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Novel technique for cranial reconstruction following retrosigmoid craniectomy using demineralized bone matrix

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ABSTRACT

Objective: A versatile neurosurgical approach, the retrosigmoid craniectomy (RS) has traditionally been associated with high rates of post-operative cerebrospinal fluid (CSF) leak, headaches, and aesthetic defects. We introduce a simple surgical strategy for bony cranial reconstruction designed to minimize peri-operative complications and improve cosmetic outcomes.

Methods: In accordance with the Institutional Review Board, the senior author's (G.M.M.) records were queried between 2006 and 2014. We identified 50 consecutive patients who underwent demineralized bone matrix (DBM)-augmented cranioplasty after RS for MVD (*DBM group*) and 92 consecutive patients in whom standard cranial reconstruction was undertaken using autologous bone chips only after RS for MVD (*non-DBM group*). Demographic and clinical information regarding the laterality of each operation, intra-dural drilling for petrous hyperostosis, method of dural closure, length of hospitalization, presence of post-operative headaches, and procedure-related complications were collected and analyzed.

Results: The DBM and non-DBM cohorts were well matched for age, laterality of procedure, surgical indications, primary versus revision surgery, intra-dural drilling of petrous hyperostosis, and dural closure techniques. Trigeminal neuralgia was the most common surgical indication (98.6%) in each cohort. Post-operatively, 15% of patients in non-DBM group experienced chronic headaches at the last follow-up compared to only 8% of the patients in the DBM group ($p = 0.21$). The non-DBM patients also suffered more incisional pain in comparison to the DBM patients (7.6% vs. 0%, $p = 0.045$).

Conclusion: DBM-augmented reconstruction of posterior fossa defects resulted in low rates of post-operative headaches, better cosmetic outcomes, and represents a simple and effective cranioplasty option for skull base surgeons.

1. Introduction

The lateral, suboccipital approach to the cerebellopontine angle (CPA) through a retrosigmoid craniectomy (RS) was first popularized in the 1920s and 1930s by Walter Dandy, who utilized this approach for surgical treatment of trigeminal neuralgia (TN) and tumors [1]. Since then, the surgical technique of suboccipital craniectomy (SOC) has undergone several important modifications. Surgeons tailor the size and location of the SOC to allow for the most direct access to lesions in the posterior fossa with minimal cerebellar retraction.

In the 1960s, Jannetta modified Dandy's surgical approach to the CPA and popularized microvascular decompression (MVD) for cranial neuralgias through the retromastoid approach [2,3]. To date, MVD remains the most cost-effective and durable treatment option for the management of cranial neuralgias in spite of the availability of percutaneous ablative procedures and stereotactic radiosurgery. Though the success of MVD is well established throughout literature, RSs have been fraught with complications related to post-operative CSF leak and pseudomeningocele formation in up to 22% of cases [4]. Additionally, the incidence of headaches following RS has been reported to be as high as 69–73% [4,5].

Despite the availability of several surgical methods and adjuncts intended to reduce the complications associated with RS, no standardized technique for reconstruction of posterior fossa cranial defects exists. Reports of surgical techniques advocating a suboccipital craniotomy versus craniectomy are available as are reconstruction techniques that incorporate titanium mesh,

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polymethylmethacrylate (PMMA), pericranial grafts, muscle, artificial dural substitutes, and closure methods augmented by fibrin-based and hydrogel sealants such as Tisseel™ (Baxter Healthcare Corp., Westlake Village, CA, USA), Evicel™ (OMRIX biopharmaceuticals Ltd., Ramat Gan, Tel Aviv, Israel), and Duraseal™ (Confluent Surgical, Waltham, MA, USA).

Here we introduce a simple and effective technique for reconstruction of suboccipital cranial defects that utilizes autologous bone chips augmented with demineralized bone matrix (DBM) product (DBX™ putty; Synthes, West Chester, PA, USA) and compare it to traditional closure techniques that do not utilize DBM. In 50 consecutive patients, the DBM-augmented closure technique resulted in excellent cosmetic outcomes and low morbidity.

2. Materials and methods

Electronic medical records were queried in accordance to the Institutional Review Board (IRB# 5998). We identified 50 consecutive patients who underwent RS for MVD with DBM–augmented cranioplasty during 2010–2014 and 92 consecutive patients who underwent RS for MVD with standard cranioplasty using autologous bone chips only during 2006–2010. Data on patient demographics, surgical indication, laterality of procedure, duration of hospitalization and treatment-related complications were collected. Patient charts were screened for CSF leak, wound complications, post-operative headaches, incisional pain and cosmetic deformity. Information about primary versus revision surgery, dural closure technique, and the use of dural substitutes or DBM was also tabulated. For statistical analyses, the patients were divided into 2 groups based on the use of DBM. We used an independent, 2-tailed *t*-test (Welch generalization of the Student *t*-test, Microsoft Excel, 2013, Redmond, Washington) to compare patient age and duration of hospitalization. Chi-square test was used to compare laterality of procedure, type of surgery, occurrence of intra-dural drilling for petrous hyperostosis, method of dural closure, and post-operative complications between the two groups. p value of 0.05 was accepted for statistical significance.

2.1. Operative technique

In all patients a retrosigmoid craniectomy as described by Jannetta was performed [6]. The senior author (GMM) performed a standard microscope-assisted MVD in all patients who suffered from cranial neuralgias; the Jannetta approach was modified to accommodate for anatomic variations such as the presence of petrous hyperostosis. It is not our practice to use a lumbar drain (LD) for brain relaxation in standard MVDs.

Following the completion of MVD, every attempt was made to primarily close the posterior fossa dura with non-absorbable 4-0 Nurolon™ stitches (Ethicon Inc., Somerville, NJ, USA) in interrupted fashion. If the dura was incompetent for primary closure, we utilized a pericranial graft or muscle attached to fascia was harvested from the same incision and sewn into the parent dura to ensure a watertight closure, as mentioned by Park et al. [7]. Occasionally, DuraGen™ (Integra Life Sciences, Plainsboro, NJ, USA) was utilized to bolster the closure and dural sealants were used sparingly. After satisfactory dural closure, the dura was then layered with a sheet of absorbable hemostatic agent (Surgicel™, Johnson and Johnson Medical, Arlington, TX, USA). Bone chips collected during the craniectomy were then placed in the craniectomy defect and the incision was closed in a standard, layered fashion. After mid-2010, the senior author (G.M.M.) started incorporating DBM into all his cranioplasties. Five milliliters of DBX™ putty was utilized to fill the cranial defect and smoothen the contour of the suboccipital bone after bone chips were placed on the dura. Standard techniques were then used for skin closure (Video 1).

3. Results

Our query yielded a total of 142 patients that were divided into 2 groups. Ninety-two patients underwent routine cranioplasty using autologous bone chips after RS for MVD of cranial nerves (non-DBM group) and 50 patients underwent cranioplasty augmented with DBX™ (DBM group) (Table 1). There were more female patients than male patients (67.6% females vs. 32.4% males, $p < 0.03$). The non-DBM group was slightly older at presentation as compared to the DBM group (57.25 years vs. 54.94 years, $p = 0.39$). In 56% of the patients, MVD was performed on the right side. Of the 142 patients, 98% underwent MVD for trigeminal neuralgia while only 2% underwent MVD for hemifacial spasm. Twelve patients (13%) had undergone prior RS at another institution and underwent revision surgery in the non-DBM group whereas four patients (8%) underwent revision surgery in the DBM group ($p = 0.36$). Intra-dural drilling for petrous hyperostosis was performed in 6 patients in the non-DBM group (7%) and in 7 patients in the DBM group (14%) ($p = 0.14$). Primary dural closure was achieved in 39 patients in the non-DBM group and in 21 patients in the DBM group (42.4% vs. 42%; $p = 0.96$). Pericranial graft or muscle with fascia was used to supplement dural closure in 26 patients in the non-DBM group (28%) and in 29 patients in the DBM group (58%). Dural substitutes were used significantly more often in the non-DBM group than the DBM group (23% vs. 4%; $p = 0.003$). Dural sealant was used in 6 patients and a mesh or plate was used in 2 patients in the non-DBM group whereas no patient in the DBM group received dural sealant or mesh. The median duration of hospitalization was not significantly different between the non-DBM and DBM groups (4 days vs. 3.5 days, respectively; $p = 0.17$). Median duration of follow-up was 302 days for non-DBM group and 68 days for DBM group patients ($p < 0.05$).

At last follow up, only 4 patients (8%) complained of persistent new headaches in the DBM group as compared to 14 patients (15%) in the non-DBM group ($p = 0.21$). In addition, significantly more patients in the non-DBM group complained of incisional pain and cosmetic defects at the surgical site as compared to none in the

Table 1
Patient characteristics undergoing cranioplasty with and without DBM.

Patient characteristics	Non-DBM group $n = 92$	DBM group $n = 50$	*p*-value
Mean age (± SD) *years*	57.25 (±15)	54.94 (±15.43)	0.39
Gender			0.03
Males	24 (26%)	22 (44%)	
Females	68 (74%)	28 (56%)	
Laterality of procedure			0.95
Right	52 (56.5%)	28 (56%)	
Left	40 (43.5%)	22 (44%)	
Surgical indications			
Trigeminal neuralgia	92 (100%)	48 (96%)	
Hemifacial spasm	0	2 (4%)	
Type of surgery			0.36
Original	80 (87%)	46 (92%)	
Revision	12 (13%)	4 (8%)	
Intradural drilling			0.14
Yes	6 (7%)	7 (14%)	
No	86 (93%)	43 (86%)	
Dural closure			0.96
Primary	39	21	
Pericranial graft	18	17	
Muscle/fascia	8	12	
Dural substitute	21	2	
Mesh/plate	2	0	
Dural sealants	6	0	
Postoperative complications			0.06
Headaches	14 (15%)	4 (8%)	
Defect/incisional pain	7 (7.6%)	0 (0%)	
Pseudomeningocele	2 (2%)	1 (2%)	
CSF rhinorrhea	3 (3%)	2 (4%)	
Meningitis	1 (1%)	1 (2%)	