Analyzing the Cost of Autogenous Cranioplasty Versus Custom-Made Patient-Specific Alloplastic Cranioplasty

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Purpose: Comparing expenses related to autogenous cranial vault reconstruction versus custom-made patient-specific alloplastic cranioplasty.

Methods: The authors retrospectively reviewed charts of a group of patients who underwent autogenous cranioplasty and poly-ether-ether ketone (PEEK) cranioplasty. The data collected from the patient files included demographic information, details of the surgery, postoperative recovery data, and also duration of surgery. The authors also added costs related to the length of surgery, utilization of intensive care unit, length of hospital stay, amount and seriousness of complications, and hardware cost. The outcomes were studied in terms of skull form maintenance and complications.

Eleven of our patients had PEEK cranioplasty at Sunnybrook Hospital, Toronto, ON, in the period from July 2009 to June 2011. The authors identified 11 patients who had split skull autogenous bone graft cranioplasty. They were matched for age and skull defect size.

Comparable information was collected for both patient groups. The information was examined to compare costs of custom-made patient-specific alloplastic implants and costs of autogenous cranioplasty.

Results: Conclusions made from this paper will hopefully serve as guidance for allocation of hospital funding and resources at the Ministry of Health level.

Key Words: Alloplastic, cost–benefit analysis, cranioplasty, PEEK, prefabrication

(*J Craniofac Surg* 2017;00: 00–00)

Cranioplasty is a surgical operation to repair cranial defects. The aim of the operation is not only to improve on the cosmetic look of the skull,[1] but also the repair of cranial defects gives psychologic and social benefits.

Both autogenous and alloplastic materials can be used in this surgical procedure. Autogenous reconstruction includes cranium, rib, tibia, scapula, fascia, sternum, and ilium[2] (Figs. 1-3). Alloplastic reconstruction includes polymethyl-methacrylate, hydroxyapatite, polyethylene, silicon, chorale, ceramic, cortoss, aluminum, gold, silver, stainless steel, titanium, lead, platinum, vitallium, and ticonium.[1–6] Another alloplastic material that is used for cranioplasty is customized poly-ether-ether ketone (PEEK)[4] (Fig. 4).

One of the techniques that we use in our institute is the customized PEEK implant. In lab studies, it has been shown that the mechanical properties of PEEK could provide better protection when used for cranioplasty.[4] Benefits of using PEEK implants in cranioplasty are not the focus of this article.

Autogenous materials possess optimum biocompatibility characteristics, which have been shown to be reliable for repairing calvarial defects.[2] However, harvesting autogenous grafts can cause severe trauma or deformity to the donor sites and require longer operation time. In most patients, autogenous grafts are not sufficient, and fitting the inflexible bone grafts to the contours of the calvarial defect is difficult[2] (Fig. 3). Aseptic bone resorption, a known long-term complication after cranioplasty (rate varies between 2% and 17%)[7] and the need for secondary surgery are other downsides for autogenous reconstruction, not to mention that some cranioplasty procedures may require an additional surgical site to harvest the bone.

Alloplastic reconstruction with a custom designed implant would eliminate many downsides of using autogenous reconstruction such as lengthy operation, resorption of bone, and the need for secondary procedures.

Costs involved in these major operations are an important factor to consider when choosing the ideal reconstruction method. In this article, we demonstrate the difference in cost between autogenous cranioplasty and custom-made patient-specific alloplastic cranial reconstruction using PEEK implants.

MATERIALS AND METHODS

After obtaining REB approval at our institute, we retrospectively reviewed the files of a group of autogenous cranioplasty patients and PEEK cranial reconstruction patients. The 2 groups of patients were matched in age, gender, and comorbidities. All cranioplasties were performed by the same surgeon. The size of skull defect was comparable in both groups.

The data abstracted from the charts included demographic information (age, gender, and comorbidities), details of the operation (procedure type, size and site of skull defect), postoperative recovery information, and length of procedure (Table 1).

We also added costs related to the length of surgery, utilization of intensive care unit (ICU), length of hospital stay, amount and seriousness of complications, and hardware cost.

The need for secondary surgery related to the primary cranioplasty procedure was not considered. Outcomes were evaluated in terms of skull form maintenance and complications.

Eleven patients had PEEK cranial reconstruction at Sunnybrook Hospital from July 2009 to June 2011. Eleven additional patients

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Received December 7, 2016.
Accepted for publication January 13, 2017.

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The authors report no conflicts of interest.

ISSN: 1049-2275
DOI: 10.1097/SCS.0000000000003708

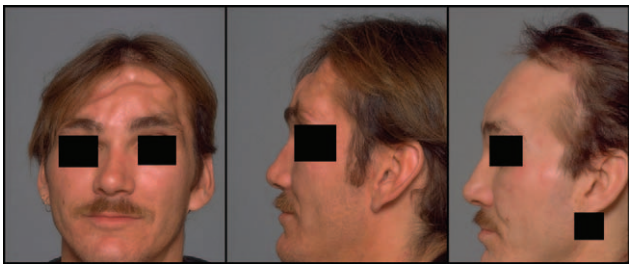

FIGURE 1. Frontal and lateral views of a patient's forehead pre and postautogenous reconstruction using calvarial bone.

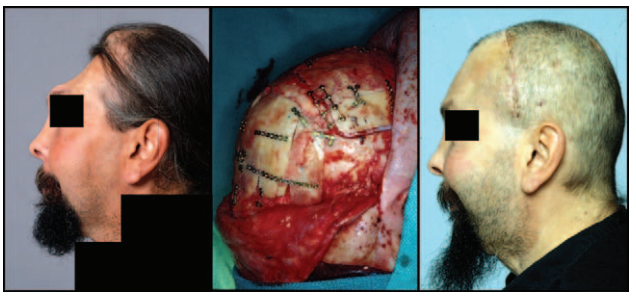

FIGURE 2. Profile views of a patient's forehead pre and postautogenous reconstruction using calvarial bone.

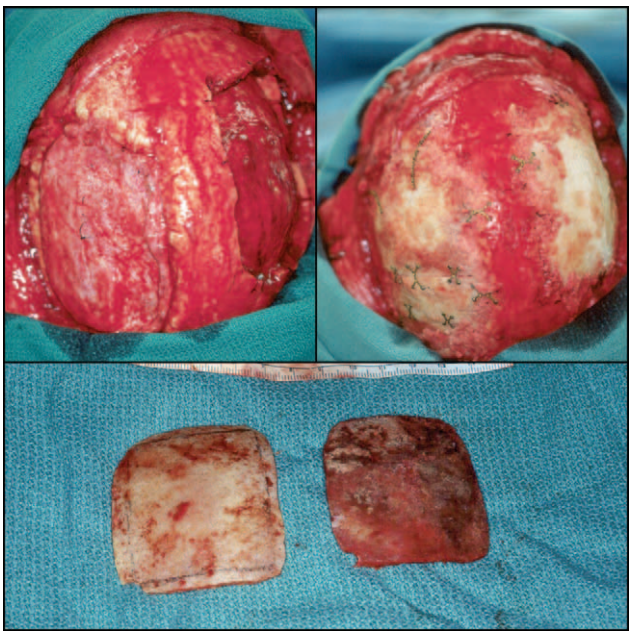

FIGURE 3. Pre and postreconstruction of a cranium using split calvarial bone grafts (shown in the figure at the bottom).

FIGURE 4. Pre and postreconstruction of a cranium using the poly-ether-ether-ketone implant.

TABLE 1. Demographic Date for Both Groups (Age, Gender, and Comorbidities), Particulars of Surgery (Type of Procedure, Site and Size of Skull Defect), Details of Postoperative Recovery, and Duration of Surgery

Group	Autogenous Cranioplasty (Column A)	Customized-PEEK Cranioplasty (Column B)
Number of patients	10	9
Age	37–66, mean 46	24–64, mean 45
Gender	8 males, 2 females	5 males, 4 Females
Average time in the operating room, h	7	3.5
Average total variable cost, $	11,378	5830
ICU average length of stay, d	2	0.2
Surgical ward average length of stay, d	6	2.6
Total length of stay cost, $	5084	1604
Average cost of procedure excluding cost of implant, $	16,463	8536
Cost of implant, $	N/A	10,000
Total cost of procedure, $	16,463	18,536

Also included were the expenses related to duration of surgery, ICU stay, duration of hospital admission, and cost of hardware.

ICU, intensive care unit; PEEK, poly-ether-ether-ketone.

were identified as having underwent split-skull autogenous osseous graft cranial reconstruction. These patients were matched for skull defect size, gender, and age.

Comparable information was collected for both patient groups. The information was examined to compare costs of custom-made patient-specific alloplastic implants to costs of autogenous cranial reconstruction.

Data regarding variable costs and fixed costs were collected from the accounting department in our hospital. These included costs for surgical beds, ICU beds, operating room, postanesthetic care unit, nursing (both during the operation and after care), surgical team, and anesthesia.

RESULTS

In total, 10 patients who underwent autogenous cranioplasty and 9 patients who underwent customized-PEEK cranioplasty were identified. Table 1 summarizes the demographic and clinical data for each group.

The average time in the operating room for the autogenous reconstruction was 7 hours. The average total variable cost for the procedure was $11,378. The ICU stay averaged around 2 days, and

TABLE 2. Total Cost Analysis of PEEK Implant Reconstruction Versus of Autogenous Reconstruction

Unpaired *t* test	
P value	0.2589
P value summary	ns
Significantly different? ($P < 0.05$)	No
1- or 2-tailed *P* value?	2-tailed
t, df	$t = 1.168$, df = 17
How big is the difference?	
Mean ± SEM of column A	16,463 ± 1197, n = 10
Mean ± SEM of column B	18,537 ± 1318, n = 9
Difference between means	2074 ± 1776
95% confidence interval	−1672 to 5821
R^2	0.07429
F test to compare variances	
F, DFn, Dfd	1.091, 8, 9
P value	0.8916
P value summary	ns
Significantly different? ($P < 0.05$)	No

There were no statistical significance when comparing both types of reconstruction without decreasing the cost of the implant and without taking into consideration any complications leading to a readmission and a secondary surgery.

PEEK, poly-ether-ether-ketone; SEM, standard error of mean.

TABLE 3. Variable Cost Analysis of PEEK Implant Reconstruction Versus of Autogenous Reconstruction

Unpaired *t* test	
P value	0.0007
P value summary	***
Significantly different? ($P < 0.05$)	Yes
1- or 2-tailed *P* value?	2-tailed
t, df	$t = 4.148$, df = 17
How big is the difference?	
Mean ± SEM of column A	11,378 ± 1136, n = 10
Mean ± SEM of column B	5830 ± 622.3, n = 9
Difference between means	−5549 ± 1338
95% confidence interval	−8371 to −2726
R^2	0.503
F test to compare variances	
F, DFn, Dfd	3.706, 9, 8
P value	0.0787
P value summary	ns
Significantly different? ($P < 0.05$)	No

There is a significant difference when comparing the variable costs of both techniques. This excludes the price of the implants.

PEEK, poly-ether-ether-ketone; SEM, standard error of mean.

TABLE 4. Stay Cost Analysis of PEEK Implant Reconstruction Versus of Autogenous Reconstruction

Unpaired *t* test	
P value	0.0007
P value summary	***
Significantly different? ($P < 0.05$)	Yes
1- or 2-tailed *P* value?	2-tailed
t, df	$t = 4.137$, df = 17
How big is the difference?	
Mean ± SEM of column A	3790 ± 457.7, n = 10
Mean ± SEM of column B	1604 ± 224.2, n = 9
Difference between means	−2186 ± 528.3
95% confidence interval	−3300 to −1071
R^2	0.5017
F test to compare variances	
F, DFn, Dfd	4.630, 9, 8
P value	0.0419
P value summary	*
Significantly different? ($P < 0.05$)	Yes

We compared the cost of stay in the hospital (including intensive care unit and hospital days) between the 2 groups. It shows a significant difference between both groups.

PEEK, poly-ether-ether-ketone; SEM, standard error of mean.

TABLE 5. Total Cost Analysis of PEEK Implant Reconstruction Versus of Autogenous Reconstruction If Implant Cost Is Dropped to $5000 for All Patients

Unpaired *t* test	
P value	0.0126
P value summary	*
Significantly different? ($P < 0.05$)	Yes
1- or 2-tailed *P* value?	2-tailed
t, df	t = 2.788, df = 17
How big is the difference?	
Mean ± SEM of column A	16,463 ± 1197, n = 10
Mean ± SEM of column B	12,626 ± 572.2, n = 9
Difference between means	−3837 ± 1376
95% confidence interval	−6740 to −933.6
R^2	0.3138
F test to compare variances	
F, DFn, Dfd	4.862, 9, 8
P value	0.0363
P value summary	*
Significantly different? ($P < 0.05$)	Yes

This is a theoretical analysis to understand the cost analysis in case the cost of the implant was dropped due to any reason (subsidizing by the government, competition to the company entering the market).

The results show a statistically significant difference between both groups.

PEEK, poly-ether-ether-ketone; SEM, standard error of mean.

the length of stay in the surgical ward was 6 days. The total length of stay cost was $5084, which brings the average cost of the initial procedure to $16,463. This does not take into account any secondary procedures or follow ups related to complications in this group.

In the alloplastic group, the average time in the operating room was 3.5 hours. The average total variable cost for the procedure was $5830. The ICU stay averaged around 0.2 days, and the length of stay in the surgical ward was 2.6 days. The total length of stay cost was $1604, bringing the cost of the procedure to $8536. An additional $10,000 (price of implant and customization) is added to this amount, bringing the total to $18,536. None of these patients needed a secondary procedure and there were no complications in this group with a minimum follow up of 1 year.

DISCUSSION

From the results shown above, the savings rising from the use of alloplastic reconstruction are statistically significant if the price of the implant is not accounted for as shown in Tables 2 to 5. The operating time dropped by half, the costs of which were also reduced by more than half. The benefits of a shorter procedure also extended to the postoperative period in which the ICU stay was almost eliminated and the total hospital stay minimized significantly.

The costs of stay was dropped from $5084 CAD to $1604 CAD. The total savings on the procedure were in the amount of $7927.

The only reason these savings are not reflected in the results is the price of the implant ($10,000).

Further statistics were made with the price of the implant reduced from $10,000 to $5000. This has also shown to be statistically significant (Table 2).

Other savings that were not considered in this study were any revision operations (which would include costs of the readmission and procedure) that may rise from complications such as resorption of bone. This was observed in 20% of the autogenous group.

We should also mention that other complications may arise from longer procedures and longer hospital stays postoperative. These include, and are not limited to, atelectasis, infections, DVT, and PE.

In this study, we only considered the cost of the primary treatment and were not specifically concerned with the final outcome of the cranioplasty.

In conclusion, the use of prefabricated patient-specific alloplastic PEEK cranioplasty is safe and cost effective on the long term. If the costs of operating rooms or hospital stays are higher in other countries than it is in Canada, then the savings would be more significant. Also, if the price of the implant drops with advances in technology (as shown in Table 5), then this method of reconstruction will prove to be much more cost effective than the autogenous reconstruction.

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