The Ertl Osteomyoplastic Amputation: History, Philosophy, Misconceptions, Misapplications

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"The biological surgical thought process is the ability to appreciate the healing powers of nature and recognize its regenerative ability. The regenerative process attempts to create optimum healing through remodeling guided by reconstruction. In effect, the surgeon's knife becomes an instrument of nature."

— Janos von Ertl, MD (1949)

Surgeons can and should have an important role in amputee care. The surgical result that any amputee receives will have a direct impact on the prosthetist's ability to apply a functional prosthesis, and in turn determines the rehabilitation potential of the amputee. In effect, the patient and the residual limb are the foundation from which success will be determined.

History

The philosophy of the osteomyoplastic amputation arose from clinical observations of the healing potential of the human body. During World War I, Janos von Ertl, MD, was charged with reconstructing maimed Hungarian veterans, many of whom had craniofacial injuries. He observed the healing potential of bone, specifically the role that periosteum plays in fracture healing. He used his understanding of the biology and physiology of bone to manipulate periosteum to heal bony facial defects and then performed soft-tissue reconstruction to improve both cosmetic appearance and to restore function. Ertl developed a bone graft (Figure 1) consisting of periosteum and cortical bone chips—an osteoperiosteal bone flap. The graft was unique in that it was flexible and, when placed in the proper environment, it would regenerate a solid osseous structure. The application of this flexible bone graft was then expanded to cranial defects, long-bone non-unions, joint fusions, posterior spine fusions for tuberculous scoliosis, and amputations.

Figure 1: This photograph demonstrates the flexible nature of the osteo-periosteal bone flap.

Prostheses of that era were uncomfortable by today's standards. By providing the patient with a limb that was end-bearing, Dr. Ertl vastly improved function and comfort. He combined the two predominant amputation thought processes at the time. Some surgeons believed in only soft-tissue reconstruction—myoplasty—as the proper form of limb reconstruction. Others, such as Bier, felt that osseous reconstruction—osteoplasty—should be the predominant surgical technique. Hence, Dr. Ertl combined them in the creation of the osteomyoplastic amputation that requires both bony and soft-tissue reconstruction to provide an end-bearing residual limb for the amputee.

As early as 1918, Ertl emphasized in his published works the importance of proper limb reconstruction based on the osteomyoplastic technique for the transfemoral, transtibial, and transmetatarsal amputation.[1] Clinically, he observed, "Thus, according to these principles, it was surprising that the amputees were able to tread with *full body weight* upon the stump. The stumps did not shrivel up, but rather were found to be in a definite state of healing. They no longer needed sloped prosthetics to relieve the weight."[2,3]

Transtibial Surgical Technique

The fundamental principles of osteomyoplastic transtibial amputation are osseous and soft-tissue reconstruction that provide a pain-free, stable, end-bearing residual limb. To accomplish these goals, osseous reconstruction requires the surgical creation of a synostosis between the tibia and fibula utilizing osteoperiosteal bone flaps. Soft-tissue reconstruction should utilize all compartmental muscles, not just the posterior compartment.

During the surgical approach, the tibia and fibula are exposed distal to the expected final bone length so that osteo-periosteal tissue can be elevated from these bones. There can be several surgical approaches for a primary transtibial amputation. We favor the skew approach, which allows for much easier exposure of the limb, almost like a tulip blooming or the peeling open of a banana. The sagittal approach may place an incision too lateral, thus not allowing for adequate exposure. The standard midcoronal approach, similar to the long posterior flap, creates two large, bulky flaps and may make it challenging to obtain adequate soft-tissue stabilization. The tibia and fibula are then transected at the same level and the osteo-periosteal bone flaps are sutured together to create a tube between the tibia and fibula (Figures 2A and 2B). The synostosis should not be created proximal to the end of the tibia because this will negate any potential benefits of end-bearing by decreasing the surface area of the bone bridge. Over time, the synostosis remodels and appears to obtain the radiographic characteristics of mature bone (Figure 3). Only about 2–3cm of bone may need to be removed from the tibia and fibula to provide adequate osteoperiosteal bone flaps. Additionally, osteo-periosteal flaps can be harvested from the contralateral limb if needed. Utilizing screws is not necessary to obtain a bony union. When placed, they may need to be removed, especially if there are radiographic signs of stress shielding.

Figure 3: Transtibial osteomyoplastic patient two years following surgery. The bony bridge appears to have developed

radiographic characteristics of mature bone.

Neurologic structures should be dissected from vascular structures and resected as proximal as possible and not be tethered or buried. These include the deep and superficial peroneal nerves, saphenous nerve, sural nerve, and tibial nerve. Soft-tissue stabilization is performed by myoplasty technique utilizing the superficial posterior, anterior, and lateral compartments (Figure 4A, 4B, and 4C). The muscle groups are usually sutured into the fascial constraints of the various compartments. Sutures can then be passed through the periosteum of the bone bridge to get additional anchoring and stability. To obtain soft-tissue stabilization, non-absorbable suture is used to obtain and maintain stabilization. This can be reinforced with a resorbable suture to provide a scarring inflammatory response. Soft-tissue tension is assessed intra-operatively. When performing this soft-tissue stabilization, the muscle groups are brought over the end of the residual bone and tensioned to provide tone to the muscle. Too much muscle laxity will create an unstable soft-tissue envelope that may also create instability in the prosthetic socket. Care should be taken not to tension the skin during closure.

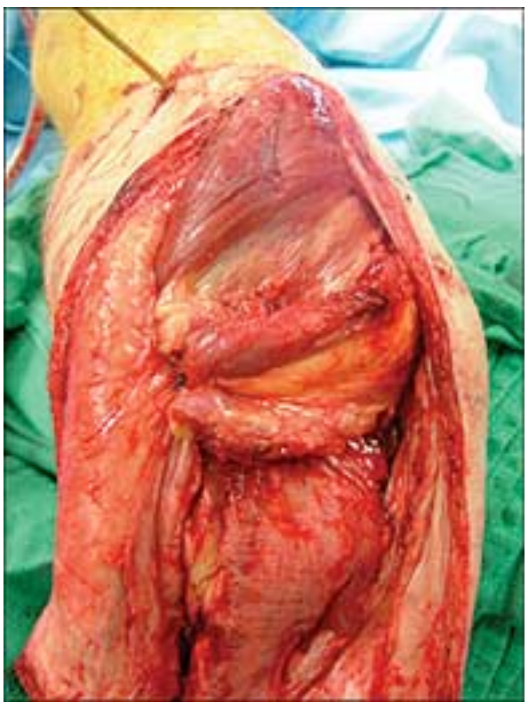

Figure 4A: Anterior and lateral musculature secured during myoplasty portion of the surgery.

Figure 4B: Superficial posterior compartment then utilized for additional soft-tissue stabilization.

Figure 4C: The resultant closed limb establishing a cylindrical shape.

Paramount to the procedure is selection of the correct level of amputation, especially in dysvascular and diabetic patients. Non-invasive studies, such as TcPO2 and arterial ultrasound, aid in determining the appropriate level. Diabetic patients also need to have their glucose levels well managed to prevent post-operative wound infections. The main and possibly only contraindications to this surgery would be the absolute nonambulating patient and the patient who requires an emergency amputation for life/limb-threatening infections/injuries. In that situation, an open amputation can be performed and then revised using the osteomyoplastic technique at a later date.

Transfemoral Surgical Technique

Transfemoral amputees also benefit from reconstructive amputation surgery because they rely exclusively on proximal musculature for ambulation. Without the surgical stabilization of the muscle groups within the residual limb, the work of ambulation increases dramatically, and the patient has less control of his/her prosthesis. With the loss of stability of the adductor muscle group, the residual limb then assumes an abducted position or "lateralizes." This creates an inefficient gait pattern in both the swing and stance phases of gait, in turn increasing oxygen demand, which can add greater cardiac stress, especially in patients with cardiopulmonary disease.

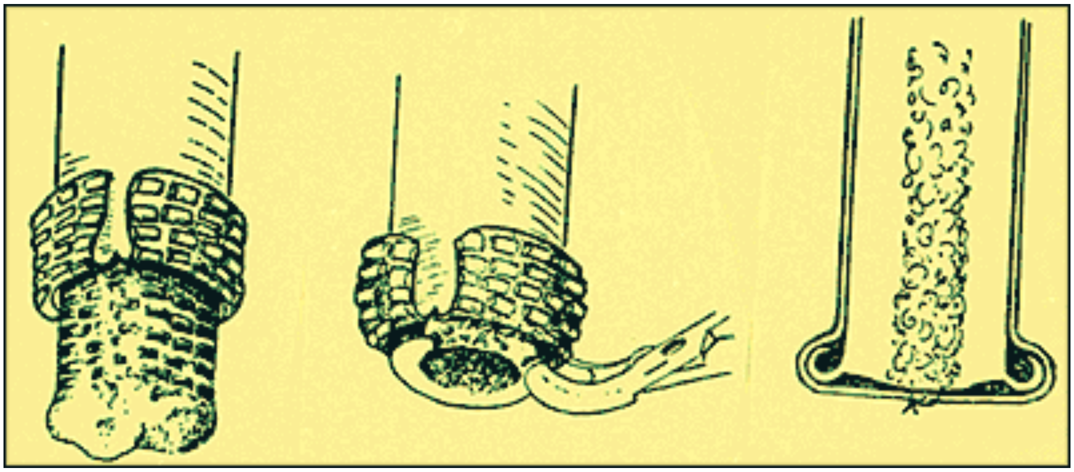

Figure 5: Schematic of medullary closure of the femoral canal with osteo-periosteal bone flaps.

In an osteomyoplastic amputation for the transfemoral amputee, a mid-coronal approach producing equal anterior and posterior flaps is our standard technique. Once all the anatomical structures have been identified and dissected, the distal portion of the femur is transected. Osteo-periosteal flaps are elevated from the femoral cortex, and the femur is shortened. In primary procedures, the surgeon only resects the necessary amount of bone to provide an appropriate length for the residual limb. In secondary or revision amputations, the amount of femur resected will depend on the quality and quantity of the soft-tissue envelope. Bone allograft may be packed into the medullary canal, and then the medullary canal is closed by suturing the osteo-periosteal flaps over the femur (Figure 5). Soft-tissue stabilization is performed by first reconstructing the adductor attachment to the femur by suturing the adductor muscles and the gracilis, if available, to the femur through drill holes. These drill holes assist in the medial stabilization of the adductors so that they will not sublux over the end of the femur. The flexors (hamstrings) and extensors (quadriceps) are then sutured together in a layered fashion to provide additional soft-tissue coverage over the residual femur (Figure 6). Performing a deep and superficial layered closure can prevent post-amputation bursa formation. The sciatic nerve should also be resected as high as possible and allowed to retract into the proximal soft tissue to prevent the formation of a painful neuroma.

While there is no bone bridge that can be formed, an "endcap" is formed, which closes the medullary canal, restores the venous gradient within the medullary canal of the femur, and restores near normal vascularity as demonstrated by Dederich.[4] The resultant residual limb can and should be able to accept an end-bearing load. A total-surface-bearing prosthetic socket should be constructed to optimize the benefits of this surgical technique.

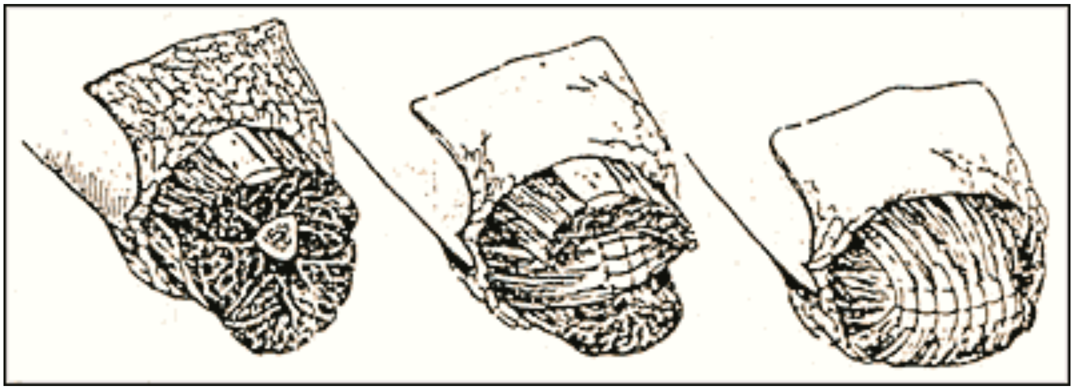

Figure 6: Schematic of soft-tissue stabilization for the transfemoral osteomyoplastic amputee.

Prosthetic Advantages

In our clinical experience, the osteomyoplastic amputation improves prosthetic fittings. A pain-free limb not only improves a patient's quality of life but it also results in less time and adjustments needed to make a prosthetic socket. A stable limb that does not atrophy significantly over time requires fewer socket changes. End-bearing on a residual limb lowers the center of rotation between the limb and the socket. This improves balance and reduces unwanted forces on the patient's limb. With end-bearing, less overall pressure on the remaining surfaces of a patient's residuum are required. Proximal trim lines may also be lowered, which improves comfort and cosmesis.

Conclusion

The osteomyoplastic amputation, or Ertl procedure, is the application of a philosophy of bony and soft-tissue reconstruction. The technique is not just about the bone bridge. The residual limb is a multi-organ system that requires reconstruction at all levels. This technique provides a stable, dynamic limb that allows for efficient rehabilitation, long-term health, and easier, more functional prosthetic fittings.

References

1. Ertl J. *Die Chirurgie der Gesichts - un Kieferdefekte*. Wien, Austria: Urban & Schwarzenberg; 1918. This book reviewed and summarized Ertl's surgical experiences and laid out the foundation of how proper surgical technique can restore function.

2. Ertl J. *Regeneration; ihre Anwendung in der Chirugie*. Leipzig, Germany: Verlag von Johann Ambrosius Barth; 1939. Ertl also summarized his surgical approach for a large range of surgeries, including amputation and reviewed the biology of osteoperiosteal flaps.

3. Ertl J. ber amputationstmpfe. *Chirurg*. 1949;20:218. Ertl's seminal article on the procedure.

4. Hansen-Leth C. Muscle blood flow after amputation with special reference to the influence of osseous plugging of the medullary cavity assessed by 133 xenon and

histamine an animal experiment. *Acta Orthopaedica*. 1976; 47(6):613–618.

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