Clinical Article
J Korean Neurosurg Soc 68 (3) : 360-368, 2025
https://doi.org/10.3340/jkns.2024.0176
pISSN 2005-3711 eISSN 1598-7876

Efficacy of Anti-Adhesive Substitute and Step-by-Step Techniques in Decompressive Craniectomy and Subsequent Cranioplasty

You-Sub Kim, Jae-Woong Kim, Sung-Pil Joo, Tae-Sun Kim

Department of Neurosurgery, Chonnam National University Hospital, Chonnam National University Medical School, Gwangju, Korea

Objective : Dural substitutes have been widely used in decompressive craniectomy to prevent adhesion, and have significantly reduced blood loss and operation time. However, there are only limited studies providing information regarding detailed techniques and the specific operation time that is associated with good prognoses. In this study, we evaluate the effectiveness of using a dural substitute as an anti-adhesive material during cranioplasty, focusing on technical details and operation time from incision to bone closure.

Methods : A retrospectively reviewed total of 66 patients were included who underwent a craniectomy and subsequent cranioplasty caused by either a severe traumatic brain injury (n=35) or malignant infarction (n=31). The patients were divided into two groups depending on whether Neuro-Patch was used or not (31 in the Neuro-Patch group, 35 in the non-Neuro-Patch group). Propensity score matching was used to minimize the differences. Associated morbidities as well as operation time, and blood loss were analyzed and compared between the two groups.

Results : To prevent adhesion, Neuro-Patch was placed as an onlay, enough to cover the surrounding skull at least 1 cm beyond the bone edges. A small piece was also placed over the temporalis muscle during the craniectomy. A step-by-step dissection was performed to minimize retraction-related injury during the subsequent cranioplasty. The mean estimated blood loss was significantly lower in the Neuro-Patch group (54.6±34.9 vs. 149.0±70.8 mL, p<0.001) and the mean time from incision to bone closure in the Neuro-Patch group was 40.8±14.3 minutes, which was significantly lower than in the non-Neuro-Patch group (91.5±38.2 minutes) as well. For each analysis of complications, the differences were not significant, however, the overall complication rate was significantly lower in the Neuro-Patch group (9.7%) than in the non-Neuro-Patch group (42.9%).

Conclusion : Neuro-Patch can be used safely and effectively as an anti-adhesive substitute during cranioplasty. To improve clinical outcomes as well as intraoperative parameters including the time from incision to bone closure, planned placement of Neuro-Patch during craniectomy and the step-by-step dissection during cranioplasty is important.

Key Words : Craniectomy · Cranioplasty · Dural substitutes · Adhesion · Complications.

• Received : October 2, 2024 • Revised : November 4, 2024 • Accepted : January 27, 2025
• Address for correspondence : **Tae-Sun Kim**
Department of Neurosurgery, Chonnam National University Hospital, 42 Jebong-ro, Dong-gu, Gwangju 61469, Korea
Tel : +82-62-220-6606, Fax : +82-62-220-6607, E-mail : taesun1963@yahoo.co.kr, ORCID : https://orcid.org/0000-0001-7134-073X

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (http://creativecommons.org/licenses/by-nc/4.0) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Copyright © 2025 The Korean Neurosurgical Society

INTRODUCTION

Decompressive craniectomy and subsequent cranioplasty are the basic neurosurgical procedures widely performed to treat severe traumatic brain injury (TBI) or malignant infarction[2,20]. Besides the large bone flap, wide opening of the dura is crucial in lowering the intracranial pressure[13]. In this process, multiple adhesions on the dura, temporalis muscle, and galea inevitably develop making the subsequent cranioplasty difficult. These adhesions can cause cranioplasty-related morbidities including infection, cerebrospinal fluid (CSF) leak, cosmetic problems caused by temporalis muscle injury, intra-axial hematoma, and extra-axial hematoma, which can occasionally necessitate re-operation[3,8,9,18]. Different craniectomy techniques have been reported that use various dural substitutes as anti-adhesive materials in an attempt to reduce the morbidity associated with subsequent cranioplasty, with most concluding that dural substitutes can lead to reduced blood loss and overall operation time during cranioplasty[6,11,15,16]. However, few studies are available for operation time from incision to bone flap closure, which reflect the key time for complete dissection and bleeding control during cranioplasty. Additionally, a detailed description of step-by-step dissection during cranioplasty has been lacking in previous studies.

We have been using a double-layer technique during craniectomy, using Lyoplant (B. Braun, Melsungen, Germany) to cover the brain surface and Neuro-Patch (B. Braun, Boulogne, France) as an anti-adhesive material. This study evaluates the efficacy of Neuro-Patch in cranioplasty by focusing on how to reduce the time from incision to bone flap closure and improving associated clinical outcomes.

MATERIALS AND METHODS

Study population

This study was approved by the Institutional Review Board of Chonnam National University Hospital (IRB No. BCRI20005), and informed consent was obtained from all individual participants or their families. We retrospectively reviewed 236 patients diagnosed with severe TBI or malignant infarction who were treated with subsequent cranioplasty following decompressive craniectomy between January 2016 and December 2021. We excluded patients treated with anti-adhesive materials other than Neuro-Patch, those using artificial bone or synthetic implants which may affect infection and confuse interpretation of outcomes, those with ambiguous medical records whether the Neuro-Patch was used or not, those with a small bone flap size of <15 cm, or those with previous infection or CSF leak. In total, 66 patients were included in this study. Baseline demographic data and intraoperative data were collected, which included estimated blood loss, the interval between craniectomy and cranioplasty, and time from skin incision to bone flap closure, as well as total operation time. The blood loss was calculated as follows; [total amount of fluid in suction bottle (mL) – total amount of irrigation (mL)] + [total weight of used gauze (g) – total weight of gauze before use].

Treatments

All patients diagnosed with severe TBI, or malignant infarc-

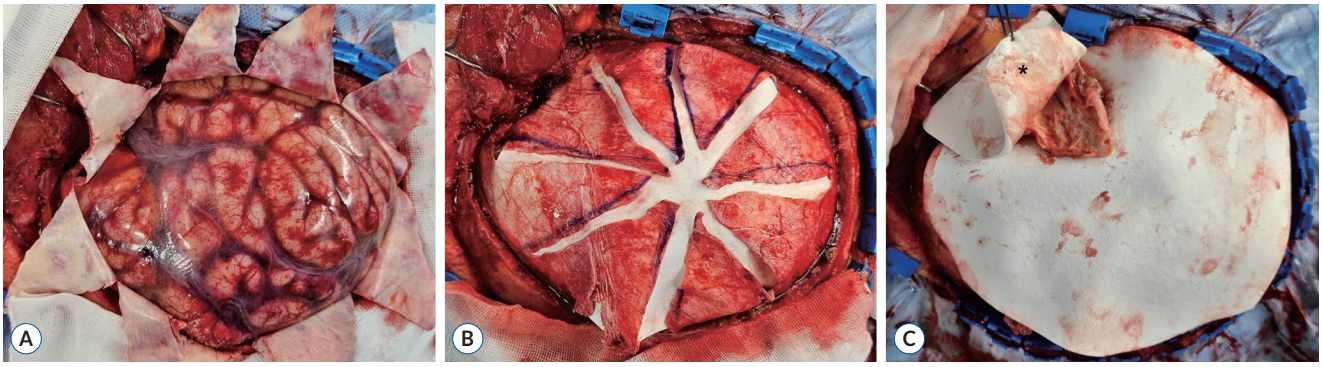

Fig. 1. Intraoperative findings during craniectomy. A : The dura is opened in a stellate fashion to achieve maximal decompression. B : A Lyoplant (B. Braun, Melsungen, Germany) is placed to cover the brain surface underneath the dura. C : Finally, a large piece of Neuro-Patch is placed over the dura and the Lyoplant, separating the overlying temporalis muscle and galea at least 1 cm beyond the bone margin. Note that a small piece of Neuro-Patch (asterisk) is applied between the galea and temporalis muscle.

tion underwent a standard fronto-temporoparietal craniectomy with a bone flap size of >15 cm. The scalp and temporalis muscle were reflected separately with interfascial dissection, not a single flap. Following craniotomy, the dura was opened in a stellate fashion extending to the bone margins (Fig. 1A) and the Lyoplant was placed so that it covered the exposed brain surface underneath the dura (Fig. 1B). Next, a large Neuro-Patch was placed over the dura as an onlay graft separating the dura from the overlying temporalis muscle and galea at least 1 cm beyond the bone margin. A small piece of Neuro-Patch was also applied between the galea and temporalis muscle (Fig. 1C). The subsequent cranioplasty was performed in two stages. First, the scalp flap was elevated, maintaining the galea-Neuro-Patch plane, ensuring not to dissect between the Neuro-Patch and dura first (Fig. 2A). After the scalp flap was fully retracted, the small piece of Neuro-Patch covering the temporalis muscle was carefully dissected and removed (Fig. 2B). Second, the temporalis muscle was fully dissected from the underlying Neuro-Patch (Fig. 2C) before the Neuro-Patch was finally removed by sharply dissecting it from the underlying dura (Fig. 2D). The schema of the operating procedure is described in Fig. 3. Any dural tears or defects were carefully inspected and restored with small pieces of Lyoplant. Finally, after the meticulous bleeding control, the autologous bone flap was closed with titanium screws and plates.

Outcomes and data analysis

Follow-up computed tomography (CT) scans were performed immediately after cranioplasty, then after 7 days, after 3 months, and finally after 1 year. Perioperative complications were reviewed, which included CSF leak, infection, and intra- and extra-axial hematomas. CSF leak was indicated as epidural and subgaleal fluid collection documented on the postoperative CT scans or persistent drainage of clear fluid into the drain bag. To assess clinical outcomes, pre- and post-cranioplasty modified Rankin scales (mRSs) were ascertained at discharge and at the final follow-up based on a chart review and the previous clinical follow-ups. All statistical analyses were performed using IBM SPSS Statistics software (SPSS, Chicago, IL, USA). To minimize the differences in baseline clinical characteristics be-

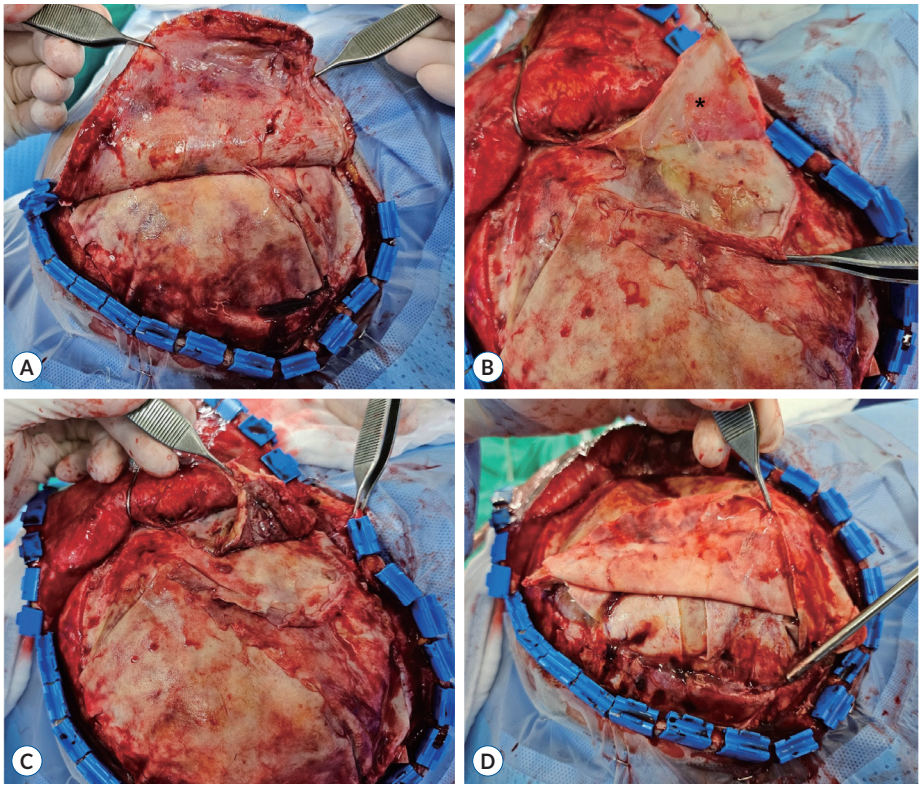

Fig. 2. Intraoperative findings during cranioplasty. A : The scalp is carefully elevated maintaining the galea-Neuro-Patch plane. B : After the scalp is fully retracted, a small piece of Neuro-Patch (asterisk) overlying the temporalis muscle is dissected and removed. C : The temporalis muscle is fully dissected from the underlying Neuro-Patch. D : Finally, a large piece of Neuro-Patch is removed by sharply dissecting it from the underlying dura.

 https://doi.org/10.3340/jkns.2024.0176

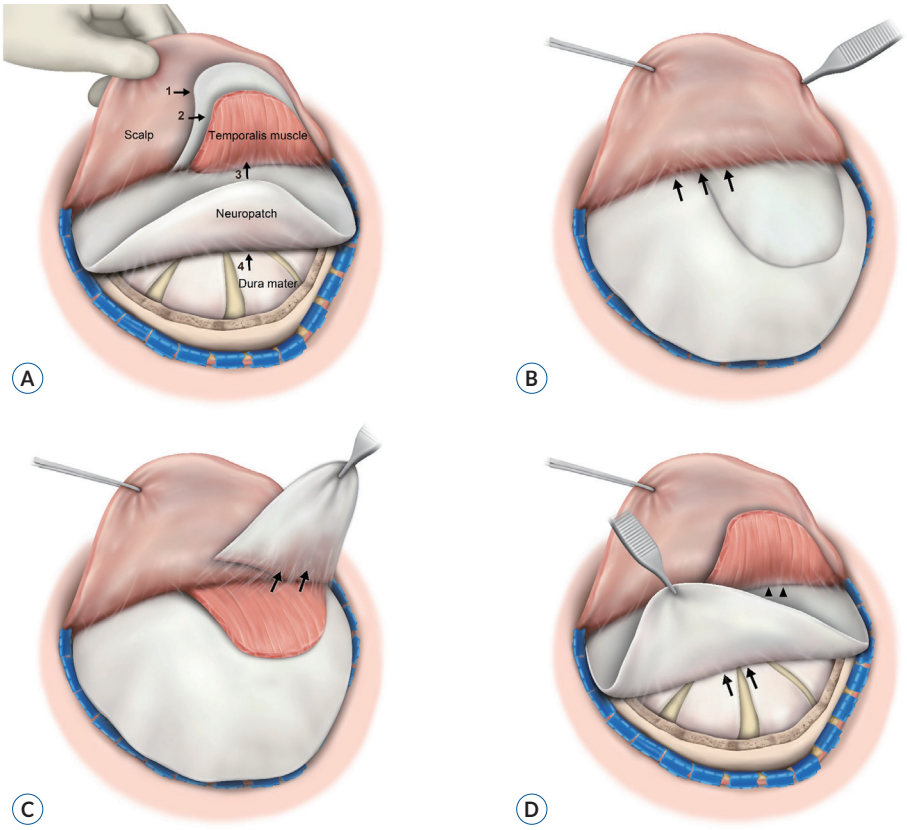

Fig. 3. A : Schema of step-by-step dissection during cranioplasty. B : First step 1. Scalp elevation between the galea and the underlying Neuro-Patch. C : Second step 2 and 3. Temporalis muscle dissection. D : Final step 4. Dissection and removal of a large piece of Neuro-Patch.

tween two groups, propensity score matching with caliper method was used before evaluating clinical outcomes. Propensity score was estimated using logistic regression model that included age, sex, primary neurologic insult, underlying diseases, thrombocytopenia, abnormal prothrombin time, activated partial thromboplastin time, interval between craniectomy to cranioplasty, pre-cranioplasty mRS, and follow-up period. This led to the formation of 19 pairs, total of 38 patients. Chi-squared tests and Fisher's exact tests were performed to compare categorical variables between the Neuro-Patch group and the non-Neuro-Patch group, while a Student's t-test was performed to compare continuous variables. Fisher's exact tests were performed to assess the effects of the Neuro-Patch on postoperative complications such as CSF leak, infection, intra- and extra-axial hematomas. *p*-values of <0.05 denoted statistical significance.

RESULTS

Baseline characteristics

Of the 66 patients, 35 were treated for TBI and 31 for malignant infarction. The mean age was 53.1±17.2 years, and the mean follow-up duration was 32.2±17.8 months. The patients were divided into two groups depending on whether Neuro-Patch was used or not (31 in the Neuro-Patch group, 35 in the non-Neuro-Patch group). The baseline characteristics of the two groups are presented in Table 1. Age and sex did not differ significantly between the two groups. Also, the type of primary neurologic insult, underlying diseases including liver disease or diabetes mellitus, and bleeding tendencies did not differ significantly between the two groups. The mean time from craniectomy to cranioplasty was 97.1±48.8 days in the Neuro-Patch group and 91.9±45.1 days in the non-Neuro-Patch group (p=0.655). There were no significant differences in the mean pre-cranioplasty mRS and mean follow-up period between the two groups. Propensity score matching yielded 38 patients (19

Table 1. Baseline characteristics of the two groups with or without Neuro-Patch

	Neuro-patch (n=31)	Non-Neuro-patch (n=35)	*p*-value
Age (years)	54.6±18.3	59.2±13.5	0.83
Sex			0.54
Male	25 (80.7)	26 (74.3)	
Female	6 (19.3)	9 (25.7)	
Primary neurologic insult			0.83
Malignant infarction	15	16	
Severe traumatic brain injury	16	19	
Underlying diseases	12	9	
Liver disease	2	1	0.39
DM	10	8	0.60
Thrombocytopenia, abnormal PT/aPTT	1	2	1.0
Interval between craniectomy to cranioplasty (days)	97.1±48.8	91.9±45.1	0.66
Pre-mRS	3.9±1.0	3.9±1.1	0.96
Follow-up period (months)	32.8±15.0	31.7±20.2	0.32

Values are presented as mean±standard deviation or number (%). DM : diabetes mellitus, PT : prothrombin time, aPTT : activated partial thromboplastin time, mRS : modified Rankin scale

Table 2. Propensity-matched baseline characteristics of the two groups with or without Neuro-Patch

	Neuro-patch (n=19)	Non-Neuro-patch (n=19)	*p*-value
Age (years)	54.8±15.6	59.2±13.5	0.67
Sex			0.74
Male	13 (68.4)	26 (74.3)	
Female	6 (31.6)	9 (25.7)	
Primary neurologic insult			1.0
Malignant infarction	7	8	
Severe traumatic brain injury	12	11	
Underlying diseases	5	6	
Liver disease	1	1	1.0
DM	4	5	1.0
Thrombocytopenia, abnormal PT/aPTT	1	0	1.0
Interval between craniectomy to cranioplasty (days)	99.3±52.3	88.4±7.4	0.47
Pre-cranioplasty mRS	4.0±1.0	3.8±1.1	0.78
Follow-up period (months)	32.6±16.9	34.7±25.4	0.66

Values are presented as mean±standard deviation or number (%). DM : diabetes mellitus, PT : prothrombin time, aPTT : activated partial thromboplastin time, mRS : modified Rankin scale

patients in each group) for analysis. There were no significant intergroup differences in baseline characteristics between the matched pairs (Table 2).

Complications and clinical outcomes

Complications and clinical outcomes in the two groups following cranioplasty are presented in Table 3. The mean mRS change (last follow-up mRS – pre-cranioplasty mRS) was not significantly different between the two groups. Regarding intraoperative factors, the mean estimated blood loss (mL) was significantly less in the Neuro-Patch group than in the non-Neuro-Patch group (54.6±34.9 vs. 149.0±70.8 mL, $p<0.001$). The

 https://doi.org/10.3340/jkns.2024.0176

Table 3. Clinical outcomes following cranioplasty with or without Neuro-Patch

	Neuro-patch (n=31)	Non-Neuro-patch (n=35)	*p*-value
mRS change	0.0±0.0	-0.1±0.4	0.13
Estimated blood loss (mL)	54.6±34.9	149.0±70.8	<0.001*
Total operation time (minutes)	114.0±29.5	166.4±41.9	<0.001*
Time from incision to bone closure (minutes)	40.8±14.3	91.5±38.2	<0.001*
Complications	6 (19.4)	15 (42.9)	0.018*
CSF leak	3 (9.7)	7 (20.0)	0.31
Infection	1 (3.2)	3 (8.6)	0.24
Intra-axial hematoma	1 (3.2)	3 (8.6)	0.62
Extra-axial hematoma	1 (3.2)	2 (5.7)	1.0
Reoperation	0 (0.0)	4 (13.0)	0.12

Values are presented as mean±standard deviation or number (%). *p<0.05. mRS : modified Rankin scale, CSF : cerebrospinal fluid

Table 4. Propensity-matched clinical outcomes following cranioplasty with or without Neuro-Patch

	Neuro-patch (n=19)	Non-Neuro-patch (n=19)	*p*-value
mRS change	0.0±0.0	0.0±0.0	-
Estimated blood loss (mL)	52.7±37.4	140.3±73.2	<0.001*
Total operation time (minutes)	116.3±32.6	155.8±40.0	<0.001*
Time from incision to bone closure (minutes)	42.1±15.0	81.8±35.0	<0.001*
Complications	3 (15.8)	11 (57.9)	0.017*
CSF leak	1 (5.3)	5 (26.3)	0.18
Infection	0 (0.0)	2 (10.5)	0.49
Intra-axial hematoma	1 (5.3)	3 (15.8)	0.60
Extra-axial hematoma	1 (5.3)	2 (10.5)	1.0
Reoperation	0 (0.0)	2 (10.5)	0.49

Values are presented as mean±standard deviation or number (%). *p<0.05. mRS : modified Rankin scale, CSF : cerebrospinal fluid

mean total operation time was significantly lower in the Neuro-Patch group than the non-Neuro-Patch group (114.0±29.5 vs. 166.4±41.9 minutes, p<0.001), while the mean time from incision to bone closure was also lower in the Neuro-Patch group than the non-Neuro-Patch group (40.8±14.3 vs. 91.5±38.2 minutes, p<0.001). The overall incidence of any complication was 30.3% (20/66 patients), and the incidence rate was significantly higher in the non-Neuro-Patch group than in the Neuro-Patch group (15/35, 42.9% vs. 6/31, 19.4%; p=0.018).

CSF leak occurred in 10 of the 66 patients (15.2%). The incidence of CSF leak was 9.7% (three of 31 patients) in the Neuro-Patch group and 20.0% (seven of 35 patients) in the non-Neuro-Patch group. However, the difference was not significant (p=0.314). The overall incidence of infection was 6.1% (four of 66 patients) comprising three epidural abscesses and one scalp infection. The rate of infection rates was 3.2% (one of 31 patients) in the Neuro-Patch group and 8.6% (three of 35 patients) in the non-Neuro-Patch group (p=0.241). Regarding intra-axial hematomas, including three temporal contusions and one frontal contusion (6.1%, four of 66 patients), there were no significant differences between the Neuro-Patch group (3.2%, one of 31 patients) and the non-Neuro-Patch group (8.6%, three of 35 patients). The incidence of extra-axial hematomas, which comprised three acute epidural hematomas (4.5%, three of 66 patients), was also not significantly different between the Neuro-Patch group (3.2%, one of 31 patients) and the non-Neuro-Patch group (5.7%, two of 35 patients). Reoperation was necessary for four patients : one for scalp infection, two for epidural hematomas, and one for a cosmetic problem caused by temporalis muscle atrophy. In propensity-matched clinical outcomes, esti-

mated blood less, total operation time, time form incision to bone closure, and rate of overall complications were also significantly less in the Neuropatch group than in the non-Neuropatch group (Table 4).

DISCUSSION

The most time-consuming, but also the key step at the time of cranioplasty, is complete dissection between the galea, temporalis muscle, and dura until the bone margin is fully exposed. Multiple adhesions and scarring frequently develop between these structures, making dissection difficult. In this setting, dural substitutes act as an effective barrier to prevent adhesion and scar formation between the temporalis muscle, dura, and galea, thereby providing a comfortable dissection plane[14].

Double-layer technique during the craniectomy might be superior to the single-layer technique regarding decreased operation time and blood loss during cranioplasty as reported in several literatures[11,14,19]. Complications in double-layer duroplasty including infection or extra-axial hematoma between the dural substitutes seems to be always risky following initial craniectomy.

In the Neuropatch group of this study, extra-axial fluid collection including hematoma was developed in 12 patients (12/31, 38.7%) following craniectomy, however, most were treated conservatively and absorbed spontaneously during follow-up period. Only one patient required reoperation for massive epidural hematoma following craniectomy in Neuropatch group (1/31, 0.3%). Wright et al.[19] reported that there was no differences in complications requiring reoperation following craniectomy between single-layer and double layer group.

In this study, the mean total operation time and estimated blood loss were significantly lower for patients in the Neuro-Patch group (114.0±29.5 minutes) than in the non-Neuro-Patch group (166.4±41.9 minutes). These results are much better when compared with previously published double-layer techniques[10-12]. Considering that the role of a dural substitute is to promote easy dissection and reduced blood loss, the total operation time may not truly reflect its advantages. Therefore, we also measured and analyzed the time from incision to bone closure, reflecting the time for complete dissection and bleeding control. The mean time from incision to bone closure in the Neuro-Patch group was 40.8±14.3 minutes, which was less than half the mean time for the non-Neuro-Patch group (91.5±38.2 minutes). Our better results can be attributed to the maximization of the role of Neuro-Patch. Although placing a dural substitute during a craniectomy and dissecting the surrounding structures during cranioplasty seems relatively simple, however, planned placement and step-by-step dissection of the Neuro-Patch is crucial to achieve the goal of reducing operation time and blood loss. Previous reports described the effects of Neuro-Patch in cranioplasty, but none of them were available on the time for complete skin flap dissection including bleeding control and on the detailed techniques[4,5].

Dense adhesion with thick scarring mainly occurs between the galea and dura around the bone edge. In most cases, significant bleeding develops at the surrounding bone and dura around the bone edge, as seen in Fig. 2A and D. Another dense adhesion occurs between temporalis muscle and underlying dura. During cranioplasty, dissecting these sites often requires excessive retraction digitally or using large forceps, for a considerable period of time. In this process, excessive retraction can lead to underlying brain injury especially in the frontal lobe and temporal lobe, where underlying dura is thin or dense adhesion exists, which are particularly vulnerable to retraction injuries as well as extra-axial hematoma. In this study, the incidence of both intra-axial and extra-axial hematoma formation after cranioplasty was lower in the Neuro-Patch group than in the non-Neuro-Patch group, although the difference was not significant. Although intra-axial hematomas were treated conservatively, two patients in the non-Neuro-Patch group required reoperation for epidural hematoma.

In order to optimize the role of the Neuro-Patch during the operation, three key factors must be considered. First, during craniectomy, the Neuro-Patch should be placed from the epidural space to the surrounding skull at least 1 cm beyond the bone edges of the craniectomy defect, as described in Fig. 1C. Second, even if the Neuro-Patch is effective in preventing adhesion, significant adhesion can still develop between the Neuro-Patch and the underlying dura. Therefore, when dissection begins, the scalp flap must be elevated from the underlying Neuro-Patch first, instead of dissecting between the scalp-Neuro-Patch complex and the underlying dura first to avoid excessive retraction of underlying brain or dural tearing.

Third, another dense adhesion develops at the site of the temporalis muscle. Placing a small piece of Neuro-Patch over the

 https://doi.org/10.3340/jkns.2024.0176

temporalis muscle during craniectomy can facilitate the clear dissection of muscle without bleeding and helps to minimize muscle injury leading to volume loss during the subsequent cranioplasty. So, it seems better to consider Neuropatch as an additional layer rather than an anti-adhesive material itself, and step by step dissection is important to minimize retraction-related injury.

Most studies have been reported that using dural substitutes during a craniectomy does not correlate with increased infection risk[4,17]. Similarly, in our analysis, the overall incidence of infection was 6.1% and the incidence did not differ significantly between the two groups. The incidence is rather lower in Neuro-Patch group (3.2%, one of 31 patients) than in the non-Neuro-Patch group (8.6%, three of 35 patients). Also, one patient in the non-Neuro-Patch group required reoperation due to a scalp infection. In fact, infection after cranioplasty is more complex and interacted with various factors such as long operation time, temporalis muscle resection, or subgaleal fluid collection rather than the use of a dural substitute itself[7]. Paradoxically, the anti-adhesive role of dural substitutes in cranioplasty may have the advantage of preventing infections by reducing operation time and intraoperative bleeding. In this study, the Neuro-Patch as an anti-adhesive material did not increase the incidence of infection at least.

CSF leak was more prevalent in the non-Neuro-Patch group (20.0%) than in the Neuro-Patch group (9.7%). All CSF leaks were managed conservatively without reoperation. Epidural or subgaleal fluid collection by CSF following cranioplasty is commonly observed on postoperative CT scans up to 41.8% and most CSF leaks can be treated conservatively[8]. However, even without a duroplasty at the time of craniectomy, the incidence of CSF leak has been reported low because severe brain injury accompanies with decreased CSF volume with brain atrophy[1,4]. This may explain why the most CSF leaks after cranioplasty may result from an iatrogenic injury during dissection not from initial duroplasty status. Moreover, in our double-layered technique (first-layer for duroplasty, second layer for anti-adhesion), the exposed brain is fully covered by another dural substitute and remaining dura as described in Fig. 1B. Our results show that a Neuro-Patch can potentially prevent this iatrogenic injury, although the difference was not significant between the two groups. There were no significant differences between the groups when analyzing individual complications. However, the overall complication rate was significantly lower in the Neuro-Patch group (9.7%) than in the non-Neuro-Patch group (42.9%).

The results of this study are limited by the small sample size and relatively short follow-up period. Although the double layer technique seems to be safe and effective during cranioplasty, most studies including this study were retrospective. So, future prospective studies need to be performed to investigate the safety of double layer technique compared to single layer technique at the time of initial craniectomy and to evaluate whether decreased operation time and blood loss during cranioplasty affect morbidities regarding infection, hematoma, and CSF leak.

CONCLUSION

In this study, using a Neuro-Patch has been shown to reduce overall complications as well as the time from incision to bone closure and intraoperative bleeding. Considering that the patients who survive severe TBI or malignant infarction following craniectomy often have functional dependency or medical problems already, every effort should be taken to avoid iatrogenic injury-related morbidities by proper placement and step-by-step dissection of a Neuro-Patch during surgery.

AUTHORS' DECLARATION

Conflicts of interest

No potential conflict of interest relevant to this article was reported.

Informed consent

Informed consent was obtained from all individual participants included in this study.

Author contributions

Conceptualization : YSK, TSK; Data curation : SPJ, JWK; Funding acquisition : YSK; Methodology : YSK; Writing - original draft : YSK; Writing - review & editing : TSK

Data sharing

None

Preprint

None

ORCID

You-Sub Kim	https://orcid.org/0000-0001-5410-7418
Jae-Woong Kim	https://orcid.org/0000-0001-8629-4270
Sung-Pil Joo	https://orcid.org/0000-0002-4983-0174
Tae-Sun Kim	https://orcid.org/0000-0001-7134-073X

- **Acknowledgements**

This study was supported by the Chonnam National University Hospital Biomedical Research Institute (grant number BCRI20005).

References

1. Colgan NC, Cronin MM, Gobbo OL, O'Mara SM, O'Connor WT, Gilchrist MD : Quantitative MRI analysis of brain volume changes due to controlled cortical impact. **J Neurotrauma 27 :** 1265-1274, 2010
2. Geurts M, van der Worp HB, Kappelle LJ, Amelink GJ, Algra A, Hofmeijer J, et al. : Surgical decompression for space-occupying cerebral infarction: outcomes at 3 years in the randomized HAMLET trial. **Stroke 44 :** 2506-2508, 2013
3. Gooch MR, Gin GE, Kenning TJ, German JW : Complications of cranioplasty following decompressive craniectomy: analysis of 62 cases. **Neurosurg Focus 26 :** E9, 2009
4. Huang YH, Lee TC, Chen WF, Wang YM : Safety of the nonabsorbable dural substitute in decompressive craniectomy for severe traumatic brain injury. **J Trauma 71 :** 533-537, 2011
5. Jeong TS, Kim WK, Jang MJ : Cranioplasty results after the use of a polyester urethane dural substitute (Neuro-Patch®) as an adhesion prevention material in traumatic decompressive craniectomy. **J Trauma Inj 32 :** 195-201, 2019
6. Khalili H, Omidvar A, Ghaffarpasand F, Yadollahikhales G : Cranioplasty results after application of anti-adhesive films (OrthoWrap™) in traumatic decompressive craniectomy. **Bull Emerg Trauma 4 :** 24-28, 2016
7. Kim H, Sung SO, Kim SJ, Kim SR, Park IS, Jo KW : Analysis of the factors affecting graft infection after cranioplasty. **Acta Neurochir (Wien) 155 :** 2171-2176, 2013
8. Kim SP, Kang DS, Cheong JH, Kim JH, Song KY, Kong MH : Clinical analysis of epidural fluid collection as a complication after cranioplasty. **J Korean Neurosurg Soc 56 :** 410-418, 2014
9. Missori P, Polli FM, Peschillo S, D'Avella E, Paolini S, Miscusi M : Double dural patch in decompressive craniectomy to preserve the temporal muscle: technical note. **Surg Neurol 70 :** 437-439; discussion 439, 2008
10. Oladunjoye AO, Schrot RJ, Zwienenberg-Lee M, Muizelaar JP, Shahlaie K : Decompressive craniectomy using gelatin film and future bone flap replacement. **J Neurosurg 118 :** 776-782, 2013
11. Pathrose Kamalabai R, Nagar M, Chandran R, Mohammed Haneefa Suharanbeevi S, Bhanu Prabhakar R, Peethambaran A, et al. : Rationale behind the use of double-layer polypropylene patch (G-patch) dural substitute during decompressive craniectomy as an adhesion preventive material for subsequent cranioplasty with special reference to flap elevation time. **World Neurosurg 111 :** e105-e112, 2018
12. Pierson M, Birinyi PV, Bhimireddy S, Coppens JR : Analysis of decompressive craniectomies with subsequent cranioplasties in the presence of collagen matrix dural substitute and polytetrafluoroethylene as an adhesion preventative material. **World Neurosurg 86 :** 153-160, 2016
13. Quinn TM, Taylor JJ, Magarik JA, Vought E, Kindy MS, Ellegala DB : Decompressive craniectomy: technical note. **Acta Neurol Scand 123 :** 239-244, 2011
14. Raghavan A, Wright JM, Huang Wright C, Sajatovic M, Miller J : Effect of dural substitute and technique on cranioplasty operative metrics: a systematic literature review. **World Neurosurg 119 :** 282-289, 2018
15. Sun H, Wang H, Diao Y, Tu Y, Li X, Zhao W, et al. : Large retrospective study of artificial dura substitute in patients with traumatic brain injury undergo decompressive craniectomy. **Brain Behav 8 :** e00907, 2018
16. Vakis A, Koutentakis D, Karabetsos D, Kalostos G : Use of polytetrafluoroethylene dural substitute as adhesion preventive material during craniectomies. **Clin Neurol Neurosurg 108 :** 798-802, 2006
17. von Wild KR : Examination of the safety and efficacy of an absorbable dura mater substitute (Dura Patch) in normal applications in neurosurgery. **Surg Neurol 52 :** 418-424; discussion 425, 1999
18. Walcott BP, Kwon CS, Sheth SA, Fehnel CR, Koffie RM, Asaad WF, et al. : Predictors of cranioplasty complications in stroke and trauma patients. **J Neurosurg 118 :** 757-762, 2013
19. Wright JM, Raghavan A, Wright CH, Alonso A, Momotaz H, Sweet J, et al. : Impact of dual-layer duraplasty during hemicraniectomy on morbidity and operative metrics of cranioplasty: a retrospective case-control study comparing a single-layer with a dual-layer technique. **World Neurosurg 125 :** e1189-e1195, 2019
20. Zhang Q, Li Y, Chang X : Role of decompressive craniectomy in the management of traumatic brain injury - a meta-analysis of randomized controlled trials. **Ann Indian Acad Neurol 26 :** 966-974, 2023

 https://doi.org/10.3340/jkns.2024.0176