing limb and is referred to as the Ertl procedure. The original procedure being based on the reconstruction of the limb to as normal an anatomic, physiologic and biologic state as possible in addition to correcting for the poor prosthetic fit at the time.

In direct contrast to the earlier part of the century the modern era of the prosthetic industry, with its current technology, has made great advances correcting for less than adequate amputated residual extremities. We believe this situation is based on the defeat amputation implies to both the surgeon and the patient. The loss of a limb effects the patient profoundly in both function and violation of appearance in the entirety of the body and its image, implying failure. In addition the procedure of amputation is often relegated to the most junior member of the surgical team at a time when the orthopaedic community is abdicating their role in amputation and prosthetic education (Orthopaedics Today).

According to Loon & Inman, difficulties as a result of amputation fall into two categories. First are those that are directly related to the amputation including pain, circulatory disturbance, and secondary skeletal and muscular changes. The second are those problems which arise from the attempt to restore function by means of a prosthetic device. On the basis of our clinical observations amputation difficulties of the residual extremity included pain, swelling, bone and soft tissue atrophy, poor extremity control and excessive fibular motion leading to extremity inactivity. We have termed this the inactive residual extremity syndrome as the residual extremity becomes inactive and is utilized only as a passive prosthetic attachment. In spite of a well performed amputation and well fitted prosthesis patients may continue to experience a combination of these symptoms. The osteomyoplastic reconstruction addresses these difficulties by attempting to reestablish the active function of tissues in preparation to accept a prosthesis and actively participate in ambulation.

In conventional amputation the medullary canal is left open, allowing intramedullary circulation to connect with the extraosseous circulation. It has also been advocated to strip the periosteum and endosteum creating an avascular segment (Hirsch-Bunge). This procedure is not recommended as it creates an avascular segment resulting in bony tenderness and ring sequestra. The osteoplastic closure of the medullary canal is performed by approximating osteoperiosteal flaps, creating a synostosis and closure of the medullary canal. A 1.5 cm length is used from both the tibia and fibula reapproximating the flaps in a tube like fashion. In very short residual extremities osteoperiosteal bone graft may be harvested from the proximal tibia transversely, iliac crest or rib. We utilize osteoperiosteal flaps as the contribution of the periosteum has been shown to favor osteogenesis over endosteum (Kojimoto 1988). The medullary closure also reestablishes normal physiologic conditions within the residual extremity. Normal bone demonstrates an intramedullary pressure of approximately 65mm Hg (Ascenzi 1972) exceeding that of normal venous pressure. This increased pressure is necessary to maintain a centrifugal drain in a rigid tubular bone which lacks a pump mechanism and valves. The medullary pressure plays an important role in venous drainage (Lopez-curto et al 1980) and probable osteocyte nutrition (Sturmer 1993). Loon observed several interesting phenomena on performing intraosseous venograms and intramedullary pressure measurements on patients amputated limbs and of the normal legs for comparison. In the amputated limb with an open medullary canal, he noted a decrease in intramedullary pressure to 0mm Hg, a slowed clearing time of dye and dilated, tortuous intramedullary sinuses. With subsequent medullary closure these conditions appeared to return to normal(Loon 1962,63) and improve the vascularity of the residual extremity (Langhagel 1968, Hansen-Leth 1976). In addition to improved vascularity the fibula is stabilized preventing lateral deviation (wandering fibula), motion and rotation as well as providing a broader surface area and foundation capable of end bearing.

Following amputation the muscle blood flow is essential for primary healing and future function. After conventional amputation the muscles are cut and allowed to retract depriving them of an insertion. The muscle atrophies, undergoes fatty degeneration, circulation decreases, venous return is no longer aided by the muscles pumping action leading to stasis and edema. With loss of an insertion, the length-tension relationship is lost, effecting the speed, strength and range of shortening of the muscle. Angiographic studies following amputation show an
initial hypervascularity and tortuosity of the vessels (Leriche 1950). This hypervascularity decreases and gives way to a hypovascular state maintaining the tortuous and corkscrew formation of vessels 1 - 2 weeks after amputation (Hansen-Leth 79). Similar angiographic findings were demonstrated in patients with vessel occlusion and peripheral vascular disease indicating pathologic circulation (LeRiche 1950, Erikson,Hulth 1962, Erikson 1965). On further angiographic evaluation callous growth beyond the cut ends of bone was seen demonstrating arteriovenous connections creating a shunt effect in the venous filling phase.

In the myoplastic portion of the procedure, the flexors are sutured to the extensor muscles covering the osteoperiosteal bridge and reestablishing muscle tension. Angiographic studies post myoplasty have shown an increase in circulation applying to both arterial supply and venous return through improved muscular function (Hansen-Leth & Reiman 1972). Changes in muscular vascularity have been demonstrated to be further compromised by inactivity and immobilization, which is reversed with myoplasty (Hansen-Leth 1979). With increased activity and utilization of the musculature following myoplasty may lead to return of muscle mass, increasing the surface area available for socket fitting (Stokosa). Vascular amputees have also been shown to benefit from myoplasty with improved terminal circulation(Medhat 1983). Function of the extremity is also improved with walking as more rhythmic and phasic activity is seen on EMG studies as opposed to an irregular pattern seen without myoplasty (Condie 1973).

Edema in the residual extremity is of concern because of frequent volume changes and is the result of altered physiologic conditions brought on by amputation (Loon 1962,63). This is secondary to inactivity of the residual extremity brought on by changes in bone and muscle. The volume changes of the residual extremity effect the patients ability to fit into the prosthetic socket limiting ambulation and may lead to skin problems. Inactivity and the inability to load bone lead to atrophy of bone and muscle producing osteoporosis, poor venous return, loss of the muscles pumping action and fatty infiltration. Osteomyoplastic reconstruction has been shown to reverse these changes maintaining constant residual extremity size.

Pain is a complex issue in the amputee and may arise centrally as phantom sensations or from local changes. Pain is the most frequently occurring and most disabling symptom for which the amputee seeks assistance. In our clinical assessment we attempted to separate phantom pain from physiologic extremity pain. Following osteomyoplastic reconstruction we have noticed a decrease in the patients local pain symptoms as well as a reduction in phantom sensations. The local pain sensations may arise from neuromas, circulatory disturbances, scar, sensitive bone ends or cutaneous sensations from soft tissue breakdown. By surgically reconstructing as near normal a physiologic state with medullary closure, high neuroma resection, myoplasty and careful skin closure, there is a decrease in the patients experience of pain. The decrease in phantom pain, which is also seen, may be associated with improved function and use of the residual extremity.

The subjective stability assessment was an attempt to quantify proprioception. The osteomyoplasty gives the patient a stronger end organ, rotational control with the capability of end bearing, allowing greater feedback from the ground. The patients also experienced a greater sense of security and control of their extremity in space and weight bearing. Functional gains showed great improvement and were related to the reduction in pain and increased sense of stability. As their function improved, patients appeared to become more confident pushing to increase their walking distance. Although the four vascular amputee patients who did not obtain significant pain relief, however they did show improvement in their ambulatory potential. We postulate that pain may be from persistent vascular claudication.

Previous prospective evaluation of the Ertl osteomyoplastic procedure with conventional amputation was attempted by Deffer, LaNoue et al in 1971. 290 war casualty transtibial amputees were identified whose average age was 22 years. Patients were selected on the basis of their dissatisfaction with prosthetic fittings and activity intolerance and pain. Early in the study the osteomyoplastic group demonstrated an increased activity level and decreased symptoms creating a trend for those with conventional amputation to demand the Ertl procedure. Deffer presented his results with the Ertl osteomyoplastic procedure in 155 patients followed over a 5 year period, at the 38th AAOS meeting. Their conclusions were that the osteomyoplasty produced a more stable and durable residual extremity with end bearing capabilities. This conclusion has also been supported by Loon and Murdoch who in addition stated the residual extremity was more powerful and prosthetically more satisfactory providing better adherence to the socket.

Conclusion

The efforts of the osteomyoplastic procedure are directed at creating a functional and active residual extremity based on reestablishing a physiologic environment. The resultant residual extremity will afford the amputee with a stronger and more durable limb with improved stability and proprioception. No unnecessary length is sacrificed to achieve the end result. We have utilized free osteoperiosteal grafts to form our bone bridge in short residual limbs in order to maintain length and achieve the desired results. In longer residual limbs minimal length is removed, if any, as has been inaccurately described (Smith 1993, Bowker,1992). In addition the overlying myoplasty will contribute to the total length of the extremity. The surgeon should not hesitate to sacrifice length when an increase in function can be achieved (Loon 1963). We have successfully applied this reconstruction to both initial and secondary amputations.

The difficulty with assessing these patients final result is that the final outcome involves variables which may effect the results, for example socket design, prosthetic componentry and the use of different prosthetists with varying experience. Our overall experience has been rewarding in treating amputees and we wished to share our results in an objective fashion with the surgical and prosthetic communities.

The osteomyoplastic lower extremity amputation reconstruction is technically challenging with a somewhat greater operative time than the conventional technique. It and may be used for both traumatic and vascular amputations with high success and high patient satisfaction. This procedure offers the surgical community with a dynamic procedure for both primary and secondary reconstructions in lower limb amputation surgery.

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