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Polyetheretherketone [Peek]: A Contemporary Modality In Cranio Maxillofacial Reconstruction

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Abstract:

This descriptive review focuses on the evolution of polyetheretherketone [PEEK] for the reconstruction of cranio-maxillofacial defects. This treatment modality is now trending and growing throughout the different aspects of the oral and maxillofacial specialty to include customized patient specific implants for reconstructive surgeries, and a material that is used in dental implants. The PEEK implants are created using computer tomography [CT]to reconstruct the defect either in the midface or cranial defects and match with the opposite side, all implants were secured using screws. Cases were followed up for 12 months, and there were no postoperative problems. This came to an end that PEEK is considered as a safe and good implanted bone substitute for the fixation of complex defects of the cranio-maxillofacial.

Key words: *cranio-maxillofacial reconstruction, polyetheretherketone [PEEK], facial deformities, patient specific implant [PSI]*

Introduction :

Overcoming problems of facial asymmetry of patients suffering from facial deformities resultant of trauma or tumor ablation is essential to achieve optimum results and patient satisfactions.[1] The desire for defect reconstruction in the best manner is challenging but possible while still saving the time needed in surgical intervention and is of a paramount importance to surgeons for enhancing patients end-results and overall health.[2] Several autografts and alloplastic materials have been used in cranio-maxillofacial [CMF] reconstruction.[3]

Treatment modalities of cranio-maxillofacial defects:

Autogenous bone grafts such as; calvarial bone, Rib bone grafts, iliac bone grafts, fibula bone grafts, embrace many advantages resembling resistance to infections, radio-transparency, growth potential with no additional financial burden on the patient and have been used all the time in reconstructive techniques of traumatic and congenital deformities in the maxillofacial and craniofacial region. [4,5,6]

Autogenous bone grafts are ideal for small, simple, and easily contoured defects. [7] However, they show important downsides such as donor site morbidity, time consuming harvests, and increased operative time. [7] As the defects become larger and more complex, the search for a more suitable non-toxic, biocompatible, and biologically inert material that would mimic the nature of bone tissue was mandatory. [7]

A significant advantage of alloplastic grafts is the lack of donor site morbidity as seen with autogenous grafts. Alloplastic grafts have also become easily and readily available for use. [8] Metals, ceramics, polymers, composites and numerous alloplastic materials are constructed using Additive Manufacturing [AM] techniques and are used extensively in orthopedic and reconstructive surgeries. [2]

The use of metallic implants [such as gold, tantalum, titanium alloys, stainless steel, and cobalt chromium] have been commonly seen all over medical institutes as permanent prosthesis for knee and hip replacements, cranio-maxillofacial prosthesis and dental implants. With the evolution of 3D printing technology, the custom-made titanium implants directly printed and applied have been reported to better accommodate challenging CMF surgical defects and to restrict the utilization of the traditional hand-shaped titanium mesh. [3,9]

Titanium is considered most compatible material and still a widely used, successful standard modality to repair bone fracture sites in the cranio-maxillofacial regions, as its osteo-inductive privilege to beneficially promote bone formation due to its titanium oxide layer. [9] However some adverse effects has been published such as[9,10]; difficulty of removal due to fibrous tissue encapsulation, their strength and elastic modulus surpasses that of normal human bone tissues and could result in a stress shielding counter effect leading to prosthetic loosening.[8,9] Other hazards have been encountered during the use of titanium meshes and metallic prostheses, which include hypersensitivity to titanium, the difficulty of design in complex cases, and injury resulting from its sharp edges.[9,10]

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Metallic hardware's drawbacks have led to the rise of ceramics as an alternative reconstructive material. Calcium phosphates and glass ceramics are the most used. They are beneficial in their ability to form an appetite layer on its surface when exposed to physiological fluids in vivo or stimulated body fluids, [11] biocompatible and therefore possess a low toxicity profile. [12]

Due to the constraints witnessed when handling metallic and ceramic biomaterials, the use of polymers as a viable alternative is on the rise as of recently. A large number of polymers, such as ultrahigh molecular weight polyethylene [UHMWPE], polymethyl methacrylate [PMMA], polylactide [PLA], polyglycolide [PGA], and hydroxyapatite [13] are example of some of the most commonly used in various biomedical applications. However, only a limited number of polymers have been used for bone replacement purposes as they tend to be too flexible and too weak for load-bearing implants orthopedic applications. [13]

Methyl Methacrylate [MM] is the most extensively used alloplastic material for minor defects due to its strong solid and inexpensive nature. [14] The material is affordable and easy to use; however, it is alarming since it shows some exothermic reactions high risk of infection. [14]

Calcium phosphate ceramics [e.g., hydroxyapatite] are often used as bone void filler in oral surgery. Its granules or putty pastes used in dental application as they are biocompatible and osteoconductive, and can be placed manually to fill bone defects. [11] Nevertheless, their mechanical brittleness and the impossibility for direct implant fabrication limit their use. [11] Overcoming this problem, the introduction of HA inside biodegradable polymeric matrices improves the bioactivity of the implants and could even endow the composite biomaterials with osteo-inductivity. [12]

The ideal material has not been discovered yet, but among the various alloplastic materials, polyetheretherketone [PEEK] has been a popular choice for the Patient Specific Implant [PSI].[15,2,3] The most universally used PEEK coating, bioactive material, is Hydroxyapatite [HA].[15] HA [chemical formula Ca10[PO4]6[OH]2] is the most broadly used calcium phosphate-based bioceramic, which significantly resembles human mineral bone and has a high mean bone-implant contact contributes to osseointegration.[16]

Customized Patient Specific Implant

Over the past years, the rapid growth of 3D modelling and printing technologies are revolutionizing numerous surgical fields.[2] The cranio-maxillofacial surgeons have been one of the most important beneficiaries as facial computerized tomography [CT] scans are conducted to evaluate the degree of tissue damage and to perform virtual pre-operative surgical planning to design and print plastic anatomical models employed to manually adapt a standard implant to anatomically reconstruct the patients' fractured bones. Patient Specific Implant [PSI] can be an efficient treatment option that fits accurately within the anatomy of the defect. [17] The rise of Patient Specific Implant led to many developments in the medical industry. [17] It shows many advantages like less operation time and the ability to incorporate dental implants and direct rehabilitation. However, extra coast as well as extra processing time are required. [2,17]

The use of Virtual Surgical Planning [VSP] and navigation in fabrication of Customized Patient Specific Implant [PSI] [2]

Multi-planar computer tomography [CT] scans associated with virtual surgical planning [VSP] computer- aided design [CAD] / computer-aided modeling [CAM] help the operator to remodel the approach and execution of complex head and neck resections and reconstructions. [3] It offers several advantages including increased accuracy of reconstruction, reduced surgery and graft ischemia time, improved patient satisfaction and ease of use. [2]

The use of computer technology in the pre-surgical planning phase includes the transfer of CT scan data in digital information and communications in medicine [DICOM] format through the CAD/CAM software, where the data can be assessed and handled virtually in all three dimensions. A simulated surgical plan can then be formulated using several methods, including segmentation of the affected areas; mirror imaging the opposite normal side; reduction of the affected bone in 3D space; virtual osteotomies; or insertion of anatomic structures as required. Moreover, fabrication of stereolithographic models from information of the virtual reconstructions permits preoperative planning of osteotomies, plate contouring, and eases the intraoperative contouring of bone grafts. Additionally, additive manufacturing [AM] for the printing process, 3D printer scan reads and analyzes CT scan data and creates customized surgical models from the information, if necessary. Both VSP and 3D models are used to precisely place the ideal amount, shape, and dimensions of autologous tissue or bio-prosthetic material needed for reconstruction. [2]

Finally, the CAD/CAM software permits the conversion of the virtual reconstruction information back into DICOM format in order to transfer data to a surgical navigation system to be used intraoperatively that could reduce the incidence of postsurgical complications due to a wrong positioning or orientation of bone grafts, plates, or fixation screws. [2]

Polyetheretherketone [PEEK]

Polyetheretherketone has been introduced as an implant material in several medical applications since the 1990s owing to its close-to-bone elasticity, high stability, low density [1.32 g/cm3] and insolubility. [18,19] Its use and popularity have also taken over the dental field. [19,20] Polyetheretherketone has been used in aircrafts, automotive and electrical industries over the past 20 years [20,21] PEEK is simply a semicrystalline polyaromatic thermoplastic linear polymer in ether and ketone linkages that presents an exceptional combination of biocompatibility, [22] stiffness, durability and natural

resistance along with resistance to high temperatures and radiation. [14,22]

It has been stated by manufacturing companies that PEEK possesses bone-like thermal conductivity of 0.4W/Km.[23] Consequently, because it resembles cortical bone it has become safe, predictable and stable option. [24,25]

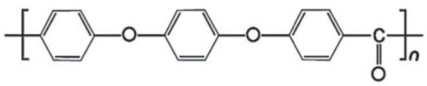
The use of PEEK in implants has been available since 1998. Initially it was used for spinal surgery and hip replacements until it became more and more employed in CMF surgery. PEEK has shown massive success in the treatment of cervical disk problem. [25-27] Explicitly, in anterocervical fusion, PEEK has been alternatively used to autogenic bone grafts and titanium cages.[27,28] The use of PEEK as plates and screws for fracture fixation has increased due to its biocompatibility.[29,30] It has also been utilized in the form of PSI for the reconstruction of cranio-maxillofacial bone defects.[30]

Physical and biological properties of unfilled PEEK biomaterial and PEEK composite

Polyetheretherketone is a polyaromatic semicrystalline thermoplastic material, with typically 30-35% crystallinity. The material bosses a melting temperature in the vicinity of 343°C, a crystallization peak of ~160°C and a glass transition temperature of ~145°C. These melt temperatures allow PEEK material to be formed by either injection molding or extrusion using conventional methods. [30,31] Its thermal properties make it durable in human body. [31,32]

According to their melt flow index [MFi] and molecular weight [Mn], PEEK- materials are divided in three material grades. [32] All follow the same standard formula [-C6H4-O-C6H4-O-C6H4-CO-] n:[18,32,33] [Fig. 1]

- LT1-standard grade [MFi-3.4; Mn = 115.000].
- LT2-optimized grade for melt strength and medium melt viscosity [MFi-4.5; Mn = 108.000].
- LT3- high-flow grade for injection molding thin-walled parts.



[Courtesy to Bathala L et al.]

Fig. 1. chemical structure of PEEK

One of the most valuable advantages of the PEEK polymer is its compounding ability either to increase its innate strength or to improve its biocompatibility. This advantage is better performed in the biomedical fields with the utilization of the standard grade PEEK LT1 materials. [34,35] Amongst the first PEEK composites seen in biomedical applications was the carbon reinforced PEEK composite [CFR-PEEK].[35] Adding filler materials by compounding, in the form of short carbon or glass fibers, improves the strength of the natural unfilled polymer. Making it more powerful in withstanding greater stress demanding applications for bone replacement. [35,36]

PEEK composite devices were first applied for fracture fixation, using carbon reinforcement in a PEEK matrix. [34,35]

Carbon reinforced PEEK composites are characterized by stiffness and high strength due to the presence of fibers. [37] Carlile et al. [1989] examined the effect of temperature on strength for fiber and matrix lay-ups. [38] They found that most of its characteristic properties were retained at varying temperatures up to 141 °C [the glass transition temperature]. On the other hand, as the crystalline melting transition temperature is reached at around 343 °C, CFR PEEK demonstrates high levels of toughness across different testing techniques such as fracture resistance, weight impact and post-impact compression. [34-36] CFR-PEEK showed to be chemically inert, nontoxic and insoluble in all conventional solvents at room temperature, except in 98% sulfuric acid. [37,38]

Glass-fiber reinforced PEEK composites [GFR-PEEKs] is another variation of PEEK composites. [39] Chopped E-glass fibers with an elastic modulus comparable to that of cortical bone are dispersed randomly within the PEEK matrix. [40] Panayotov et al. demonstrated a significant increase in elastic modulus of the bioactive PEEK composites in contrast with carbon fiber and glass fiber additives. Moreover, soaking PEEK/carbon fiber composites in physiological Saline up to 5000hrs duration followed by compression tests confirm its stability. [40]

Polyetheretherketone and its composites can undergo steam sterilization repeatedly without losing their mechanical characteristics. [2,30-32] One of the methods of sterilizing medical devices is through gumma radiation. [31] As for polymeric materials, they often become weakened and embrittled when exposed to radiation as a result of induced cross-linking and/or chain scission. PEEKs resilient chemical structure makes it well tolerated to gumma radiation. [31]

Polyetheretherketone Implants in Cranio-Maxillofacial Reconstruction:

Honigmann et al. [2018] [2] represented the PEEK filament used in the printing process as a semicrystalline polymer having a density of 1.30 g/cm3 and tensile strength of 97MPa [Fig. 2a]. This filament combines the perfect amount of strength, toughness, and stiffness with great chemical resistance. Moreover, it is highly stable against hydrolysis, and is sterilizable. [2] The results revealed that the 3D printed PEEK PSI were even smooth devoid of irregularities. [2] No discoloration [improper crystallization] or black specks formation were noticed. All the 3D printed parts were assessed for certified sterilization test and passed without any deformation. [2] Five different PEEK structures were fabricated for the cranio-maxillofacial reconstruction:[2]

1. Osteosynthesis plate. [Fig. 2b]
2. Cranioplasty PSI for repair of defects in the cranial vault. [Fig. 2c]
3. Lightweight midface-zygomatic bone PSI with support structures for immediate replacement. [Fig. 2d]

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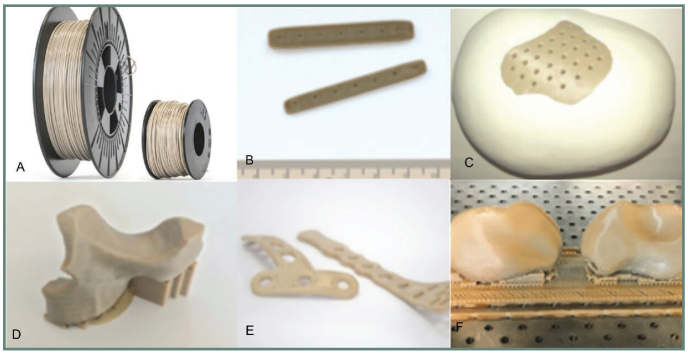
4. Small fragment PSI osteosynthesis plates. [Fig. 2e]
5. Prosthetic implant for scaphoid bone replacement. [Fig. 2f]



[Courtesy to Honigmann et al.]

Fig. 2. A] Medical grade PEEK filament-3Dprinting. B] Osteosynthesis plate. C] Cranioplasty PSI for repair of defects in the cranial vault. D] Lightweight midface-zygomatic bone PSI with support structures for immediate replacement] E] Small fragment PSI osteosynthesis plates F] Prosthetic implant for scaphoid bone replacement.

[a] Polyetheretherketone in Cranial Bone Reconstruction

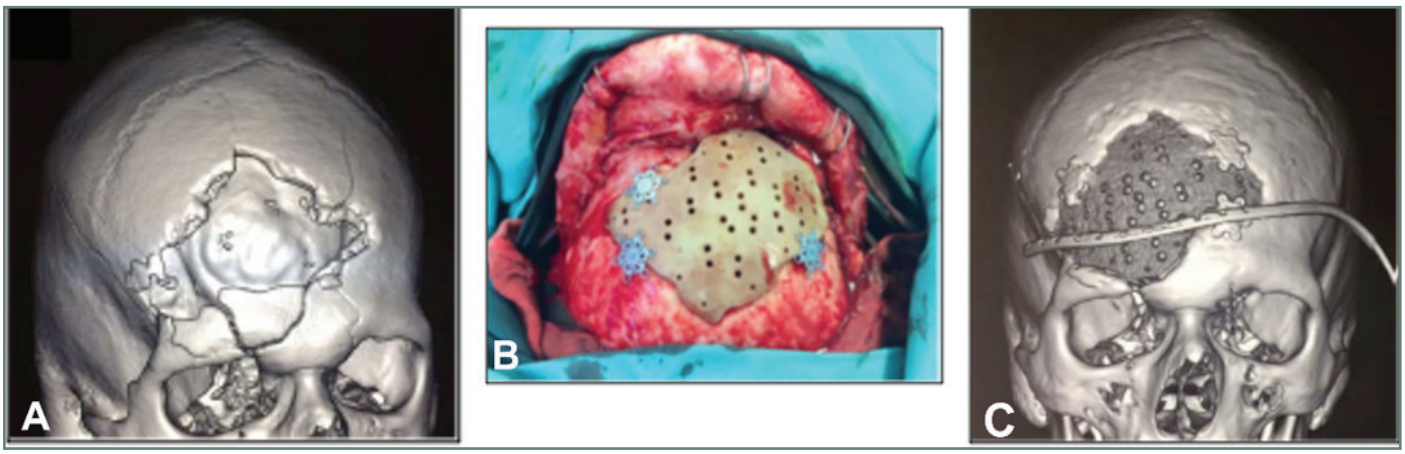
During decompressive craniectomy, cranial defects usually arise and a segment of the cranial vault is excised for surgical access to decrease the intracranial pressure that can be caused by surgical intervention secondary to chronic infection or uncontrolled osteoradionecrosis, several types of traumas, tumors, infections and congenital cranial anomalies causes. [41,42] The frontal bone is so strong and it requires high velocity to fracture from 800 to 2,200lb. [41,42]

Cranio-plastic techniques have been reported previously in prehistoric times and many materials were available at that time, some of which are still being used to date. [104] The "gold standard" for cranial vault reconstruction has always been Autogenous bone grafts of calvaria, rib grafts, or iliac source or tissue free grafts, but the major problem was always local resorption[43] inability to be used with complicated multi-fragmented fractures, ex. gun shots injury, poor bone quality after chemotherapy and radiotherapy [44,45], limited bone availability and shaping in addition to donor site morbidity.[43]

There is no such thing as a perfect ideal material, but PEEK patient specific implants have been highly appraised in the reconstruction following craniofacial tumors resection or traumatic brain injuries [18,45,46] and it is supplied as single or multiple pieces and conventional fixation. It showed massive success because of its structural durability at high temperatures and radiation maintained by the polymer. [21,22,23] It is sterilizable in moist or dry heat without dimensional changes. [35]

In 2015, O'Reilly et al. [47] made a 6-year retrospective review of cranioplasty procedures in nineteen patients receiving 22 CT-based PEEK cranioplasty. Three patients had re-operation following PEEK plate reconstruction. The authors concluded that use of CAD/CAM PEEK plate for cranial reconstruction has several benefits: ease of insertion with excellent anatomical precision and aesthetic results; potential intra-operative time saving; and the plate is also easily modified in the operating room. [47]

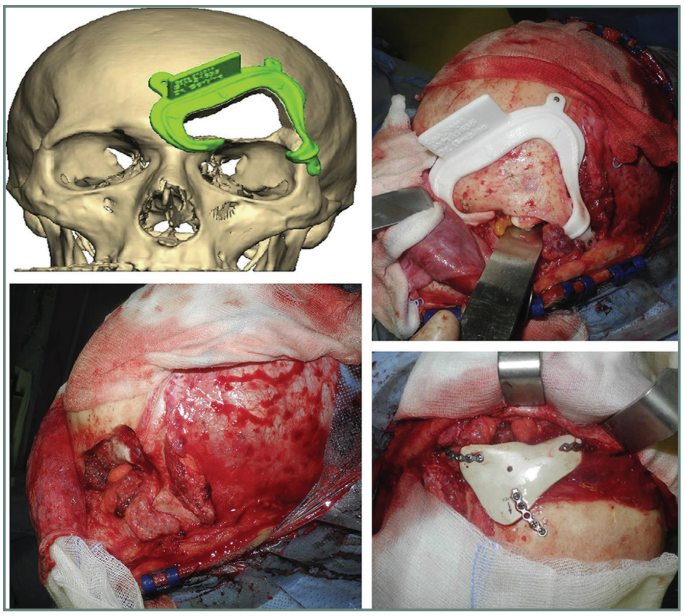
Malivuković et al., described a case [48] of a 21-year-old male patient victim of a gunshot injury to the frontal region, [48] 6 months after the primary surgical debridement, removal of bone fragments and absence of signs of infection. The patient presented with an intricate defect of the skull involving both frontal and sphenoidal bones. The decision was made to use 3D fabricated implant using a non-resorbable thermoplastic material PEEK- OPTIMA®. [48] [Fig. 3]



[Courtesy to Malivuković et al.]

Fig. 3. A] Preoperative computed tomography showing a complex defect of the skull B] cranioplasty was performed through a bi-coronal approach with the prefabricated 3D PEEK OPTIMA® implant and fixed after preparing the bone edges with titanium screws and stars C] Computed tomography [3D recon-striction] postoperatively showing the fixed PEEK OPTIMA® implant filled the bone deficiency.

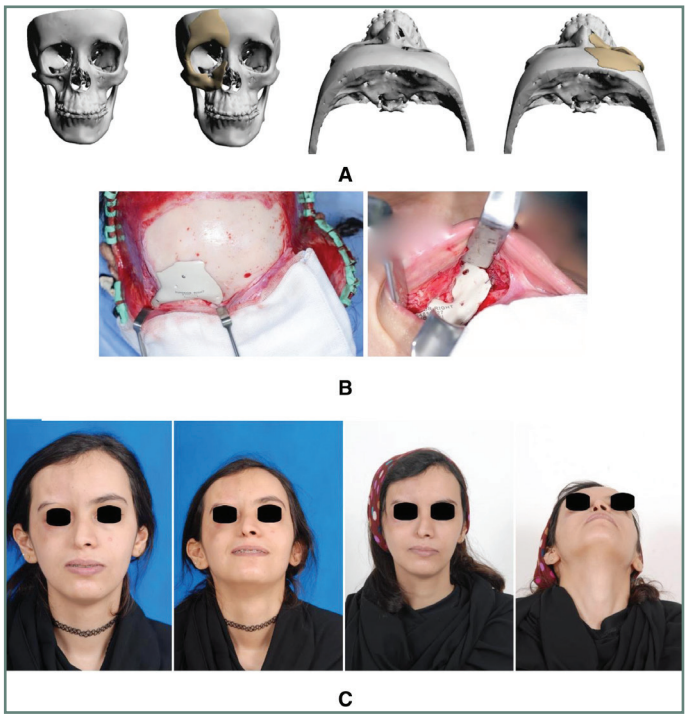
Gerbino et al. [49] described their experience with the PEEK PSIs on a group of patients that underwent cranio-orbital reconstruction as being cosmetic and with mechanically favorable outcomes. One of those patients was a 46-year-old man with fronto-ethmoidal sinusitis following fronto-orbital osteoma involving both anterior and posterior walls of the frontal sinus. The patient had gone through one-step resection and primary reconstruction with polyetheretherketone [PEEK] patient-specific implant [PSI]. [Fig.4]



[Courtesy to Gerbino et al.]
Fig. 4. A]
Virtual planning of the resection with computer-generated cutting guide. B] Intraoperative view of the cutting guide] C] Exclusion and obliteration of the naso-frontal recess and preparation of the pericranial flap] Intraoperative view of the implant fits into the defect, pericranial flap rotated under the implant.

The objective of surgical treatments of frontal bone fractures is to restore the front anatomic contour especially in severe defects involving the front orbital region, [41,47,48] besides preventing infection of intracranial components and frontal sinuses. [47,48]

In another case reported by Nasser Alasseri and Ahmed Alasra,[50] PEEK was used as a reconstructive method for craniosynostosis birth defects conditions. A 23-year-old female with a diagnosis of Parry-Romberg syndrome that lead to hypoplasia in the right side of her face. She had a history of fat grafting and fillers to cover the defect with unacceptable results. [50] The patient underwent PEEK PSI reconstruction for her frontal bone, zygoma, and maxilla on the right side of her face through bicoronal and vestibular approaches. Patient satisfaction has revealed excellent postoperative results. [50] [Fig. 5]



[Courtesy to Nasser Alasseri and Ahmed Alasra.]
Fig. 5. Parry-Romberg syndrome case. A]3D reconstruction of the CT showing the defects andthe planned implants. B] Intraoperative views of the implants. C]Pre- and postoperative photographs of the patient.

[b] PEEK in Midface Complex Reconstruction

Amongst the first facial areas to reveal aging signs is the midface.[51] Midface is an area bounded by the canthal and oral commissure,[51] Deficiencies of the midface either secondary to tumor removal, traumatic injury, bony insufficiency from birth or skeletal resorption with aging that will exaggerate the seeming age of such areas,[51] as loss of volume occurs in the bony and soft tissue skeleton it produces a widespread orbital opening and less anterior projection, this minimizes the overall projection of the cheek and decreases bone support available for the overlying soft tissue structures.[51]

Orbito-zygomatic complex fractures are one of the most frequently seen injuries of the craniofacial skeleton [52] resulting from personal violence, road traffic accidents, falls and sport injuries. [49,52] Restricted eye movement, altered globe level, diplopia, visual impairment, circumorbital ecchymosis and altered sensation over the division of the infraorbital nerve are the main encountered problems in orbital floor fractures.

All these signs need immediate surgical intervention. [52] M.L. Goodson et al.[53] fabricated two-pieces PEEK implants; one zygomatic implant [as a two-piece jigsaw] was used in treating a patient with flattened cheeks after a fracture of the right zygomatic complex, and the other implant for a patient with a defect in the inferior orbital rim and hypoglobus after presentation of a fracture of the orbital floor and rim.[53] In both cases, the implants were designed on a stereolithographic model using CT.[53][Fig. 6] The two-piece design

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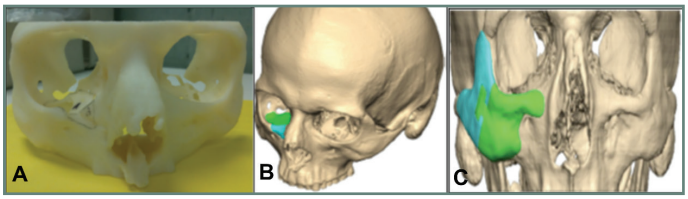
allowing segments of the implant to be inserted through different paths. Both patients were followed up for 12 months, the implants were easily inserted with no need for adaptation and no signs of rejection were reported using the two-piece PEEK implants for orbito-zygomatic reconstruction. [53]

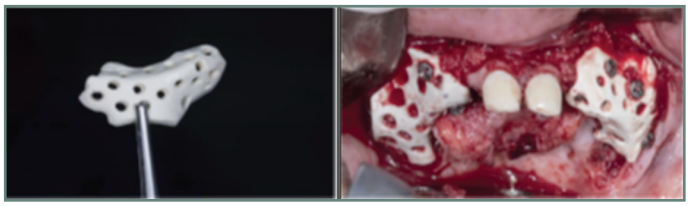


[Courtesy to M.L. Goodson et al.]

Fig. 6. A] Stereolithographic model for orbital rim and floor implant B] Two-piece orbital floor and rim implant] C] Zygomatic implant; [up to the zygomaticofrontal suture, infraorbital rim, zygomatic arch, and piriform rim]

Zain et al. [54] in their pilot study, fabricated PSI of PEEK while using it to contain the bone graft within and reconstructing the bony defect for future implant rehabilitation, the significant difference in bone density between immediate and 4 months postoperative C.T. is a sign of ongoing bone remodeling and calcification. [54] The technique was regarded as a promising solution to reconstruct the maxillary intrabony defects without dispersion of the graft into the sinus cavity. However, soft tissue dehiscence was evident, and infection occurred in some cases that should have been considered in the PSI design and material. [54]

Mounir et al. [55] conducted a randomized clinical trial, including two equal groups of patients who had a partial or completely edentulous maxillary alveolar ridge defect following teeth loss. Eight patients in each group who underwent 3D ridge augmentation using either a titanium mesh [control group] or a patient specific milled PEEK mesh [study group] utilizing a 50:50 mixture of autogenous bone harvested from the iliac crest of each individual patient and xenogeneic bone. [55] [Fig. 7] Collagen membrane was then applied on top of the meshes in both groups. They reported that titanium mesh exposure in one case of the control group at two weeks resulted, but this complication was not found in the PEEK group. [55] This exposure, however, did not result in a compromised regeneration and implants were successfully installed in the newly regenerated bone. [55]



[Courtesy to MOUNIR et al.]

Fig. 7. 3D PEEK mesh in place fixed with bi-cortical titanium screws.

[C] PEEK in Mandibular Reconstruction

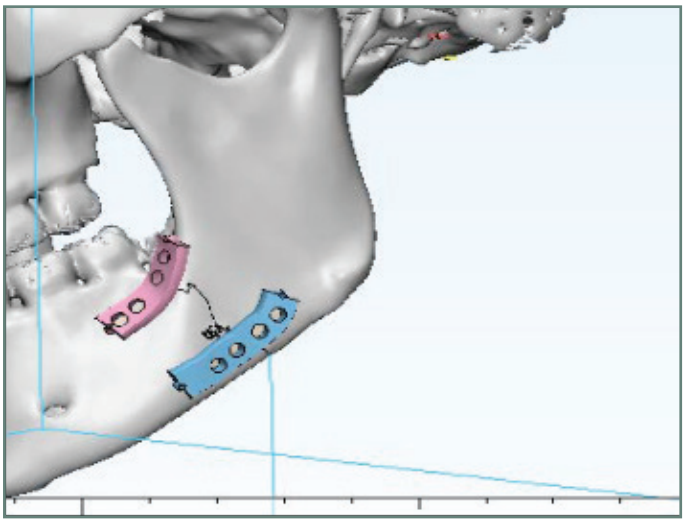
The mandible is only one of its kind bones having a complex role in esthetics of the face and functional occlusion. Because of the prominent position of the lower jaw, mandibular fractures are the most common fractures of the facial skeleton. It has been stated that fractures of the mandible account for 36% to 59% of all CMF fractures. [56]

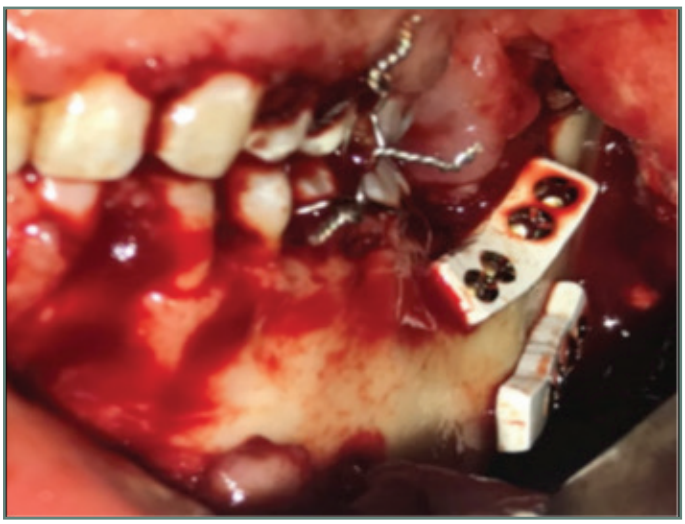
The fractured segments of the mandible are protected against micro motion under function leading to minimized inter-fragmentary strains.[56] Therefore, a mechanically stable fixation permits adequate bone repositioning and allows for functional healing.[56] The most accustomed mandibular reconstruction method, with a fibula free flap showed some limitations like second surgical harvested site, plate exposure, plate fracture, infections and vascular issues.[57]

With the introductory movement of computer-assisted mandibular reconstruction and the virtual planning to produce a PSI for bone replacement, three dimensional miniplates osteosynthesis and custom-made reconstruction of plates for fixation of reduced mandibular fractured segments,[57] leading to greater surgical precision, increasing the accuracy of pre-operative planning, reducing surgical time and better aesthetic result.[57] Owing to its bone-like elasticity [elastic modulus: three-four GPa], PEEK [polyetheretherketone] is considered a practical alternative material. Its use as an implant material has been successfully evident in several medical aspects since the 1990s [18,19] due to its superior stability, minimal density [1.32 g/cm3] and lack of solubility. [21,22]

Dessoky et al. [30] used in their study PEEK in mandibular fractures. They included patients suffering from recent, uninfected, non-comminuted mandibular body fracture, unfavorable fracture that demands open reduction and internal fixation. [30] Three-dimensional reconstruction of the segmented mandible along with dental hard tissue was created and virtual reduction of mandibular fracture was verified. [30] Inter maxillary fixation [IMF] was temporarily secured to offer proper occlusion that worked as a guide for fracture reduction. Placement of the custom-made PEEK plates in place and fixed by mini screws [Fig. 8]. They stated that the occlusion was productively achieved in all patients. After six months followed up postoperatively, they concluded that Fixation of mandibular fracture with custom made PEEK plate is anti-microbial and provides satisfying clinical and radiographically. [30]

El-Hawary et al. [57] reported a case of a 24-year-old male with mandibular 'follicular ameloblastoma' and parathesia. The authors followed a guided protocol; guided resection, guided alignment of the reconstruction plate secured to digitally mirror-imaged PEEK.[57] Their aim was to evaluate the efficiency of CAD/CAM to fabricate PEEK to duplicate both of the exact anatomic position and the configuration of the resected mandibular condyle, post segmental tumor resection. [57] However, they stated that the degree of accuracy between the virtual planned condylar location and that surgically executed was judged as good to excellent in all operated cases.[57] They considered the custom designed PEEK unit simply and efficiently reformed the deficient condyle position and configuration. Yet, the success of preoperative virtual planning and surgical execution is mainly dependent upon the resected proximal mandibular segment anteriorly. [57]

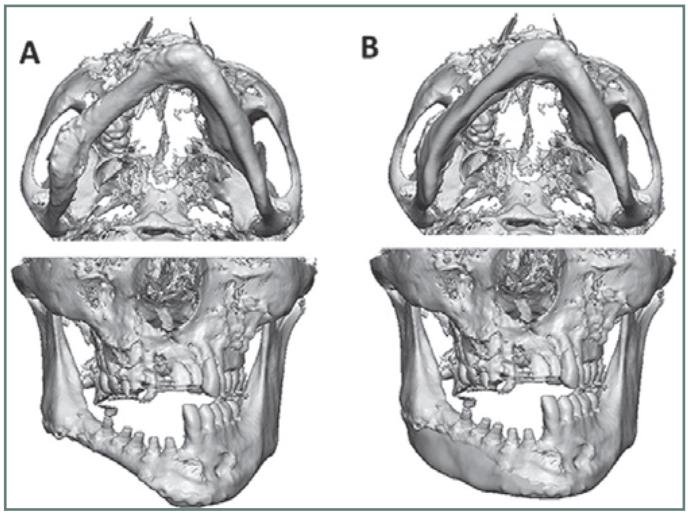




[Courtesy to Dessoky et al and M. Berrone et al.]

Fig.8. A] PEEK custom plates after being planned on the virtually reduced mandible and fixation of PEEK plates intraoperatively.

M. Berrone et al.[58] in their report cases included a 27-year-old man referred for correction of facial asymmetry as a result of major trauma with loss of hemi mandible which has been reconstructed primarily with a fibula free flap.[58] Using the 3D virtual model of the mandible and the mirroring technique, a PEEK PSI [Fig. 9] was fabricated to restore the symmetry of the mandible.[58] After eight months of follow-up of the implant positioning in the fibula and provisional dental restoration to stabilize the maxillo-mandibular relationship, there were no clinical or radiological complications.[58]



[Courtesy to M. Berrone et al.]

Fig. 9. [A] 3D reconstruction of the craniofacial skeleton: virtual inferior view and frontal view. [B] Virtual inferior view and frontal view after positioning of the custom-made prosthesis.

Conclusions:

In the scope of this review, it can be concluded that:

1. 1. PEEK is biocompatible, adapts anatomically, remains still stiff and stable and is nonmagnetic.
2. 2.PEEK is regarded as a safe and good implanted bone substitute for the treatment of complex defects of the cranio-maxillofacial in comparison to alternative alloplastic materials.

Conflict Of Intrest:

The authors acknowledged that they do not have any conflict of interest.

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