

Clinical Article



# Complications of Cranioplasty Following Decompressive Craniectomy: Risk Factors of Complications and Comparison Between Autogenous and Artificial Bones

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**Conflict of Interest**

The authors have no financial conflicts of interest.

## ABSTRACT

**Objectives:** Craniectomy is widely performed to lower the intracranial pressure in various conditions, such as traumatic brain injury, stroke, or brain swelling. Several complications can occur after craniectomy and cranioplasty, which significantly affect the prognosis of the patients after surgery. We studied the complications of craniectomy and cranioplasty and the factors affecting prognosis after the operation.

**Methods:** Patients who underwent cranioplasty after craniectomy at Daejeon St. Mary's Hospital from 2015 to 2021 were included. We retrospectively reviewed their medical records and images. All patients were classified according to their sex, age, clinical grade, and diagnosis. Complications after craniectomy and cranioplasty were investigated for 1 year after surgery. The complications included postoperative hemorrhage, infection, hydrocephalus, and bone resorption.

**Results:** This study included 104 patients. Complications after decompressive craniectomy were significantly frequent in patients with hypertension history ( $p=0.03$ ). In contrast, complications of cranioplasty were significantly frequent in patients with history of diabetes mellitus, hepatic failure, or trauma ( $p=0.03$ ,  $p<0.01$ , and  $p=0.01$ , respectively). Artificial bones were used more frequently than autologous bones in patients with trauma ( $p=0.03$ ); however, there was no difference in the incidence of complications between them ( $p=0.64$ ).

**Conclusion:** Hypertension is a significant risk factor for decompressive craniectomy complications, especially rebleeding. Diabetes, hepatic failure, and trauma are significant risk factors for cranioplasty complications. There was no statistical difference in the incidence of complications between the use of autologous and artificial bones.

**Keywords:** Bone; Decompressive craniectomy; Patients; Risk factors

## INTRODUCTION

Craniectomy is a neurosurgical operation widely performed to lower intracranial pressure in various situations including trauma, hemorrhagic or ischemic stroke, and brain tumors.<sup>10,15)</sup> If the intracranial pressure decreases after craniectomy, cranioplasty is required for cosmetic purposes and to protect the brain from trauma.<sup>6)</sup> In addition, it is essential for the management of normal intracranial pressure.<sup>2,18)</sup>

After craniectomy & cranioplasty, various complications such as infection, hematoma, and bone resorption can occur and these complications can have a very significant impact on the prognosis of patients after surgery.<sup>5)</sup> For example, bone flap graft infection is an important postoperative complication associated with cranioplasty, and it can lead to prolonged hospitalization and the need for long-term antibiotic treatment.<sup>16,19)</sup> There have been studies on the factors affecting the prognosis of craniectomy & cranioplasty in many past kinds of literature, but many factors are not yet uncertain. We studied complications of craniectomy & cranioplasty and factors affecting prognosis after the operation. The purpose of this study is to 1) present the complications after craniectomy and cranioplasty, 2) investigate the risk factors for postoperative complications, and 3) compare two groups with autologous and artificial bone used during cranioplasty.

## MATERIALS AND METHODS

From 2015 to 2021, patients who underwent cranioplasty after craniectomy at Daejeon St. Mary's Hospital were selected for the study, and a retrospective study was done for these patients. All patients over the age of 18 who underwent craniectomy due to head trauma, stroke, or brain swelling (except for cases with a malignant brain tumor) were included in this study. Patients who performed only craniectomy or cranioplasty only were excluded. Institutional Review Board approval was obtained for clinical and imaging data collection. The surgeon decided whether to use autologous or artificial bone and the types of artificial bones, though artificial bones were used in most traumatic cases.

In the aspect of medical history, hepatic failure means markedly decreased hepatic function, like liver cirrhosis, hepatocellular carcinoma, or acute hepatitis. Renal failures were classified as the patient receiving dialysis. The diagnosis was classified with non-traumatic (intracerebral hemorrhage, aneurysmal subarachnoid hemorrhage, cerebral infarct, brain swelling, etc.) and traumatic causes. We investigated initial preoperative demographic factors before decompressive craniectomy (DC) as well as post-craniectomy demographic factors before cranioplasty, like external ventricular drainage (EVD), the period between craniectomy and cranioplasty, and mRS just before cranioplasty. Complications after craniectomy and cranioplasty mean cases requiring re-operation and additional medical therapy due to hematoma, infection, hydrocephalus, bone resorption, and others. Including autologous skull bone, a variety of bone flap materials were used, such as resin, mesh plate, medpor, 3D plate, etc.

We compared the various parameters between good and poor surgical and clinical results. A Student's *t*-test was applied for comparison between two groups and  $\chi^2$  test for checking the association for the outcome variable. In each case, the values were expressed as mean $\pm$ SD, and  $p < 0.05$  was considered statistically significant. Statistical analyses were conducted using the SPSS statistical package (version 25, SPSS Inc, Chicago, IL, USA).

## RESULT

A total of 104 patients were included in this study and **TABLE 1** shows initial preoperative demographic factors before DC. There were 56 male and 48 female patients, with a mean age of  $56.54 \pm 17.23$  years. Hypertension and diabetes mellitus were observed in 40, 13 patients, and hepatic, and renal failures were in 3, and 2 patients. Non-traumatic was slightly more than a traumatic cause (56.7% vs. 43.3%). Post-craniectomy demographic factors were described in **TABLE 2**. EVDs were performed in 24 patients and 64 patients received cranioplasty within 90 days after craniectomy. 19 patients were operated on with artificial bones and good mRS was observed only in 21 patients just before cranioplasty. Additional surgery or special medical treatment like antibiotics were needed 17.3% after craniectomy and 10.6% after cranioplasty. Total complication rates were 17.3% in craniectomy and 22.1% in cranioplasty. Rebleeding and infectious complications are the most frequent and severe complications of craniectomy (13.5%) and cranioplasty (12.5%) surgery (**TABLE 3**).

**TABLE 4** shows related factors with complications (rebleeding, infection, bone flap resorption, etc.) after craniectomy and cranioplasty. In the case of cranioplasty, hypertension

**TABLE 1.** Initial preoperative demographic factors of patients undergoing cranioplasty following decompressive craniectomy (n=104)

| Variables       | Values    | Mean (range)        |
|-----------------|-----------|---------------------|
| Sex             |           |                     |
| M               | 56 (53.8) |                     |
| F               | 48 (46.2) |                     |
| Age             |           | 56.54±17.23 (18–83) |
| <65             | 65 (62.5) |                     |
| ≥65             | 39 (37.5) |                     |
| HTN             | 40 (38.5) |                     |
| DM              | 13 (12.5) |                     |
| Hepatic failure | 3 (2.9)   |                     |
| Renal failure   | 2 (1.9)   |                     |
| Diagnosis       |           |                     |
| Non-traumatic   | 59 (56.7) |                     |
| Traumatic       | 45 (43.3) |                     |
| GCS             |           |                     |
| <8              | 41 (39.4) |                     |
| 8–12            | 32 (30.8) |                     |
| >12             | 31 (29.8) |                     |

Values are presented as number (%).

HTN: hypertension, DM: diabetes mellitus, GCS: Glasgow Coma Scale.

**TABLE 2.** Post-craniectomy demographic factors (n=108)

| Variables                                   | Values    |
|---|-----------|
| EVD   | 24 (23.1) |
| Complications associated with craniectomy   | 18 (17.3) |
| Period between craniectomy and cranioplasty |           |
| <90 days                                    | 64 (61.5) |
| ≥90 days                                    | 40 (38.5) |
| Cranioplasty bone flap                      |           |
| Autologous                                  | 86 (81.7) |
| Artificial                                  | 19 (18.3) |
| mRS at cranioplasty                         |           |
| ≥3  | 83 (79.8) |
| <3  | 21 (20.1) |
| Complications associated cranioplasty       | 11 (10.6) |

Values are presented as number (%).

EVD: external ventricular drainage, mRS: modified Rankin scale.

**TABLE 3.** Types of complications after craniectomy and cranioplasty (n=104)

| Variables  | Craniectomy | Cranioplasty |
|------------|-------------|--------------|
| None       | 86 (82.7)   | 81 (77.9)    |
| Rebleeding | 11 (10.6)   | 6 (5.8)      |
| Infection  | 3 (2.9)     | 7 (6.7)      |
| Etc.       | 4 (3.8)     | 10 (9.6)     |

Values are presented as number (%).

**TABLE 4.** Correlating factors of complications of craniectomy and cranioplasty

| Variables                                   | Complications after craniectomy |    |             | Complications after cranioplasty |    |               |
|---|---------------------------------|----|-------------|----------------------------------|----|---------------|
|   | N                               | Y  | p-value*    | N                                | Y  | p-value*      |
| Initial preoperative demographic factors    |                                 |    |             |                                  |    |               |
| Sex   |                                 |    | 0.47        |                                  |    | 0.23          |
| M   | 45                              | 11 |             | 47                               | 9  |               |
| F   | 41                              | 7  |             | 44                               | 4  |               |
| Age   |                                 |    | 0.50        |                                  |    | 0.59          |
| <65   | 55                              | 10 |             | 56                               | 9  |               |
| ≥65   | 31                              | 8  |             | 35                               | 4  |               |
| HTN   |                                 |    | <b>0.03</b> |                                  |    | 0.99          |
| N   | 57                              | 7  |             | 56                               | 8  |               |
| Y   | 29                              | 11 |             | 35                               | 5  |               |
| DM  |                                 |    | 0.85        |                                  |    | <b>0.03</b>   |
| N   | 75                              | 16 |             | 82                               | 9  |               |
| Y   | 11                              | 2  |             | 9                                | 4  |               |
| Hepatic failure                             |                                 |    | 0.42        |                                  |    | < <b>0.01</b> |
| N   | 83                              | 18 |             | 91                               | 10 |               |
| Y   | 3                               | 0  |             | 0                                | 3  |               |
| Renal failure                               |                                 |    | 0.51        |                                  |    | 0.59          |
| N   | 84                              | 18 |             | 89                               | 13 |               |
| Y   | 2                               | 0  |             | 2                                | 0  |               |
| Diagnosis                                   |                                 |    | 0.91        |                                  |    | <b>0.01</b>   |
| Non-traumatic                               | 49                              | 10 |             | 56                               | 3  |               |
| Traumatic                                   | 37                              | 8  |             | 35                               | 10 |               |
| GCS   |                                 |    | 0.13        |                                  |    | 0.43          |
| <8  | 31                              | 10 |             | 35                               | 6  |               |
| 8–12  | 26                              | 6  |             | 30                               | 2  |               |
| >12   | 29                              | 2  |             | 26                               | 5  |               |
| Post-craniectomy demographic factors.       |                                 |    |             |                                  |    |               |
| EVD   |                                 |    |             |                                  |    | 0.99          |
| N   |                                 |    |             | 70                               | 10 |               |
| Y   |                                 |    |             | 21                               | 3  |               |
| Complications of craniectomy                |                                 |    |             |                                  |    | 0.83          |
| N   |                                 |    |             | 79                               | 11 |               |
| Y   |                                 |    |             | 12                               | 2  |               |
| Period between craniectomy and cranioplasty |                                 |    |             |                                  |    | <b>0.06</b>   |
| <90 days                                    |                                 |    |             | 59                               | 5  |               |
| ≥90 days                                    |                                 |    |             | 32                               | 8  |               |

HTN: hypertension, DM: diabetes mellitus, GCS: Glasgow Coma Scale, EVD: external ventricular drainage.

\*The meaning that boldface *p*-value is less than or equal to 0.05 means that the results according to the difference in the survey items are statistically significant.

was a statistically significant risk factor for post-craniectomy complications ( $p=0.03$ ), although there was no significant difference in complications after cranioplasty ( $p=0.99$ ). On the other side, diabetes, hepatic failure, and traumatic cause were the significant risk factors for complications after cranioplasty ( $p=0.03$ ,  $p<0.01$ ,  $p=0.01$ , respectively). Among the post-craniectomy demographic factors, there was no statistically significant risk factor of complications after cranioplasty, although a longer-time interval ( $\geq 90$  days) between craniectomy and cranioplasty tended complications ( $p=0.06$ ).

**TABLE 5.** Comparison of autologous and artificial bone at cranioplasty

| Variables                                   | Autologous | Artificial | p-value     |
|---|------------|------------|-------------|
| Sex   |            |            | 0.54        |
| M   | 44         | 12         |             |
| F   | 40         | 8          |             |
| Age   |            |            | 0.78        |
| <65   | 53         | 12         |             |
| >65   | 31         | 8          |             |
| HTN   |            |            | 0.17        |
| N   | 49         | 15         |             |
| Y   | 35         | 5          |             |
| DM  |            |            | 0.71        |
| N   | 73         | 18         |             |
| Y   | 11         | 2          |             |
| Hepatic failure                             |            |            | 0.53        |
| N   | 82         | 19         |             |
| Y   | 2          | 1          |             |
| Renal failure                               |            |            | 0.49        |
| N   | 82         | 20         |             |
| Y   | 2          | 0          |             |
| Diagnosis                                   |            |            | <b>0.03</b> |
| Non-traumatic                               | 52         | 7          |             |
| Traumatic                                   | 32         | 13         |             |
| GCS   |            |            | 0.06        |
| <8  | 32         | 9          |             |
| 8–12  | 30         | 2          |             |
| >12   | 22         | 9          |             |
| EVD   |            |            | 0.12        |
| N   | 62         | 18         |             |
| Y   | 22         | 2          |             |
| Complications of craniectomy                |            |            | 0.31        |
| N   | 71         | 15         |             |
| Y   | 13         | 5          |             |
| Period between craniectomy and cranioplasty |            |            | 0.87        |
| <90 days                                    | 52         | 12         |             |
| ≥90 days                                    | 32         | 8          |             |
| Complications of cranioplasty               |            |            | 0.64        |
| N   | 67         | 15         |             |
| Y   | 17         | 5          |             |

HTN: hypertension, DM: diabetes mellitus, GCS: Glasgow Coma Scale, EVD: external ventricular drainage.

In the comparison between autologous and artificial bone, artificial bones were more frequently used in traumatic patients (**TABLE 5**, 11.8% vs. 28.8%,  $p=0.03$ ). Expect the diagnosis, there was no statistically significant factor between autologous and artificial bones. The type of bones also did not affect the complications after cranioplasty ( $p=0.64$ ). Although we investigated subgroup analysis according to disease entity (trauma, stroke, etc.), there was no statistical significance of complications according to the type of disease. It is presumed that it is because the number of patients is small.

## DISCUSSION

DC is performed frequently in patients with refractory intracranial hypertension resulting from traumatic brain injury (TBI) or cerebrovascular disease.<sup>17)</sup> On the other side, cranioplasty is a time-honored surgical procedure to restore the calvarias form and function.<sup>4,12)</sup> Complications after DC include contusion or hematoma expansion, epilepsy, herniation of cortex, CSF leakage, infection, and subdural effusion. Hydrocephalus can

also develop due to CSF malabsorption or obstructed CSF flow.<sup>5)</sup> The complications associated with cranioplasty are also similar to craniectomy, including hematoma, CSF collection, wound dehiscence, flap necrosis, graft infection, exposure of the reconstruction material, contour defect, resorption of graft, loss of fixation, etc.<sup>9,12,13)</sup> These postoperative complications may require additional surgery, lengthen hospitalization, worsen the prognosis, and are even associated with mortality. As with all surgeries, any surgeon needs to reduce or anticipate complications of surgery.

In our study, the presence or absence of hypertension showed a significant difference ( $p=0.03$ ) in the incidence of the overall complications after craniectomy. Of the 104 patients included in the study, 43.3% had cerebrovascular disease and the most common complication of decompression surgery was rebleeding (10.6%). Hypertension is a well-known important risk factor for poor prognosis for cerebrovascular patients with hemorrhagic and ischemic stroke. Hypertensive disorders promote stroke through an increased shear tear, endothelial dysfunction, and large artery stiffness that transmits pulsatile flow to cerebral microcirculation.<sup>11)</sup> For these reasons, the frequency of postoperative complications, including rebleeding, is expected to increase in hypertension patients. On the other hand, complications of cranioplasty occurred evenly and varied, including rebleeding (5.8%), infection (6.7%), and others (9.6%).<sup>7)</sup>

Diabetes ( $p=0.03$ ), hepatic failure ( $p<0.01$ ), and traumatic cause ( $p=0.01$ ) were statistically significant risk factors for complications of cranioplasty. Many of the complications were related to wounds at the surgical site, including hematoma or infection, and diabetes is also one of the well-known major risk factors for wound complications. Diabetes mellitus is a stroke risk factor and is correlated in patients with atherosclerosis.<sup>1)</sup> Although, hepatic and renal failure may increase the bleeding complication of craniectomy as well as cranioplasty due to abnormal coagulation factors, hepatic failure was the only significant factor for complications of the cranioplasty, not for the craniectomy. Interestingly, the traumatic cause was the significant factor for complications after cranioplasty ( $p<0.01$ ). Of the 23 complications that occurred after plastic surgery, 7 were infection-related complications, and all of these 7 cases used autologous bones. As in several other studies, the use of autologous bone in trauma appears to frequently cause infection problems.<sup>3,18)</sup> Although most autologous bones are stored frozen below  $-50^{\circ}\text{C}$ , the temperature is not kept constant or bacteria can grow. In particular, the longer the storage period, the greater the possibility of contamination. To make the extracted calvaria sterile, a high-temperature and high-pressure sterilization (autoclave) sterilization device must be used, however, this method is not appropriate because it destroys normal bone tissue.

TBI might be a risk factor for some complications, such as infections and bone flap resorption.<sup>14)</sup> Especially, TBI patients appeared to be at higher risk of an infection and also at higher risk of re-operation when autologous grafts were used.<sup>8)</sup> The long period between DC and cranioplasty ( $\geq 90$  days) showed a tendency to increase postoperative complications of cranioplasty, although there was no statistical significance ( $p=0.06$ ). Among the 8 patients who underwent cranioplasty more than 90 days after DC and developed complications, the autologous bone was used in 6 patients and infection-related complications occurred in 5 patients.

In the results of comparing autologous and artificial bones, there was no statistically significant difference in the complications after cranioplasty. However, the use of artificial bones was prominent in trauma patients ( $p=0.03$ ), and this is thought to be a natural result

due to the causes of bone fractures and open windows due to trauma. The use of autologous or artificial bones is not considered to have any effect on complications after cranioplasty, and detailed surgical techniques to reduce complications for the operator will be important. In the past, the surgeon had to mold the shape of the bone with resin or medpor products, but in recent years, 3D technology has been used to create artificial bones with the same shape as the patient's original shape, reducing the burden on the surgeon to mold the bone.

There are several limitations to this study. First of all, it was difficult to identify significant risk factors conclusively due to the small sample size. Secondly, the data were analyzed retrospectively, there are limitations in the retrospective itself, such as loss of patient information. Lastly, we did not consider the correlation between bone flap materials and complications.

## CONCLUSION

Despite some limitations, this study showed some notable results. Hypertension was an important risk factor for complications of DC in critically ill patients, and diabetes, hepatic failure, and traumatic causes are important factors for a craniectomy. Although statistical significance was not recognized, a long period between craniectomy and cranioplasty may be a risk factor for complications of cranioplasty.

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