Turk Neurosurg 32(5):841-844, 2022

Original Investigation

DOI: 10.5137/1019-5149.JTN.37476-21.1

Received: 24.12.2021
Accepted: 28.01.2022

Published Online: 19.04.2022

The Comparison of Autologous Bone, Methyl-Methacrylate, Porous Polyethylene, and Titanium Mesh in Cranioplasty

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ABSTRACT

AIM: To discuss four different materials that are frequently used in cranioplasty, and to reveal their advantages and disadvantages.

MATERIAL and METHODS: We retrospectively reviewed 85 of our cranioplasty surgeries between 2016 and 2019. Reconstruction surgeries were excluded from our study due to craniofacial trauma.

RESULTS: Of the materials used in cranioplasty, 33 are autologous bone, 32 are methyl-methacrylate, 12 are porous polyethylene, and 8 are titanium mesh. Complications developed in 16 patients. Of these, 10 are infection, 3 are flap collapse, 2 are wound healing disorders, and 1 is reactive effusion complications due to the used material. The highest complication rate was 21.9% in cranioplasty with methyl-methacrylate. No major complications were observed in cranioplasty with titanium mesh.

CONCLUSION: Cranioplasty, which are among the surgeries with high complications in neurosurgery, maintain their importance today. As technology is developed and cost problems are resolved, cranioplasty takes its place among the safer and standard neurosurgical operations.

KEYWORDS: Titanium, Prosthesis implantation, Skull, Cranioplasty

ABBREVIATION: CT: Computer tomography

INTRODUCTION

Cranial defect and anomaly reconstruction due to various reasons has an important place in neurosurgery. Trauma (acute subdural hematoma, shifting edema in midline structures, and contusion), cerebral ischemic events, oncological surgeries, intracerebral infections with craniectomy, epilepsy, and aneurysm surgeries are among the main causes of cranioplasty (4,10).

Cranioplasty aimed to preserve neuronal structures, restore empty flow dynamics, and for cosmetic reasons. It gives a different perspective to neurosurgery since it is also performed for cosmetic reasons.

The timing of cranioplasty varies depending on the cause of the existing defect. It can be done in the same session in tumors and traumas, and in cases, such as infection and brain edema, it can be done in elective conditions after the acute picture is healed (7).

Appropriate material selection to close bone defects remained controversial. The main materials used in cranioplasty are autologous bone (autograft), titanium mesh (metal), porous polyethylene implants (polymer), methyl-methacrylate (polymer), calcium phosphate bone cement (ceramic), and hydroxyapatite-polymethyl methacrylate (ceramic-polymer mixture) composites (7,10).

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MATERIAL and METHODS

Cranioplasty that is performed in our institution between 2016 and 2019 were retrospectively reviewed, and the age, gender, diagnosis, materials used in the surgery, and complications were categorized. Routine brain computer tomography (CT) imaging was performed. Trauma, tumor, ischemic and hemorrhagic strokes, and intracerebral hematomas were included in the study. Reconstruction surgeries due to craniofacial trauma were excluded from the study. Postoperatively, patients were kept under control for at least 1 year. Imaging was performed with brain CT in each patient and brain magnetic resonance imaging was observed when necessary in the pre-operative preparation phase. Whether each patient had an infection at the wound site or a systemic infection focus was investigated. With such a situation, the surgery was planned for at least 1 month after the infection focus was resolved. Bone flaps of patients, who underwent decompressive craniectomy and preserved their bones, were routinely placed in the intra-abdominal subcutaneous tissue in the same session. In cranioplasty operations that involve the frontal sinus region, the frontal sinus ostium was closed with bone wax and the patient's bone, the sinus mucosa was excised, and the frontal sinus was cranialized. The bone flap that is stored in the abdominal subcutaneous fat tissue was removed in the same session for cranioplasty and thoroughly washed with saline containing vancomycin before use. Autologous bone, methyl-methacrylate, and porous polyethylene implants are fixed to the cranium with thick vicryl sutures as standard. Titanium mesh is fixed to the cranium with mini-screws.

The percentage distribution of categorical data between groups was made using the Chi-Square test. Fisher's Exact Test was performed when the Chi-Square conditions could not be met. The Statistical Package for the Social Sciences v20 program was used in the analysis of the data and a *p*-value of <0.05 was considered significant.

RESULTS

Considering the etiological causes of 85 patients who underwent cranioplasty, 43 operations were performed due to trauma (acute subdural hematoma, intracerebral hematoma, edema and contusion, and depression fracture), 16 were due to spontaneous intracerebral hematoma, 13 due to ischemic stroke, 10 due to tumor, and 3 due to other causes (subdural hygroma and sinus pericranii). The age range of the patients was between 12 and 87 years, and 63 of 85 patients were males and 22 were female. Cranioplasty was performed in the same session in 10 cases, with the highest rate (n=6) performed due to tumor, followed by post-traumatic depression fracture (n=4). The average time to perform the cranioplasty is approximately 4 months (127 days).

Of the materials used in cranioplasty, 33 are autologous bone, 32 are methyl-methacrylate, 12 are porous polyethylene, and 8 are titanium mesh (Table I). Complications developed in 16 patients. Of these, 10 are infection, 3 are flap collapse, 2 are wound healing disorders, and 1 are reactive effusion complications due to the used material. Of the 10 patients, ethyl-methacrylate was used in 6, autologous bone in 3, and porous polyethylene in 1. The repetitive collection, contrarily, developed due to methyl-methacrylate, and this problem was solved using titanium mesh in its revision. Methyl-methacrylate was used in 1 of the 2 patients with wound healing problems and porous polyethylene was used in the other. All three complications due to flap collapse occurred in patients who used autogenous bone (Figure 1). Revision surgery was performed on 4 of 16 patients who developed complications, and the cranioplasty kit of 2 patients with wound site problems was left untouched and was treated with minor surgery (Table II).

DISCUSSION

Cranioplasty revision and complication rates are quite high compared to other surgeries in neurosurgery practice. Cranioplasty revision rates in the literature range from 5% to 26% (9). Our study revealed this rate (16.5%) as compatible with the literature. The overall complication rate in the post-operative period in patients who underwent cranioplasty was 18.8%.

The literature revealed a 5%–33% infection rate in cranioplasty (2). In our study, the highest rate of complications was an infection in 11.7%, followed by flap collapse in 3.6%, wound site problems in 2.3%, and recurrent collection in 1.2%.

Infection was mostly developed in methyl-methacrylate and autologous grafts, and no statistically significant correlation was found in the comparison of porous polyethylene and titanium due to the insufficient number of patients; however, significant results could be obtained with other prognostic parameters in studies that are conducted with more cases. Additionally, as we evaluate with our clinical observation and

Table I: Complication Rates

Material	Number of patients	Number of complicated patients	Complication rates (%)	Infection rates (%)
Autologous bone	33	6	18.2	9.1
Methyl methacrylate	32	7	21.9	18.7
Porous polyethylene	12	2	16.6	8.3
Titanium mesh	8	0	0.0	0.0

experience, considering the experience we gained from using titanium alloys in other body areas, the absence of infection in 8 patients who used titanium mesh is not a situation to be ignored.

Methyl-methacrylate is good in terms of ease of use, good cosmetic results, and low cost; however, its high infection rates and exothermic and inflammatory reaction are among its disadvantages (12). Our study revealed infection as the most common cranioplasty material with a rate of 18.7%. The autologous graft has the advantages of being the body's tissue, being viable, and having the possibility of growth; however, its disadvantages include the relatively worse cosmetic results, high infection risk, and resorption possibility. The infection rate was 9.1% and the rate of the inability to fix well due to resorption and collapse was 9.1%. The use of autologous bone was as safe as other cranioplasty materials in the study of Baldo et al.; however, many studies in the literature obtained results close to ours (1-3).

Porous polyethylene, which is one of the 2 most reliable materials in our study, has a fibrovascular growth in its porous structure, with positive cosmetic results and a low infection rate; however, among its disadvantages is the difficult revision

Figure 1: Bone window brain tomography images of 3 patients with collapse complication.

Table II: Complicated Cranioplasty Patients

	First Cranioplasty	Complications	Revision Cranioplasty	The time between two surgeries
1	Autologous bone	Infection	Methyl methacrylate	1 month
2	Autologous bone	Infection	Titanium mesh	3 month
3	Autologous bone	Infection	Titanium mesh	3 month
4	Autologous bone	Collapse	Autologous bone	6 month
5	Autologous bone	Collapse	Autologous bone	9 month
6	Autologous bone	Collapse	Methyl methacrylate	8 month
7	Methyl methacrylate	Infection	Porous polyethylene	2 month
8	Methyl methacrylate	Infection	Porous polyethylene	4 month
9	Methyl methacrylate	Infection	Methyl methacrylate	9 month
10	Methyl methacrylate	Infection	Methyl methacrylate	23 month
11	Methyl methacrylate	Infection	Methyl methacrylate	5 month
12	Methyl methacrylate	Infection	Titanium mesh	2 month
13	Methyl methacrylate	Repetitive collection	Titanium mesh	9 month
14	Porous polyethylene	Infection	Titanium mesh	28 month
15	Porous polyethylene	Wound problem	-	1 month
16	Methyl methacrylate	Wound problem	-	1 month

due to fibrovascular growth and high cost. Our results in 12 patients were compatible with the literature, as well as the infection in 1 patient and wound site problem in another 1. The series of 598 cases by Liu et al. used porous polyethylene and revealed no infection, very good cosmetic results (5). Titanium mesh, which draws attention with its low infection rate, absence of inflammatory reaction, and material that integrates with the bone structure over time, is high in cost and difficult to shape, with possible bad cosmetic results among its disadvantages. Complications did not develop in 8 patients we operated on, which was compatible with the literature (6,11). We generally used titanium mesh in cases where we had revision after infection. Bending it is difficult, thus we preferred it in areas with a low slope of the cranial defect, and our cosmetic results were good.

Complication, due to flap collapse, was seen in 3 cases, which developed due to autologous bone in all three. Among the reasons was that the bone flap remained small compared to the existing defects. While the reason was resorption in 2 cases, in 1 case, it was the enlargement of the existing craniectomy defect after malignant edema that developed after elective tumor surgery, of which the bone flap remained small. A titanium plate was used instead of the suture in the revision surgery in 2 of these 3 cases, and the long-term results are satisfactory. Additionally, a solution was reached using methyl-methacrylate. Rashidi et al. examined the displacement of 13 cranioplasty materials and explained the advantages of using titanium miniplates (8).

CONCLUSION

Cranioplasty operations, which are among the surgeries with high complications in neurosurgery, maintain their importance today. Despite the development of technology, the ability to perform three-dimensional imaging in many clinics, and the introduction of new cranioplasty materials, a gold standard approach has not yet been determined. Our study compared the autologous bone, methyl-methacrylate, porous polyethylene, and titanium mesh and revealed that the complication rates were quite low in porous polyethylene and titanium mesh. However, the small number of cases is one of the limiting factors of our study. The infection rate was highest in methyl-methacrylate, and titanium mesh and porous polyethylene gave relatively better results in this regard. The biggest limitation of the use of porous polyethylene and titanium mesh is its high cost. Therefore, autologous bone and methyl-methacrylate are still the best options in most clinics.

AUTHORSHIP CONTRIBUTION

Study conception and design: HC, AK

Data collection: MEY, HK

Analysis and interpretation of results: YE, MAB

Draft manuscript preparation: AT

Critical revision of the article: HC, AK

Other (study supervision, fundings, materials, etc...): KK, MEY

All authors (HC, AK, MEY, AT, YE, KK, HK, MAB) reviewed the results and approved the final version of the manuscript.

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