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Technical Notes

Rigid but nonmetallic cranioplasty after pterional craniotomy: Technical note

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ABSTRACT

Background: Given the popularity of pterional craniotomy, numerous modifications have been made to prevent postoperative deformities. With the advent of titanium plates, fixation has become both simple and excellent. However, titanium plates can cause skin problems, infection, or cause skull growth to fail.

Methods: To develop a simple, cost-effective, and esthetically satisfactory fixation method, without the use of non-metallic materials, six young and older patients underwent pterional craniotomy. CranioFix Absorbable clamps were used to fix the bone flap in the frontal and temporal regions such that the frontal part was in close contact with the skull. After fixation, the bone chips and bone dust were placed in the bone gap and fixed with fibrin glue. We measured the computed tomography values of the reconstructed area and thickness of the temporal profiles postoperatively over time.

Results: Bone fusion was achieved in all patients by 1 year after surgery. Both the thickness of the temporalis muscle and the thickness of the temporal profile had changed within 2 mm as compared with the preoperative state.

Conclusion: Our simple craniotomy technique, gentle tissue handling, and osteoplastic cranioplasty yielded satisfactory esthetic results and rigidness in pterional craniotomy.

Keywords: Absorbable materials, Autologous bone dust, Fibrin glue, Non-metallic cranioplasty, Pterional craniotomy

INTRODUCTION

Pterional craniotomy was widely introduced by Yaşargil *et al*. in the 1960s.[1,10,20] This procedure allows us to approach various regions of the brain. This craniotomy has become very popular, and numerous modifications have been reported to prevent postoperative deformity.[7,13,14,17-19,21] Bone sinking is a major cause of postoperative deformities. However, with the advent of titanium plates, fixation methods have become simple and esthetically excellent. Although these titanium plates are very useful, they can sometimes cause skin problems or infection and can hinder the growth of the skull, particularly in young patients.[5] Therefore, skull fixation with absorbable materials is desirable.[4] However, this is expensive, has limitations in fixation, and is rarely performed.

To overcome these issues, we developed a simple, cost-effective, and esthetically satisfactory fixation method for use in adult patients, which does not require the use of any non-absorbable materials.

MATERIALS AND METHODS

This study was approved by the Ethics Committee of our institute, and written informed consent was obtained from all the patients included in the study (IRB number is R04-092).

Craniotomy

The patient was placed in a supine position on the operating table. The head was rotated 30° to the opposite side and secured using a Mayfield skull clamp (Ohwa Tsusho Co., LTD, Tokyo, Japan). A curvilinear skin incision was made in front of the tragus and continued to the midpoint of the hairline to preserve the superficial temporal arteries.

After the skin incision, the scalp was reflected subgaleally and the temporalis fascia, temporalis muscle, and periosteum were incised along the skin incision. They were then gently dissected with irrigation and reflected anteriorly. The temporalis muscle was dissected in a retrograde fashion to prevent muscle atrophy.[15] The temporalis muscle was dissected until the frontozygomatic fossa and root of the zygoma were exposed. Two burr holes were made in the coronal suture and temporal bone. Bone dust derived from the creation of the burr holes was collected and preserved in saline for reconstruction. A craniotomy was then performed. The sphenoid ridge was fractured after a groove was created in the ideal craniotomy line to obtain a bone flap with minimal bone gaps [Figure 1]. The residual sphenoid ridge was, then, rongeured to expose the appropriate surgical field. Rongeured bone chips were also preserved in saline for reconstruction. Subsequently, an intradural procedure was performed.

Cranioplasty

After completion of the intradural procedures, the dura was closed in a watertight fashion, using 4–0 polydioxanone suture (PDS, Johnson and Johnson K.K., Tokyo, Japan). In the case of a dural defect, the defect was patched with an autologous periosteal flap or a fascial flap. After dural closure, dural tenting sutures were placed through the tenting holes in the bone flap. A CranioFix Absorbable fixation system (AESCULAP Inc., Hessen, Germany) was employed.[11] This system is available in two diameters: 16 mm and 11 mm. We used only the 16-mm diameter CranioFix Absorbable. This type of fixation system has gap pins [Figure 2a]. Under normal use, the presence of the gap pin creates a gap between the bone flap and the skull [Figure 2b upper]. Therefore, pivot holes were created to allow gap pins to escape. This enabled firm contact between the frontal bone and the bone flap [Figure 2b lower]. We used a guide (Tanaka Medical Instruments, Tokyo, Japan) to drill pivot holes accurately to avoid the gap pins [Figure 2c]. We marked the skull and bone flap using this guide so that the corresponding surfaces fit together exactly [Figure 3a]. Pivot holes were drilled in the skull and bone flap [Figures 3b and c]. After the bone was temporarily fixed with 2–0 PDS threads, a CranioFix Absorbable clamp was used to fix the bone flap so that the frontal bone was in close contact with the skull. Another CranioFix Absorbable clamp was used in the temporal region [Figure 3d]. After fixation, bone chips harvested from the rongeured sphenoid ridge were placed in the bone gap. The remaining bone gaps and burr holes were filled with bone dust from the burr holes and fixed using fibrin glue [Figure 3e]. The temporal fascia and periosteum were sutured to cover the entire flap [Figure 3f]. A subcutaneous vacuum drain was placed, and the galea and scalp were sutured layer by layer.

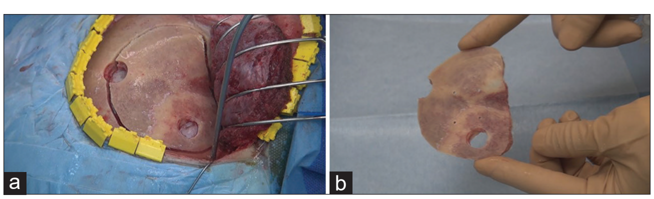

Figure 1: Procedures of craniotomy (a) The sphenoid ridge was fractured after a groove was created in the ideal line. (b) A bone flap with minimal bone gaps was obtained.

Evaluation of computed tomography (CT) scan-based ossification

The extent of ossification of the bone gap was assessed using CT at 3, 6, and 12 months after surgery. CT scans of 0.5-mm slices were performed using a multirow high-resolution CT scan system (Toshiba Aquilion Prime, Tochigi, Japan; GE Discovery 750HD, Boston, MA, USA). Bone density CT scans were performed at a window level of 500 and a window width of 2000. CT values of bone gap ossification in Hounsfield Unit (HU) were calculated using the SYNAPSE Enterprise-PACS (Fujifilm Medical Corporation, Tokyo, Japan). The extent of ossification was determined by comparing the HU in the bone gap with that in the intact region.

Evaluation of CT scan-based temporal profile

The thickness of the temporalis muscle and overlying soft tissue was measured in the frontozygomatic fossa at the level of the orbital roof using a CT scan and was compared before and 1 year after surgery. The sum of the thickness of the temporalis muscle and overlying soft tissue was taken as the thickness of the temporal profile.

Statistical analysis

All statistical analyses were performed using Easy R (EZR)[8] (Saitama Medical Center, Jichi Medical University, Saitama, Japan), a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria). The data were analyzed using the Wilcoxon signed-rank test. Statistical significance was set at $P < 0.05$.

RESULTS

Six patients, ranging in age from 44 to 73 years, underwent head closure using the method described in this study. The male-to-female ratio was 2:4 [Table 1].

In all cases, satisfactory bone fixation was achieved with the CranioFix Absorbable system. None of the patients required

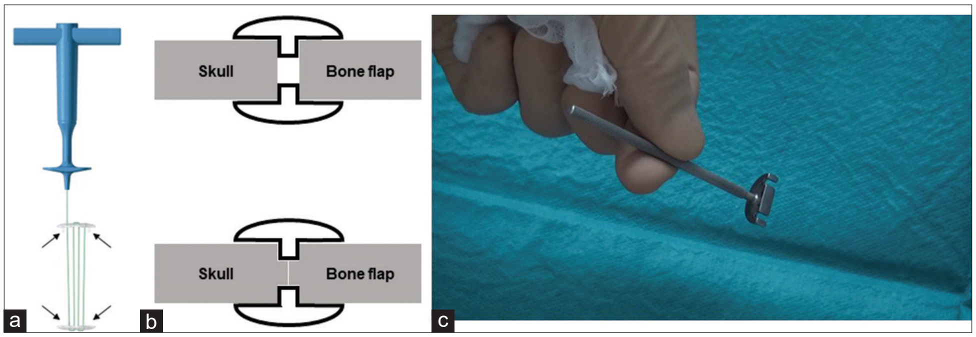

Figure 2: CranioFix Absorbable and Guide (a) illustration of the CranioFix Absorbable system. Arrows indicate the gap pins. (b) Schematic drawing of the gap pins. The upper scheme indicates the creation of a gap between the skull and the bone flap using the usual method. The lower scheme indicates firm contact between the skull and bone flap achieved by making pivot holes to allow the gap pins to escape. (c) Photograph of the guide to mark the position for gap pins.

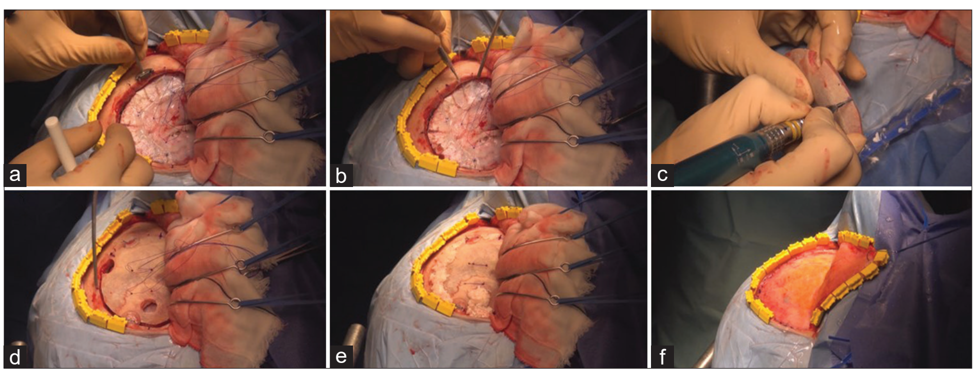

Figure 3: Procedures of cranioplasty (a) Guide to marking the position for gap pins. (b) Pivot hole drilling according to the markings. (c) Pivot hole drilling on the bone flap to match skull markings. (d) Fixation with two CranioFix Absorbable clamps. (e) Pegging gaps with bone chips, and filling the gap and burr holes with bone dust and fibrin glue. (f) Closure of the temporalis fascia and periosteum.

Table 1: Patient characteristics.

Number	Diagnosis	Age (year)	Sex	Comorbidities
1	Rt MCA An	63	F	Lt MCA An, HT, DLP
2	Lt MCA An	73	M	CKD, HT
3	Rt MCA An	54	F	HT, DLP
4	Lt IC-Acho An	71	M	HT, DLP, COPD
5	Lt clinoidal meningioma	45	F	none
6	Rt paraclinoid An	44	F	none

Two women of menopausal age were included in this study. Rt: Right, Lt: Left, M: Male, F: Female, MCA: Middle cerebral artery, An: Aneurysm, IC: Internal carotid artery, Acho: Anterior choroidal artery, HT: Hypertension, DLP: Dyslipidemia, CKD: Chronic kidney disease, COPD: Chronic obstructive pulmonary disease.

reoperation due to postoperative infection or poor fixation. Moreover, bone fusion was detected in the frontal region where the skull was in contact with the bone flap. In the temporal region, where a bony gap occurs, bone fusion occurs over time, although only partially. Bone fusion was achieved in all cases 1 year after surgery, resulting in overall fusion and fixation of the bone flap and skull [Figure 4a]. No deformity was observed in appearance over several years, and symmetry was maintained on both sides [Figure 4b]. The CT values of the bone gap increased with time and eventually became comparable to those of the skull [Figure 5a]. There were no cases of sinking of the bone flap up to 5 years after surgery. In addition, atrophy of the temporal region was not noticeable, and the thickness of the temporal region changed within 2 mm in comparison with the preoperative thickness [Figures 5b and c].

DISCUSSION

A frontotemporal craniotomy is one of the most basic and important techniques used in neurosurgery and is used for treating various lesions, such as anterior circulation aneurysms and parasellar tumors. In the era when the Gigli saw was commonly used, a so-called keyhole, or key burr hole, was required.[3] As long as the currently used high-speed drill is used, the keyhole is not essential, as demonstrated in this study. The keyhole has been cited as one of the causes of postoperative temporal deformity.[6,9,12] When considering the postoperative appearance, it is more reasonable to perform craniotomy without the keyhole.

With the advent of titanium plates, postoperative cranioplasty became easier and bone defects could more easily be covered. However, titanium plates can sometimes cause postoperative skin problems, and because they are foreign bodies, they can also cause infection.[5] The use of absorbable materials under the skin is advantageous in terms of infection. At present, a fixation device of a non-metallic material called Poly-Ether-Ether-Ketone (PEEK) is also available, which may be more advantageous than titanium plates in terms of skin problems. However, PEEK is also a non-absorbable material, and from the standpoint of infection, our method is more advantageous.[2] On the other hand, absorbable skull fixation materials are generally expensive, whereas titanium plates are superior in terms of cost-effectiveness. The CranioFix Absorbable system is available at a low cost in Japan, and the price of one CranioFix Absorbable is almost the same as the price of titanium plates and screws combined [Table 2]. In addition, as shown in this study, our method requires only two CranioFix Absorbable clamps for one craniotomy, and postoperative fusion with the bone is achieved, resulting in strong fixation. In this respect, the cost of using CranioFix Absorbable clamps can be the same as or lower than that of using two or three sets of titanium plates and screws.

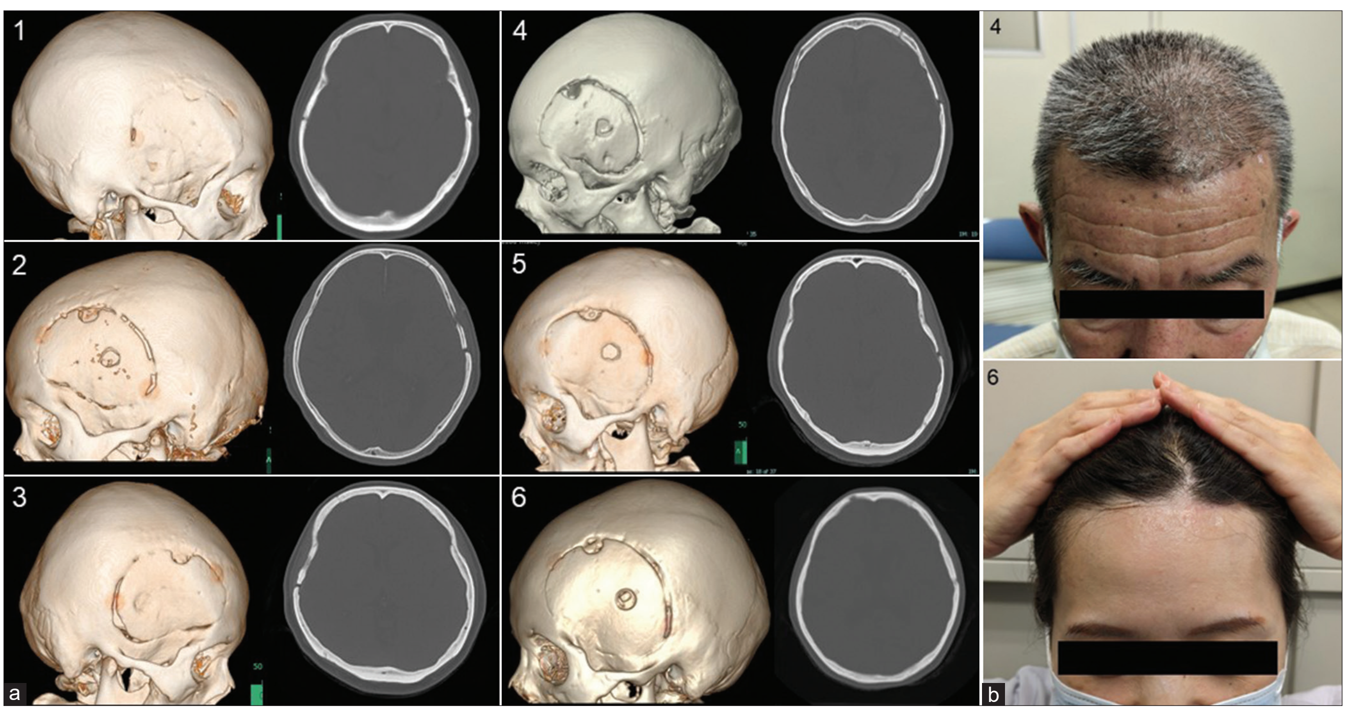

Figure 4: Postoperative images. (a) Postoperative computed tomography images were obtained 1 year after the operation. The numbers correspond to those in Table 1. Bone fusion was detected in the frontal region, where the skull was in contact with the bone flap in every case. No marked flap depressions were observed. (b) Postoperative photographs of representative cases. The numbers correspond to those in Table 1. Case 4 photograph was taken 4 years after the operation, and Case 6 photograph was taken 3 years after the operation. No deformity was observed in appearance over several years, and symmetry was maintained on both sides.

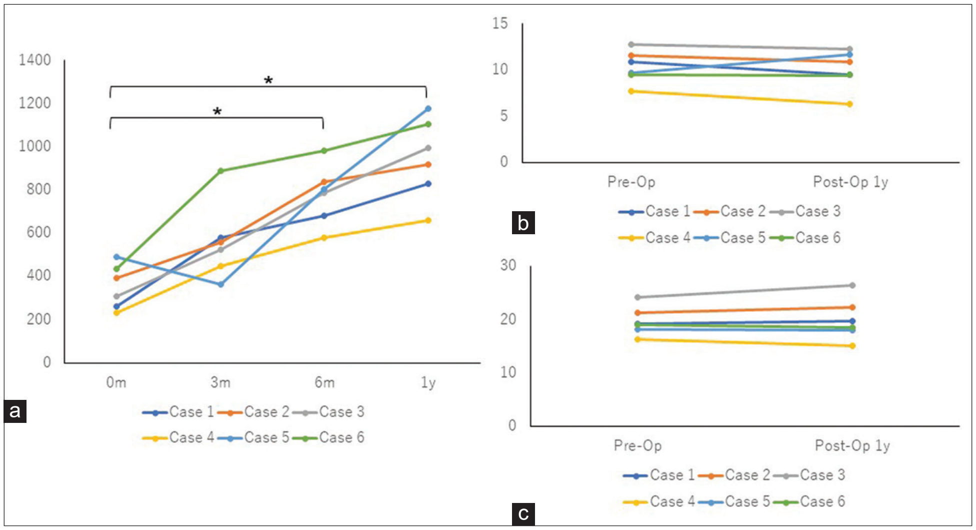

Figure 5: Change of the computed tomography (CT) values of the bone gap and comparison of the thickness of the temporal profiles. (a) CT values of the bone gap were assessed by CT scan at 3, 6, and 12 months after the operation. The CT values of the bone gap gradually increased over time. (b) Comparison of the thickness of the temporalis muscle at the level of the orbital roof preoperatively and 1 year postoperatively. The difference was <2 mm in all cases. (c) Comparison of the thickness of the temporal profile at the level of the orbital roof preoperatively and 1 year postoperatively. There was little difference between the pre-and post-operative values in any of the cases. 0 months: Immediately after the operation; 3 m: 3 months after the operation; 6 m: 6 months after the operation; 1 y: 1 year after the operation. *$P < 0.05$; Pre-Op: Preoperatively; Post-Op 1 y: 1 year postoperatively.

Table 2: Cost comparison of titanium plates, common absorbable plates, and CranioFix Absorbable.

Materials	Unit cost per device	Average cost per fixation site
Titanium screw	JPY 3,170 (USD 22.2)	JPY 19,040 (USD 133.6) (2 screws/1 plate)
Titanium plate	JPY 12,700 (USD 89.1)	
Absorbable screw	JPY 33,700 (USD 236.5)	JPY 105,900 (USD 743.2) (2 screws/1 plate)
Absorbable plate	JPY 38,500 (USD 270.2)	
CranioFix Absorbable (AESCULAP Inc., Hessen, Germany)	JPY 19,100 (USD 134.0)	JPY 20,725 (USD 145.4) (2 CranioFix/2 threads)
PDS-II thread	JPY 812.5 (USD 5.7)	

The price of one titanium plate and two screws is almost equivalent to one CranioFix Absorbable. Prices are converted at JPY 142.5 per US dollar, PDS: Polydioxanone suture

Absorbable bone fixation devices are generally used in younger patients because they do not interfere with bone growth.[16] Because bone healing can be expected, fixation problems are unlikely to occur, even after resorption.[5,12] In adults, they are not widely used, probably due to concerns about rigidity. For effective bone fusion, it is important to contact and fix the bones to be fused, but in normal use of the CranioFix Absorbable, the gap pin creates a gap between the skull and the bone flap [Figure 2b]. If the CranioFix Absorbable is used over a burr hole, the bone flap can be fixed without creating a gap; however, this will result in poor fixation, and there is a possibility of the bone flap shifting. Using the method presented here, by drilling pivot holes to allow the gap pins to escape and placing the clamp on it, the bone flap was fixed in firm contact with the skull, with no shifting. In the present study, effective bone healing was observed in adults, particularly in postmenopausal women, and bone dust solidified with fibrin glue was found to regenerate the bone. Therefore, this method is considered to ensure bone fixation after the CranioFix Absorbable is absorbed, even in adult patients.

The postoperative deformity is not only caused by the sinking of the bone but also by atrophy of soft tissues, such as the temporalis muscle. In our method, the postoperative temporal profile was not markedly atrophic but was maintained at the preoperative level [Figures 4 and 5]. This was achieved by retrograde dissection of the temporalis muscle to prevent muscle atrophy by not creating bone defects such as the keyhole, and by effectively contacting and fixing the bone flap to the skull.

Limitations

Our current study includes several limitations. First, the number of cases was small. Second, the long-term outcome of this procedure was unclear. Finally, histological confirmation of bone fusion was not proven. However, the CT values of the bone gap that appeared to be regenerated on CT were equivalent to bone, and continuity with the skull was observed. Therefore, we believe that the bone was regenerated and firmly fixed and that the long-term esthetic outcome will be satisfactory.

CONCLUSION

Our simple craniotomy, gentle tissue handling, and osteoplastic cranioplasty yielded satisfactory esthetic results. This method allows cost-effective cranioplasty and provides esthetically satisfactory fixation without the requirement of nonabsorbable materials, even in older patients.

Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Declaration of patient consent

Institutional Review Board (IRB) permission obtained for the study.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The author(s) confirms that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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