Welcome to the special session on craniofacial surgery prepared for you by the International Confederation of Plastic Reconstructive and Aesthetic Surgery. My presentation concerns reconstructive plastic surgery as it impacts craniofacial surgery. I am from the Tampa Bay Craniofacial Center in Tampa, FL. This lecture reflects my experiences over the last 40 years, since I was introduced to the field by my mentor, Doctor Joseph Murray of Harvard Medical School in Boston, where I was a house officer in the service witnessing the first such extensive procedure in our country. Today, in craniofacial surgery, we have a perspective that enables us to look over the horizon to see what will be coming our way in this special field in the future. Historical perspectives predict the future advances, and the future is today’s action. For the future, we have skill, science, and diligence. Craniofacial surgery is a global specialty that we would like to keep within the wide scope of plastic surgery. Craniofacial surgery was started by plastic surgeons, and it will stay within plastic surgeons’ activities. More than 40 years ago, the first presentations on craniofacial surgery were made at the international congress meeting in Rome. That record emphasizes the appropriateness of our historical perspective as the keynote lecture here at a similar congress in Berlin where surgeons from all around the world have gathered to see what is upcoming in the field. Craniofacial surgery started on both sides of the Atlantic and flourished on both sides of the Atlantic to spread all over the world as a superspecialty discipline. The focus at first was on the orbits as a technical skill of changing the anatomic boundaries and subsequently addressed all other components as well as involvement of the functional analysis of the craniofacial skeleton.

What we had accomplished during the last 40 years and what we will achieve in the future will continue to stress innovations, science, and new frontiers. The skull comes in different sizes, shapes, and configurations within globally accepted parameters demarcated by a range of norms. Not all skulls are alike. We try to make the skulls we treat as nearly normal as possible with function as our goals (Fig 1).

Skull wars emerged during the middle part of the century, as we started to disseminate the techniques and trends of craniofacial surgery. We focused on the location of the cuts, or osteotomies, who would have his name on which cut, where the osteotomies are, and related issues, to bone grafting and fixation systems. The focus was on short-term results with apparent avoidance of concern for long-term results (Fig 2). We have passed through that particular era or stage, and now we are engaged in the mind wars, the functional aspect of what we do. There’s a new book out, Mind Wars, by Doctor Jonathan D. Moreno; recommend that for those intensely involved in the field. If you want to look at what’s going on with the functional structures in patients with craniofacial problems, take a look at this book. Published recently, it deals with an emerging topic called the New Neurometrics. If the face looks nice but does not function well, it is important to take the necessary steps to get the best possible function. This is where we are now, moving from the techniques to function and functional analysis to base the outcome on.

Thus far in craniofacial surgery, we have preferred and continued to focus on principles and stay away from the skull wars. Techniques continue to change, but the principles remain the same. We are going to be stressing those principles and guided growth processes more and more as they relate to the skull, bones, and especially bone grafts (Fig 3).
Grafts are an essential component of craniofacial surgery as we change the anatomic boundaries of patients; only autologous bone is used in craniofacial surgery. We need precision, proper and timely decisions, and vision. Without vision we cannot embark on craniofacial surgery. An example of this from the past and how it can progress is Crouzon syndrome (Fig 2). This is a miraculous operation. With one operative procedure, we can change the patient’s appearance and anatomic configuration, maintain vision, and facilitate the functions of breathing, deglutition, mastication, and speech. How long these changes will last is going to reveal the surgeon’s appreciation of bone physiology and anatomy, the main question at present time. Apert syndrome is another similar clinical problem. We saw this patient as a child (Fig 4), and this is how she looks 22 years later (Fig 5). We need to focus on multiple areas and stress their interrelationships to keep them in the appropriate alignment. Here the patient is working as a volunteer dispatch operator for the police department (Fig 5). It is important not only to change the face but also to enable functional changes that support and produce a productive citizen. Another patient with Saethre-Chotzen syndrome 18 years later is a violinist (Fig 6). On the 3-dimensional imaging of her craniofacial skeleton, you can see it is almost normal. This patient still has a little residual dysmorphology in the temporal region that can be included in the maintenance program, but today, she has elected to leave the temporal region as is. She does not want that changed. She is happy with what she has. Another patient with Saethre-Chotzen syndrome (Fig 7) is...
going into medical school. She still has her hardware in and does not want it removed. This is how she looks today, 20 years after corrective surgery (Fig 7). She enjoys functional and craniofacial configurations that are within normal limits. The maintenance program individually designed for each patient after reconstructive surgery is the most essential part of our

Fig 4  Newborn with Apert syndrome as seen in the nursery right after birth.

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Fig 5  Progression over 25 years with an operative procedure and maintenance program that involved the dentist’s and the plastic surgeon’s coordinated efforts, the standard for the repair of that particular deformity. Note the 4-fingered hand.

Fig 6  Patient with deformity corrected as a child, and now years later, she enjoys her being and progressed functionally as a normal child.

Fig 7  Another child with deformity corrected as a child, enjoying the progression of good function and normal appearance.
cooperative efforts. Over extended time, we follow closely the patient’s functional progress, not limiting our observations to the healing of the surgical wound. The critical need for patient follow-up and maintenance program emphasizes the lack of regard for itinerant surgery.

If we list craniofacial deformities into system categories for craniofacial surgery, we see that severe clefts are at the front and are the most common ones seen today. Long-term treatment for those patients is especially important. In syndromic clinical problems, we start to understand what the bone stock is in relation to these differences. I think the most important paper we have had in the past came from Doctor Aduss at the University of Illinois at Chicago. He published a supplement 5-year follow-up on a group of patients who were operated on without a close monitoring of the bony configuration. He discussed the patients’ long-term conditions after major craniofacial surgery without maintenance. He found that the patients looked worse than they looked immediately after the initial surgery which was then considered miraculous. Rather than looking at the appearance, as a dentist, he focused on the functional occlusal relation which did not display adequate long-term stability of the repair. He called the finding a relapse of initial stability.

This newborn baby has a holoprosencephaly with severe cleft area (Fig 8). You can see the outcome of carefully timed multiple-stage repairs. This is not the result of one miraculous operation. We need guided growth increments over a period, giving the patient the chance after each repair to be within age-related norms in appearance and in normal function. We need functional preservation, a maintenance program, a touch-up procedure, and ancillary work. The timing of treatment from birth is also essential in how we can maintain the bone stock to hold the mechano-function. Another patient with similar protruding severe bilateral clefts (Fig 9) 21 years later is a functioning citizen. You can hardly see evidence that she had a procedure. In our center, we have seen that the earlier the surgeries are done, the better the immediate result, but without maintenance, calamitous results can occur. So, the focus is on the soft tissue...
first and the hard tissue next. Another patient with a severe cleft (Fig 10) who was referred to us was expected to die because the diagnosis by a geneticist was holoprosencephaly. You can see her here (Fig 10) graduated from college with an interest in going into the medical field. These are selected examples primarily to demonstrate points and principles and to elucidate the process that we have followed to achieve a good outcome, which include normal function and configuration.

We have considered the different implications of the timing of surgery, orthodontics, distraction, and functional preservation, which are very important. With good training, a maintenance program, and touch-up procedures including bone grafts and fat grafts, which are really very essential, the patient can achieve the desired outcome. Doctor Marketa Duskova, the pioneer of the fat grafts is sitting in the front row. We have found her work is an important approach for it can balance the surgical result and achieve the desired outcome by enhancing the deficient soft tissue in these patients with multiple

Fig 10 Severe deformity of the craniofacial skeleton corrected with guided growth principles, bone grafting, facial anatomic boundaries changes, and a strict maintenance program.

Fig 11 Guided growth is an important principle to follow in a patient with severe deformities; when a gap is created by changing the anatomic boundaries, it is essential to prevent any soft tissue from herniating and filling the space. The guided growth will allow the bone to continue growing without any interruption of the regenerative processes.

Fig 12 A youngster with Apert syndrome with severe craniofacial deformities. Note the misshaped head as well as the beginning of midfacial collapse.
surgeries. Doctor Marketa Duskova’s papers were published in the Journal of Craniofacial Surgery few years back.

Bone stock is another important part of the principles of craniofacial surgery. Its involvement necessitates that we ensure adequate biomechanics, biomanometrics placed into a system of adaptation, and the adoption of the material into the adjacent structures, as well as biosynthesis wherein bone grafts are in the forefront of all these changes. As the anatomic boundaries are changed, we have to ensure that the biomechanical properties are in good position to withstand the elastic recoil of the soft tissue and the myofunctional considerations of the surrounding structures. Let’s look at this guided growth principle. This patient (Fig 11) had multiple previous surgical procedures and was referred to the center to see if we could help with his function. His face has collapsed totally after all the different techniques to change the anatomic boundaries. In each of these procedures and instances, the result of his surgery was unable to withstand the mechanical forces on the new position for more than 1 year. The mother said this last collapsed position took place about 6 months after the last surgery, although everybody was very happy with the immediate surgical outcome. When you look at his scans, you see everything contracted. What we found is that there was not enough bone stock to maintain the mechanical strength needed for the patient to retain the orbits and face in their appropriate positions. It took us 4 years with distraction using guided growth to achieve the outcome desired and to maintain the present functional position. Any skeletal component we externally advance to change the anatomic boundaries needs to have enough mechanical stability, resistance, and support to keep it in place. If we do not preserve the bone growth in a protective manner, whether you call it protected bone regeneration or guided bone regeneration, it will collapse because of inadequate structures to maintain the altered position of bone segments and hold them together. As a youngster with Apert syndrome who has a severe craniofacial deformity (Fig 12), this is how the patient looks now (Fig 13). He and his family are very pleased. But as you see, it took 4 years of maintenance to stabilize his face. He has several deformities. The main principles

**Fig 13** After multiple operations of the patient with Apert syndrome to allow for stabilization building a good bone stock, he is seen a few years later with good stability of the newly configured face; he has regained the important functions associated with these changes.

**Fig 14** Revision surgery is among the common procedures done, partially because of the restricting effect of the hardware, growth, and development, and in part due to the understanding of the operating surgeon beyond the technical aspect of a procedure; the procedures themselves are dynamic in nature. This patient has Crouzon syndrome and had multiple procedures before he was referred to our center; we were able to correct the condition fully following the designated principles, remove the hardware, move to the functional anatomic boundaries, and replace the missing component with stable bone, either regenerated bone or grafted ones.
in all bone surgeries are addition, substitution, removal, reshaping, and reposition. These are the elements we proposed together in 1991 for craniofacial surgery published in the *Advances of Plastic Surgery* that year. Revision surgery is now in the forefront, the principles to remove all the hardware, replace the missing bone areas with bone grafts, and produce a mechanically solid new craniofacial configuration (Fig 14).

Now we take a closer look at bone grafts and bone substitute, which is coming to the forefront along with the new technology and anticipated technological advancements (Fig 15). Bone tissue engineering is a new frontier and has many applications in craniofacial surgery. Bones that are tissue engineered have to replicate the mechanical technology, molecular technology, and nanotechnology of the area to be reconstituted. We also look at the functions of the replacement parts using osseointegrated implants that require collaboration with anaplantologists and an audiologist; the ear and the Bone-Anchoring Hearing Aid (BAHA) have been major contributors to the rehabilitation of the patients with craniofacial deformities (Fig 16). We are now working with the nanotechnology on nanofibers to help us with tissue engineering of bone graft substitute. Every plastic surgeon should be well versed and adept at bone graft acquisitions and reconstruction. We have to understand that bone reconstituted areas are not dead tissue or dead bone as termed in some circles, but live tissue to be regenerated given the proper local and environmental factors to do so, plus the proper milieu, as noted by some. Instead, they are living tissue replacing the bone that is missing. We have to have adequate penetration of blood vessels to allow for proper revascularization. We have to make sure they are well fixated in position. Our book on bone grafts was published 10 years ago, the first book on the topic in 75 years. However, it is now out of print. You may obtain used copies through Amazon if you are interested. The dogma that plastic surgeons are soft-tissue surgeons is, in view of today’s modern plastic surgery principles, a historical event to be reckoned with.

Where do today’s bone engineering stem cells come from? They are adult versus embryonic stem cells. In the United States, we can use only adult stem...
cells. We cannot use embryotic stem cells, although recently, it was found that amniotic stem cells are also chimeras and do not retain their immunogenetic nature. In the future, these cells may also be available for clinical trials and perhaps regular use. But we will not breach the embryotic area ban that we have now. The scaffold is the second element needed for tissue engineering. It is a copolymer of polylactides; the other element needed is the matrix that is the morphogenetic cytokines that are produced by most genetic enzyme manufacturers, and the stimulus is the presence of the defect itself. It has to be a critical-size defect, which means a defect that does not heal or close spontaneously. The adult stem cells used, whether they come from fat or bone marrow, is a big issue. The accepted concept on that is that the fat stem cells come from the bone marrow and basically get stored in the fat tissue, where they can be retrieved for further use. There are a couple of companies now that produce stem cells and store them for use from the patient’s own fat deposits as autologous tissue (Fig 17). An example of a defect in the skull in this patient is shown; the patient was hit by a car (Fig 18). You can see she has a large porencephalic cyst on the trauma site; she was dysfunctional. The brain was nonfunctioning on that side. She behaved and looked like a stroke victim. We reconstructed the defect. The bone grafts were obtained from different anatomic sites: ribs, hips, and skull, all heterotypic grafts. We fenestrated the bone for rapid vascularization, and we placed the other biologic components there, and you can see that the patient 2 years later (Fig 19) is nearing solidification into the area. The function was improved tremendously by containing the residual brain in the vault and not only by simple bone reconstruction. This second patient is an example of a youngster with an invasive tumor on the skull (Fig 20). The instrument shown in Figure 19 is a depth-control power unit to cut the bone with precision; it is the latest technological advance we have in bone surgical manipulation. You can dial the depth in the bone needed as well as dial the skull cut any depth you want. We removed the tumor and reconstructed the skull with a bone graft and bone morphogenetic proteins. You can see the ground-glass appearance on the patient’s later scan showing the bone regeneration is taking place.
This next patient, a patient with craniopagus deformity, is courtesy of the World Craniofacial Foundation. The separation process requires many advances in technology, skill of the operating surgeon, and scheduled interactive processes by a coordinated team who appreciates the principles of craniofacial surgery. The important things here are skill, ethical knowledge, potential for functional outcomes, and expense. There are a number of instances wherein attempts to separate conjoined twins were undertaken by working with a "cookbook" like fashion and ended up with disastrous results. This is not for the novice who wants to spend a day following a recipe for publicity. I have seen this in my own backyard, and many other incidences have been brought to my attention as editor of our journal.

Revision craniofacial surgery is another aspect of what we do. Many times, patients undergo surgery, and then their results collapse. This patient presents a system deformity seen by the combination of hardware and configuration schema defects (Fig 14). The patient presents an example of this particular issue; it is now common to see such grown-up patients with craniofacial deformities achieving this functional disability, a new category in craniofacial deformities, which has increased during our times and continues to increase. The patient had a surgery, a classical approach with no vision, just a cookbook fashion. Well, here he is years later; he cannot bite, eat, chew, and his lack of an occlusal relationship interferes with swallowing and speaking. You can see the totally collapsed area. That also needs to be adjusted and addressed appropriately. What was done was inappropriate. The first principle that needs to be applied here is removal of the hardware that was placed in the wrong site, restricting the patient's growth and producing in him the loss of function. The hardware was installed in a sort of tongue-and-groove pattern to hold his face together when he was a youngster. This restricted the growth on the tethered side, rotating the other side in. The new advances today are replacing the nondissolving biomaterials with biomaterials that have the capability to resorb, allowing bone regeneration to take place within growing bone. We have to use platelet-rich plasma, primarily a material containing a number of growth factors that allow us to create a site in which the patient can engineer his own skeleton and encourage further growth. This is how he is now (Fig 14). It takes time to reach that stage through combinations of basic principles; it is not an overnight procedure. Biomaterial today such as copolymer of the polylactides is in the forefront of craniofacial reconstruction. It does not make a difference what brand or named product you use, for they all have the same basic element with different components. Actually, they all come from the same basic element manufacturer. The bone regenerative material, which is the bone implant, is also in the forefront (Fig 21). There are some currently...
available materials that are bioactive. We need to make sure they are reliable to produce stability for a period. Most of them resolve within a year and a half. So, if the bone cannot regenerate within a year and half, there will not be enough mechanical strength for that tissue to hold in position. They are all mechanically active, and that is what we intended. The most common application of the bioresorbable fixation components is as seen in the orbital fracture (Fig 22), which changed the whole understanding and technology of the components of such fixation. We like the transconjunctival approach on the patient with orbital fracture, especially on the young ones, so no scar exists outside. Thus, repair of the orbital fracture is done, and there is not an external scar. Those polylactides resorb in a year, and after that, the patients have all regenerated bone without a scar and enjoy normal orbital configuration and function.

We need to look at the matrix component of the specialty. Although there remains an arc with impressions and beliefs, we do not want craniofacial surgery to become a cookbook with which surgeons enter the operating room, read a manual, note the details, and follow them. Ours is an applied science. It addresses a biologic system through carpentry that involves the skill of the surgeon, tissue engineering, and a new barrier, and probably, the next time we meet, we will hear more about this and other barriers.

Another principle I would like to bring to your attention is that function is very important at this point. Two components that make a world of difference in the function of our patients are the implantable ear with osteointegrated implants and the BAHA. Besides the surgical advantage, the BAHA gives good functional improvement to the patient with conductive hearing loss (Fig 16). We apply them to many of the patients with craniofacial deformity and functional hearing loss. Our
tissues are mostly strongly antigenic. We have skin, immune suppression for the rest of their lives. The have allografts that require having the patients on other geographic sites. With crossing the barrier, we should be done by well-trained specialists in places. Such procedures are not available in our area. Such procedures would have been ideal. We would have been able to reconstitute his facial configuration rather than allow him to be crippled for life. In research, we also have ethical issues, religious issues, functional issues, immunologic issues, and experimental issues. We must go to the institutional review board to undertake extraordinary measures. That young issue. The craniofacial surgeons are seeing more injuries from war, mass casualties, civilian injuries, and, of course, cancer, which continues to be a major causative factor. For people living in Florida, skin cancer is a high contributor for those skull defects after head trauma and mass casualties. If the bone is not involved or grossly contaminated, the removed bone is stored within the biologic system, such as the abdomen, and later on retrieved for the reconstruction.

A dramatic instance of crossing barriers took place a year ago with a face transplant. Here is a material that we think will be the future of young plastic surgeons and involve the craniofacial skeleton. The 2 issues—the tissue engineering and facial component transplantation—will be a prominent part of all the advances in plastic surgery during the coming 20 years. Research is indeed on the cutting edge in our field. If I were starting my career now, I would be there, for it is most exciting. In brief, when a young patient had his face ripped off by a family dog, transplantation of missing components would have been ideal. We would have been able to reconstitute his facial configuration rather than allow him to be crippled for life. In research, we also have ethical issues, religious issues, functional issues, immunologic issues, and experimental issues. We must go to the institutional review board to undertake extraordinary measures. That young patient ended up with basically a skin graft and a nonfunctioning eye. Facial component transplantation is not available in our area. Such procedures should be done by well-trained specialists in places such as the big clinics, of course, subsequently in other geographic sites. With crossing the barrier, we have allografts that require having the patients on immune suppression for the rest of their lives. The tissues are mostly strongly antigenic. We have skin, fat, and muscle today. Maybe in the future, a whole composite of tissue component will be transplantable for the patient. Regardless, we are still a matrix specialty with many specialists dedicating their time, effort, and passion to what we are doing. It is a professional group approach rather an interdependent team endeavor.

We look for a common vision, pursuit of performance measures, quality, and safety and orient our thinking to long-term clinical outcomes. These data are essential, for without them, we will be unable to continue doing what we do.

In addition, in our work, we must consider biologic predeterminism, understanding that what we change anatomically with or without barriers is not changing the totality of what is going on with the patient. Here is an example. This patient is a musician now (Fig 23). This is how he looked when he was a youngster 26 years ago (Fig 23). We carried out operative procedures and a maintenance program. He is a functioning adult citizen in all aspects. He got married and sired a baby. The baby has the same congenital defect, Pfeiffer syndrome. Our surgical work did not alter the genetic components of his fabric nor the physiology that was there for the patient. The syndrome is biologically predetermined to produce the differences they have, and the biologic nature of the inherited deformity is not at all changed by surgery. The Amazon women syndrome does not apply to what we do in craniofacial surgery.

We need to discuss here our future direction involving evidence-based medicine and quality control. We have press on those topics from everywhere during this congress. We have already spent a couple of weeks this year trying to work on performance measures for the future. We cannot just say we would like to do this or that operation. Instead, we must recognize that our actions are predicated on evidence derived from what we have done. We have to show that there is a quality of value in what we want to do for the patient and that over a period we are permanently improving the patient’s function. There has to be a value, and there has to be an improved function element for us to be allowed to continue doing what we do.

A summative approach to the principles of craniofacial surgery falls into a pattern of structural pillars balanced for function and skill (Fig 24). We have produced what we call the structural pillars of today. They may or may not be applicable tomorrow. The pillars are the basic components of craniofacial surgery: its dynamic nature, the capacity for molding the skeleton, the adaptation of
differences and changes, as well as the function and the anatomy. To produce the desired outcome for the patient, these pillars must be balanced in conjunction with the skill of the operating surgeon and quality-based performance measures. The performance gives us evidence-based outcome that reveals the quality of performance measures that are metrically assessed by what is done. The quality not only is the quality for today but also must represent long-term functional gain. We always have to remember that we should minimize the mishaps and maximize the outcome. This is the foundation of clinical judgment noted in early years in another journal publication.

Our communication system is extremely important, and the Journal of Craniofacial Surgery is that modus of communication around the world. It is now in its 19th volume, 25 years in the works, and the best-quality journal in the field. This has fully enabled us to have a global forum of communication. When new procedures, innovative methods, new techniques or instrumentation, and new skills are discovered, created, or improved anywhere around the world, we can share all of those things among our colleagues with all in craniofacial surgery family. The horizons are wide open, limited only by the imagination of the practicing surgeon. I thank you very much for the chance to present to you our work, our thoughts, and concerns about our future direction in the field of craniofacial surgery. Always remember, the principles last forever and the techniques do not.