Orthoplastic Extremity Reconstruction

Since the days of Hippocrates, surgeons have treated traumatized extremities. By definition, a patient sustaining an open fracture has a soft tissue injury as well as a bony injury. These two injuries are inextricably linked. Since the days of Hippocrates, fracture stabilization has been performed by using splints or external fixators, and soft tissue injuries have been treated with various potions and salves. The need for proper limb alignments, soft tissue as well as fracture healing, has been the subject of medicine throughout the modern era.

The history of medicine allows us to introduce the concept of orthoplastic surgery. Individuals such as Ambroise Pare, Gaspar Tagliacozzi, Dupuytren, Velpau, and Malgaigne had careers as master surgeons. Ranging from the 16th Century to the middle of the 19th Century. If we read the history of orthopaedic surgery or the history of plastic surgery, each of these individuals are mentioned as founding fathers of these respected specialties.

The evolution of surgical specialties really developed at the conclusion of the 19th Century. Modern plastic surgery has its roots in the trenches of World War I and is approximately 100 years of age. Probably the first modern orthopaedic plastic collaboration was between W. Arbuthnot Lane and Sir Harold Gilles. In 1919, Lane an orthopaedic surgeon wrote the preface for Major Gilles’ textbook, and so began the modern era of “orthoplastic surgery”.

The development of reconstructive microsurgery allowed modern orthoplastic surgery to develop. In 1960, Jacobsen and Suarez introduced the operating microscope for the suture of small vessels. In 1968 Tamai reported the first successful digital replantation. Other microsurgical successes evolved in the later part of the 1960’s. Composite transfers of vascularized tissue became commonplace in the 1980’s, with an explosion of techniques, flaps, and the popularization of microvascular surgery not just for the traumatic injury of the hand and replantation, but also for elective reconstructive surgery.(1) Refinements continue to take place such as flap exapansion, prefabrication, and modification of tissue transfers in the 90’s.(2,3) In the later part of this millennium, government agencies, surgical societies, and insurance companies began to ask for “outcome data” as it relates to subjects such as cost effective medicine, or patient satisfaction to determine whether complex microsurgical procedures actually help patients, and improve quality of life. (4,5) Keller, AAOS, 1990)

Orthoplastic surgery as we define it is “the principles and practices of both specialties applied to a clinical problem either by a single provider, or teams of providers working in concert for the benefit of the patient.”(5,6,7)

37 years after Tamai’s report that generated interest from surgeons around the world such as Harry Buncke (Plastic Surgeon), Harold Kleinert (General Surgeon), Jim Urbaniak (Orthopaedic Surgeon), Alain Gilbert in France, care of the Mutilated Hand with Microsurgical technique is standard practice.
There has been a gradual shift in training from orthopaedic surgeons performing microsurgery currently, where mainly plastic surgeons do microsurgery, depending on nationality. Hand and microvascular fellowships may or may not prepare young surgeons adequately to perform the full spectrum of reconstructive microsurgery which is vitally important in orthoplastic reconstruction.

If we look at plastic surgery specialization over the last 50 years; burn care, aesthetic surgery, craniofacial surgery, and hand surgery have all become subspecialties of plastic surgery. Similarly orthopaedic specialization has occurred with development of separate societies concentrating on pediatric orthopaedics, trauma, musculoskeletal oncology, and hand surgery. Orthopaedics is a specialty that mainly concentrates on function biomechanics, bone and joints. Plastic surgery is specialty that concentrates on aesthetics, form and soft tissue reconstruction. The blending of these two specialties, “orthoplastic surgery”, allows the principles and practices of both specialties to be applied to clinical problems simultaneously.

Historically, process based outcome analyzes parameters such as healing, range of motion, biomechanics, and flap success. Now more emphasis is placed on patient based outcome as it relates to factors such as pain, functional outcome, satisfaction and patient quality of life. When the outcomes movement began, the challenge was to be able to demonstrate this highly variable and very expensive and complicated surgery for limb salvage, (orthoplastic surgery) is cost effective and can make the patients better. According to Keller in the Journal of the Academy of Orthopaedic Surgeons in 1990 if surgeons cannot demonstrate this, then their services could no longer be paid for! (8,9)

**LIMB SALVAGE**

We have learned a great deal about limb salvage compared to immediate amputation in the injured lower extremity. We have clear indicators based on clinical assessment and scoring systems, for patients before we perform immediate amputation. (1) For example, a limb that has multiple levels of comminution, or an elderly patient with a disrupted posterior tibial nerve, ipsilateral crush to the tibia and foot, precludes limb salvage. Patients that have long protracted periods of ischemia with nerve disruption also make limb salvage unfeasible. We must avoid [as we go forward in care for our patients] the triumph of “technology over reason”. A clear understanding is needed of prosthetic of alternatives for both upper and lower extremity amputees particularly as it relates to the new technology such as carbon fiber, pilons, energy absorbing ankle articulations, and special materials that allow one to couple the prosthesis to extremity producing comfort and durability for the patient.[figure 3a&amp;b] Similarly in the upper extremity the use of prosthesis such as the myoelectric prosthesis and prosthesis such as the “Utah arm” for patients undergoing shoulder disarticulation injuries or tumors to the upper extremity are important to appreciate as alternatives to limb salvage. (10,11,12)

Orthoplastic surgery can be categorized into trauma, tumor, and septic conditions, both in the upper and lower extremity. In addition to understanding the indication for amputations and the alternatives to limb salvage such as a prosthesis, the modern orthopaedic surgeon should understand that there are techniques, based on biomechanics and soft tissue reconstruction, that enable the potential amputee to have a better functional residual limb.(13) These include island pedicle or free flap, fillet flaps to preserve not only sensibility but leg coverage. For example, in the patient that has a severe lower extremity crush injury to the tibia with a normal foot and a normal knee, that may require resurfacing or knee joint preservation, it may require that the foot be filleted as an island pedicle flap or even as a free flap to provide below knee coverage. (pictures of below knee fillet flap salvage). [figure 3a-c] The
concept of fillet flaps classifications, indications, and analysis of the clinical value has been well described by Germann and others from Germany. Other examples of soft tissue augmentation of an amputation include the patient with a hip disarticulation, the patient with a mid-foot amputations that can be effectively and more functionally rehabilitated with a better soft tissue envelope often using microsurgical techniques. (Case Example). (14,15) [figure 4a&b]

The greatest advances in orthoplastic surgery have been in the domains of trauma, tumor, and septic reconstruction. In the upper extremity, microsurgical revascularization, rigid stabilization, and soft tissue reconstruction are common techniques for limb salvage.(16-22) In addition we are now concentrating on the aesthetic aspects of post traumatic reconstruction, and techniques such as endoscopic tissue expansion can be applied to the traumatized limb, to not only release contractures but resurface the extremity for a more aesthetically pleasing result, that may have positive psychological implications for the patient. (English) (23-29) [figure 5a-e]

One of the early pioneers in modern orthoplastic surgery is Marco Godina, who introduced several important concepts to extremity salvage efforts. First was the concept of radical necrectomy. This implies that all non viable tissue can be resected and then immediately covered, such as one would perform in tumor surgery with microsurgical reconstruction. Second, the concept of one stage reconstruction, where as much can be done on bony and soft tissue for coverage and function is very important, and is now practiced. (30) [figure 6a-d]

In upper extremity tumor reconstruction, orthoplastic surgery integrates concepts from reconstructive plastic surgery into orthopaedic oncology. For example in a child with a chondro sarcoma in the humerus that requires intercalary humeral reconstruction, the techniques related to tumor removal fixation, vascularized bone grafting, and functional rehabilitation are all important and must be coordinated.

One of the great tools in orthoplastic surgery is the use of vascularized bone tissue, specifically the fibula.(31-35) The fibula has undergone an evolution of design, beginning with transplantation of vascularized bone only. In the 80’s and 90’s the popularity of the peroneal system that can carry skin, muscle, and even innervated tissue has enjoyed popularity. An example of this reconstruction is the osteotucaneous fibula graft, for treatment of complex forearm injuries. (31).

One should have a clear understanding of the reconstructive ladder as it relates to the lower extremities in trauma, tumor, and sepsis. The proximal third of the leg, while well suited for the gastroc nemius muscle for relatively small anterior defects, often requires free tissue transfer for closure. One of the principles of orthoplastic surgery, when dealing with traumatic lower extremity lesion is to establish parameters and guidelines for treatment of bone and soft tissue early in the patient’s course, preferably the night of injury. The choice of stabilization (provisional or definitive) or the choice of coverage once an extremity is deemed salvageable, planned bony reconstruction or bone grafting, or tendon transfers, should all be coordinated and a treatment plan defined, so that expeditious care of the patient can be provided.

Just as microsurgery has had a great impact on orthoplastic surgery, the impact of thin wire fixation (the Ilizarov technique) has had a very profound influence on lower extremity and some upper extremity reconstructions. (36) The ability to do distraction osteogenesis and angular correction of bony deformity and juxta articular deformities, has had a great impact on limb salvage, in providing
functioning extremities. This is a very powerful tool, that when combined with microsurgery can serve well the needs of injuries and elective reconstruction of the lower extremity.

Examples of lower extremity salvage include the use of Ilizarov for temporary stabilization of an extremity. Soft tissue work can be done around the frame either with local or pedicle flaps. Then the distraction or conventional bone grafting with the Ilizarov frame can be performed. In the lower extremity as well as the upper extremity the osteocutaneous fibula has been quite a workhorse [figure 8] and can provide up to 20cm of intercortically vascularized bone for femoral or tibia reconstruction. This has been well suited for large defects related trauma or osteomyelitis in the lower extremity and in the femur or preference is to fold the fibula in half, to provide increased cross sectional area that mimics the diameter of the femur.

The evolution of the school of fasciocutaneous flaps popularized by Masquelet, based on angiosomes and perforating vessels has added an armentarium of soft tissue reconstructive techniques that have allowed lower extremity limb salvage in cases where this is no longer possible. (37-40) [figure 7]

Tumor in the lower extremity has been enhanced by the orthoplastic approach; the use of simultaneous free flaps with tumor extirpation and allograft as well as use of the Ilizarov has provided salvage to patients that would have previously undergone amputation. Aesthetic considerations in the lower extremity, like in the upper extremity, can be served by tissue expansion.

OTHER APPLICATIONS OF ORTHOPLASTIC SURGERY

One of the areas in orthoplastic surgery that deserves comment is osteomyelitis. (41,42) Any patient who experiences suppuration has the right to ask the surgeon to explain how it occurred. This was pointed out by Carrel in 1918 and is still true today. Adult osteomyelitis has been classified by Cierney and Mader, based on anatomical type and physiological status. Anatomic types are divided into medulary, superficial, localized, and diffuse. Physiologic class is normal, compromised and treatment deferred. A clinical stage is produced combining anatomic type and physiological class. Based on this it’s possible, as in tumor surgery, to predict outcomes for treatment of longstanding osteomyelitis. (20) Treatment algorithm involves cooperation of soft tissue as well bone surgeons. First radical necrectomy and sequestrectomy is performed on all non viable tissue and implants. A healthy wound and healthy bone is then established. This often involves removal of implants, creation of another stable construct such as use of the Ilizarov or external fixation, treatment of dead space with soft tissue techniques such as free flaps and subsequently coming back and doing bone reconstruction. [figure 9a-c] The role of hyperbaric oxygen plays little role in the treatment of osteomyelitis and the current role of hyperbaric oxygen in extremity salvage is to provide augmentation for granulation tissue so that threatened dysvascular diabetic extremities that are not candidates for microreconstruction or macroreconstruction, can be resurfaced with skin grafts. (1,17)

There are patients that undergo attempted limb salvage with proper planning and execution, only to result in failure, based on chronic sepsis intractable pain or lack of patient desire to continue limb salvage. In cases where there is complex reconstruction undertaken in patients that have threatened extremities, a contract has to be made with the patient and the family, indicating that if reconstructive orthoplastic techniques cannot provide effective limb salvage by a certain date, with a functional extremity, then amputation should be performed.
The diabetic represents a specialized form of limb salvage in that a high percentages of diabetics will develop neuropathy and structural changes based on the neuropathic changes in the foot resulting in the tendency for the foot to undergo abnormal stress resulting in ulceration and skin breakdown. (6) This often results in deep infection in bone in soft tissue and because of diabetic difficulty with healing they are often resistant to conventional treatment techniques. The first determination for salvage of the diabetic threatened extremity is to determine inflow. This is often overlooked by primary care providers and even orthopaedists. Often just simple stenting or vascular bypass procedures can augment blood flow to the extremity, resulting in healing wounds or wound beds that are suitable for simple solutions such as skin grafts or local flaps. (10,19) If in the event large areas of tissue are destroyed, resulting in dead space, or the need for large area resurfacings, free tissue transfer can be considered in conjunction or following a vascular bypass procedures.(4) The propensity of limbs in diabetics to undergo amputation as high as such as 50% at 5 years, and subsequently all attempts should be made to salvage diabetic extremities. (3)

The future of orthoplastic surgery will be based on the possibility of tissue transplantation. In short of this, the use of bone allografts combined, with soft tissue reconstructive techniques have been effective in salvaging extremities (Phil Collins). Other orthoplastic domains also include the reconstruction of the mandible with rigid fixation and vascularized bone grafts. This is a problem similar to osteomyelitis in the extremities. Often radiation induced osteonecrosis, or tumors with localized skin infection, require the need for tumor extirpation, tissue debridement, mandibular stabilization and soft tissue coverage. This can be done similar to the extremities.

Another domain of orthoplastic surgery that has been unrealized is the need for orthoplastic surgery of the chest wall.(12) While soft tissue procedures are designed to treat mediastinitis, and help reconstruct the chest wall, structural instabilities such as sternal nonunion and chronic pain based on sternal instability it can be treated with devices such as custom plates. [figure 10 a,b,c]

The area of minimally invasive surgery as it relates to orthoplastic surgery has been well developed. Current techniques by the author in tissue expansion have been related balloon assisted endoscopic tissue expansion. (PRS Levin) Free flap prefabrication using endoscopic placement of tissue expanders has been well established, and cuts down on the length of time it takes to do complex limb reconstruction. It is true with minimally invasive surgery, and other technologies, those technologies in search of surgical procedures will not sell and be helpful. The future of orthoplastic surgery is further integration with concepts in soft tissue and bone technology and further development of limb salvage and reconstruction.

REFERENCES


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