Iranian Journal of NEUROSURGERY
2025, Volume 11, E25

Case Report

Recurrent Epidural and Subgaleal Effusion After Patient-Specific PEEK Cranioplasty as an Allergic Reaction: A Two-Case Report

Morteza Modaenama[1*], Khatere Mokhtari[2]

1. Guilan Road Trauma Research Center,Trauma Institute, Guilan University of Medical Sciences, Rasht, Iran.
2. Department of Cell and Molecular Biology and Microbiology, Faculty of Biological Science and Technology, University of Isfahan, Isfahan, Iran.

Use your device to scan and read the article online

Citation Modaenama M, Mokhtari kh. Recurrent Epidural and Subgaleal Effusion After Patient-Specific PEEK Cranioplasty as an Allergic Reaction: A Two-Case Report. Iran J Neurosurg. 2025; 11:E25. http://dx.doi.org/10.32598/irjns.11.25

http://dx.doi.org/10.32598/irjns.11.25

Article info:
Received: 27 Sep 2025
Accepted: 06 Oct 2025
Available Online: 23 Dec 2025

Keywords:
Cranioplasty, Polyetheretherketone (PEEK), Epidural effusion, Subgaleal effusion, Decompressive craniectomy, Titanium mesh

ABSTRACT

Background and Importance: Patient-specific polyetheretherketone (PEEK) implants are increasingly used in cranioplasty due to their biocompatibility, radiolucency, and favorable cosmetic outcomes. However, postoperative complications such as fluid collections remain a clinical concern.

Case Presentation: We describe two male patients with severe traumatic brain injury who underwent bilateral decompressive craniectomy followed by delayed cranioplasty using custom-made PEEK implants. Both patients developed recurrent epidural and subgaleal effusions during follow-up. The first case was successfully managed conservatively with aspiration, corticosteroid therapy, and compressive bandaging. The second case developed progressive effusion resistant to conservative management, ultimately requiring implant removal and reconstruction with a titanium mesh, which resolved the complication. Although PEEK implants offer significant advantages in cranial reconstruction, they may be associated with recurrent effusion. Conservative management may be sufficient in some cases; however, persistent or refractory effusions may necessitate implant removal. Careful follow-up is essential for early detection and management of such complications.

Conclusion: Although PEEK implants offer significant advantages in cranial reconstruction, they may be associated with recurrent effusion. Conservative management may be sufficient in some cases; however, persistent or refractory effusions may necessitate implant removal. Careful followup is essential for early detection and management of such complications.

*** Corresponding Author:**
Morteza Modaenama, MD.
Address: *Guilan Road Trauma Research Center, Guilan University of Medical Sciences, Rasht, Iran.*
Tel: *+98 (013) 333311483*
E-mail: *morteza_Moddaeinama@gums.ac.ir*

Highlights

- Patient-specific PEEK implants offer favorable biomechanical and cosmetic outcomes in cranioplasty.
- Recurrent epidural and subgaleal effusions may develop following PEEK cranioplasty.
- Selected postoperative effusions can resolve with conservative management.
- Persistent or refractory fluid collections may necessitate removal of the PEEK implant.
- Close postoperative follow-up is essential for early detection and management of complications.

Plain Language Summary

Custom-made PEEK implants are commonly used to repair skull defects because they are safe and provide good cosmetic results. However, some patients may develop fluid accumulation under or above the implant after surgery. In this report, we describe two patients with recurrent fluid collections following PEEK cranioplasty, one of whom improved with non-surgical treatment, while the other required implant removal. These cases show that although conservative treatment can be effective, surgery may be necessary when fluid persists. Careful follow-up after cranioplasty is important to identify and manage such complications early.

1. Background and Importance

Cranioplasty is an essential procedure in neurosurgery, typically performed after decompressive craniectomy for severe traumatic brain injury, cerebrovascular accidents, or other causes of increased intracranial pressure. Beyond its protective and cosmetic roles, cranioplasty has been shown to improve cerebral hemodynamics and neurological function [1, 2].

Various materials have been employed for cranial reconstruction, including autologous bone, polymethylmethacrylate (PMMA), titanium mesh, and patient-specific three-dimensional (3D) implants [3]. Among these, polyetheretherketone (PEEK) has gained increasing popularity due to its biocompatibility, strength, radiolucency, and ability to be fabricated into custom implants with excellent cosmetic results [4, 5].

Despite these advantages, postoperative complications such as infection, bone resorption, hematoma, and fluid collection (epidural or subgaleal effusion) remain challenges for both clinicians and patients [6, 7]. While some effusions resolve spontaneously or with conservative treatment, others may persist and necessitate surgical intervention, including implant removal.

In this report, we describe two patients with traumatic brain injury who underwent delayed cranioplasty with patient-specific 3D PEEK implants and subsequently developed postoperative epidural and subgaleal effusions with divergent clinical outcomes. In addition, we provide a review of the literature on the management of effusions associated with PEEK implants.

2. Case Presentation

Case 1

A 27-year-old male patient was admitted following a motor vehicle accident with severe traumatic brain injury, diffuse cerebral edema, and an initial glasgow coma scale (GCS) of 8 with bilaterally mid-dilated pupils. He underwent emergency bilateral decompressive craniectomy in April 2024. Over the following four months, neurological recovery was achieved, the patient regained full consciousness, and tracheostomy was removed. In August 2024, he underwent cranioplasty using a three-dimensional custom-made PEEK implant. The postoperative course was uneventful, and the patient was discharged in good condition. At three and six months follow-up, the patient presented with recurrent temporal swelling on the left side. Imaging revealed epidural and subgaleal effusion. Both episodes were successfully managed conservatively with aspiration, short-term corticosteroid therapy, and compressive bandaging, leading to complete resolution within two weeks (Figure 1).

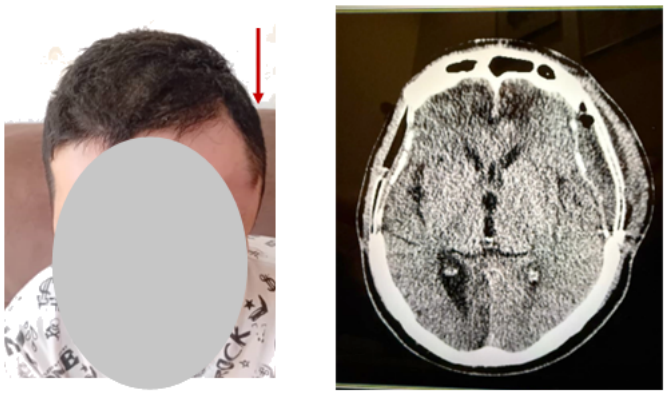

Figure 1. Clinical photograph and axial CT scan of Case 1 showing left temporal swelling (red arrow) consistent with subgaleal and epidural effusion following PEEK cranioplasty

Case 2

A 30-year-old male patient sustained a severe traumatic brain injury in a motorcycle accident in October 2024. Initial GCS was 7. Imaging revealed a large right frontal intracerebral hematoma associated with a severe open compound depressed skull fracture. The patient underwent bilateral decompressive craniectomy, evacuation of the hematoma, and removal of the bone fragments. Two months later, in November 2024, he underwent cranioplasty with a custom-made PEEK implant. Postoperative recovery was uneventful, with satisfactory cosmetic results. During follow-up visits at two and four months,

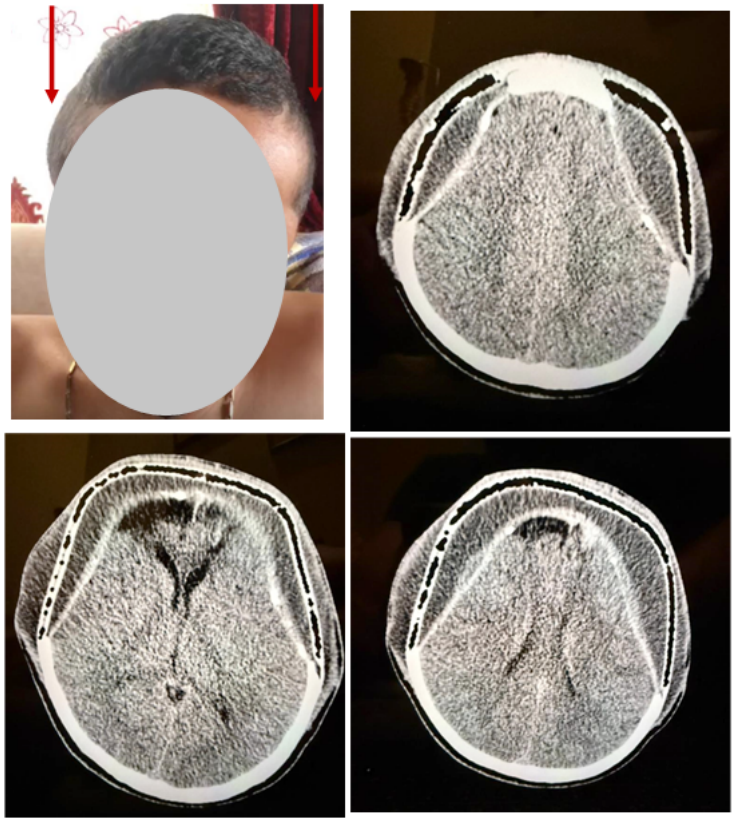

Figure 2. Clinical photograph and axial CT scans of Case 2 demonstrating progressive bilateral epidural and subgaleal effusions (red arrows) after PEEK cranioplasty

the patient reported mild swelling that resolved spontaneously without intervention. However, nine months postoperatively, he presented with marked swelling. CT scan revealed extensive bilateral epidural effusion extending into the subgaleal space. Despite two weeks of conservative management with aspiration and corticosteroids, the effusion progressed. The PEEK implant was removed, and cranioplasty was performed using a titanium mesh. Postoperatively, the swelling resolved completely, and no recurrence was observed during follow-up (Figure 2).

3. Discussion

Cranioplasty using PEEK has gained wide popularity as one of the most frequently employed alloplastic materials, alongside titanium mesh, PMMA, and bone cement [4, 8-11]. Its favorable characteristics—including biocompatibility, radiolucency, resistance to radiation, lightweight structure, and the ability to fabricate three-dimensional, patient-specific implants—make it particularly attractive for cranial reconstruction. PEEK also possesses high tensile strength and energy-absorbing properties similar to native bone, conferring a low risk of traumatic fragmentation. Unlike autologous bone or PMMA, it does not undergo resorption, and infection rates appear comparable to those of native bone [11]. Nevertheless, despite these advantages, complications such as infection, hematoma, and fluid collections remain clinically significant. Among these, recurrent epidural or subgaleal effusion following PEEK implantation is rare but increasingly recognized.

In a large series of 1,688 patients receiving custom-made prostheses, Morselli et al. documented a 20.6% overall complication rate, including 49 cases involving PEEK. The most common adverse events were infections, epidural hematomas, hydrocephalus, fluid collections, and graft displacement, with no allergic reactions identified [12]. Similarly, Jonkergouw et al. reported a 28% complication rate in 40 PEEK cranioplasties, mainly infections and postoperative hematomas, while Punchak et al. described a 15.3% complication rate in 183 cases, with implant failure and infections being predominant [4].

Two published cases have specifically implicated allergic or hypersensitivity mechanisms in the pathogenesis of post-PEEK effusions. Qiu et al. (2019) reported an adult patient who developed bilateral epidural effusions seven days after PEEK cranioplasty. The effusion fluid was light yellow and sterile, with elevated IgG protein concentration but normal glucose and negative bacteriological findings. The effusion resolved after dexamethasone therapy and drainage, suggesting a delayed-type allergic reaction without the need for implant removal [13]. In contrast, Shields et al. (2022) described a pediatric patient who developed combined epidural and subgaleal effusions three weeks after PEEK cranioplasty. Laboratory investigations revealed elevated ESR, CRP, and high IgG levels in the effusion [11]. Although corticosteroid therapy initially reduced the effusion, recurrence occurred after tapering, and definitive resolution was only achieved following removal of the PEEK implant and replacement with autologous bone.

Nevertheless, rare reports of hypersensitivity to PEEK have emerged. To date, only three cases of PEEK-related allergic reactions have been described in the literature: An intervertebral cage used in anterior cervical discectomy and fusion (ACDF) [14], a PEEK-containing device for rotator cuff repair [15], and a cranial implant following bilateral cranioplasty [3]. Symptoms appeared within hours to four weeks after implantation. Diagnostic findings often included sterile fluid collections with elevated immunoglobulin G (IgG) levels and negative bacteriological cultures. In most cases, removal of the PEEK implant resulted in symptom resolution, although Qiu et al. reported one patient in whom epidural effusion resolved with corticosteroid therapy and drainage without explantation [13].

Our two adult cases add further perspective to this spectrum of clinical outcomes. The first patient experienced recurrent effusions that responded well to conservative management including aspiration, short-term corticosteroids, and compressive dressing. The second patient, however, developed progressive effusions refractory to conservative therapy, ultimately requiring removal of the PEEK implant and reconstruction with titanium mesh. These divergent outcomes underscore the heterogeneity in the pathophysiology and clinical course of post-PEEK effusions.

Taken together, the literature and our cases suggest that post-PEEK effusions may have multifactorial etiologies, including hypersensitivity reactions, sterile inflammatory responses, or impaired fluid resorption. Management should therefore be individualized. Conservative treatment may suffice in transient or mild cases, whereas persistent or progressive effusions may necessitate implant removal. Importantly, allergic etiologies must be distinguished from infection or cerebrospinal fluid leak through appropriate imaging, sterile fluid analysis, and laboratory investigations.

Ultimately, careful follow-up and a high index of suspicion are essential for early recognition and appropriate management of effusions after PEEK cranioplasty. Future studies are needed to clarify the underlying immunological mechanisms and to identify patients at higher risk for this rare but significant complication.

4. Conclusion

Patient-specific PEEK implants provide excellent cosmetic and functional outcomes in cranioplasty. However, recurrent epidural or subgaleal effusions may complicate postoperative recovery. While some cases respond well to conservative management, others may require implant removal and reconstruction with alternative materials such as titanium mesh. Careful patient monitoring and individualized management strategies are crucial to achieving optimal outcomes.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

Authors' contributions

All authors contributed equally to the conception and design of the study, data collection and analysis, interpretation of the results, and drafting of the manuscript. Each author approved the final version of the manuscript for submission.

Conflict of interest

The authors declared no conflict of interest.

References

[1] Honeybul S, Ho KM. Cranioplasty: Morbidity and failure. British Journal of Neurosurgery. 2016; 30(5):523-8. [DOI:10.1080/02688697.2016.1187259] [PMID]

[2] Szymoniuk M, Litak J, Sakwa L, Dryla A, Zezuliński W, Czyżewski W, et al. Molecular mechanisms and clinical application of multipotent stem cells for spinal cord injury. Cells. 2022 Dec 28;12(1):120. [DOI:10.3390/cells12010120] [PMID] [PMCID]

[3] Zanaty M, Chalouhi N, Starke RM, Clark SW, Bovenzi CD, Saigh M, et al. Complications following cranioplasty: Incidence and predictors in 348 cases. Journal of Neurosurgery. 2015; 123(1):182-8. [DOI:10.3171/2014.9.JNS14405] [PMID]

[4] Punchak M, Chung LK, Lagman C, Bui TT, Lazareff J, Rezzadeh K, et al. Outcomes following polyetheretherketone (PEEK) cranioplasty: Systematic review and meta-analysis. Journal of Clinical Neuroscience. 2017; 41:30-35. [DOI:10.1016/j.jocn.2017.03.028] [PMID]

[5] Rosenthal G, Ng I, Moscovici S, Lee KK, Lay T, Martin C, et al. Polyetheretherketone implants for the repair of large cranial defects: A 3-center experience. Neurosurgery. 2014; 75(5):523-9; discussion 528-9. [DOI:10.1227/NEU.0000000000000477] [PMID]

[6] Thien A, King NK, Ang BT, Wang E, Ng I. Comparison of polyetheretherketone and titanium cranioplasty after decompressive craniectomy. World Neurosurgery. 2015; 83(2):176-80. [DOI:10.1016/j.wneu.2014.06.003] [PMID]

[7] Alkhaibary A, Alharbi A, Alnefaie N, Oqalaa Almubarak A, Aloraidi A, Khairy S. Cranioplasty: A comprehensive review of the history, materials, surgical aspects, and complications. World Neurosurgery. 2020; 139:445-52. [DOI:10.1016/j.wneu.2020.04.211] [PMID]

[8] Brommeland T, Rydning PN, Pripp AH, Helseth E. Cranioplasty complications and risk factors associated with bone flap resorption. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine. 2015; 23:75. [DOI:10.1186/s13049-015-0155-6] [PMID] [PMCID]

[9] Zhang J, Tian W, Chen J, Yu J, Zhang J, Chen J. The application of polyetheretherketone (PEEK) implants in cranioplasty. Brain Res Bull. 2019; 153:143-9. [DOI:10.1016/j.brainresbull.2019.08.010] [PMID]

[10] Jonkergouw J, van de Vijfeijken SE, Nout E, Theys T, Van de Casteele E, Folkersma H, et al. Outcome in patient-specific PEEK cranioplasty: A two-center cohort study of 40 implants. Journal of Cranio-Maxillo-Facial Surgery. 2016; 44(9):1266-72. [DOI:10.1016/j.jcms.2016.07.005] [PMID]

[11] Shields LB, Vessell M, Mutchnick IS. Epidural effusion as allergic reaction following polyetheretherketone cranioplasty: An illustrative case and review of the literature. Cureus. 2022. 14(1):e21390. [DOI:10.7759/cureus.21390]

[12] Morselli C, Zaed I, Tropeano MP, Cataletti G, Iaccarino C, Rossini Z, et al. Comparison between the different types of heterologous materials used in cranioplasty: A systematic review of the literature. Journal of Neurosurgical Sciences. 2019; 63(6):723-36. [DOI:10.23736/S0390-5616.19.04779-9] [PMID]

[13] Qiu S, You W, Wang H, Zhou X, Yang X. Allergic epidural effusion following polyetheretherketone cranioplasty. The Journal of Craniofacial Surgery. 2019; 30(3):e241-3. [DOI:10.1097/SCS.0000000000005192] [PMID]

[14] Maldonado-Naranjo AL, Healy AT, Kalfas IH. Polyetheretherketone (PEEK) intervertebral cage as a cause of chronic systemic allergy: A case report. The Spine Journal. 2015; 15(7):e1-3. [DOI:10.1016/j.spinee.2015.04.011] [PMID]

[15] Kofler L, Wambacher M, Schweinzer K, Scherl M, Kofler H. Allergic reaction to polyether ether ketone following cross-reactivity to epoxy resin. Journal of Cutaneous Medicine and Surgery. 2017; 21(1):78-9. [DOI:10.1177/1203475416665606] [PMID]