



PMMA Cranioplasty Making by Using Open-Source CAD Software, PLA Printers, and Silicone Rubber Molds: Technical Note with Two Illustrative Cases

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Dear Editor,

We read with great interest Malikov et al's case report/technical note entitled "PMMA cranioplasty making by using open-source CAD software, PLA printers, and silicone rubber molds: technical note with two illustrative cases."¹ We were the first in the literature to begin an ultra-low-cost patient-specific polymethyl methacrylate (PMMA) cranioplasty implant service in Pakistan, that too in a public sector hospital, and we have already published our technical note and limited case series with 1-year follow-up.² Since then, our technique has been adopted by our colleagues at neighboring centers, and we have amassed an experience of over 50 cases, and many of our patients are in long-term follow-up. At the national level, the lowest cost offered by commercial companies for a patient-specific PMMA implant exceeded US\$ 1,000 and US\$ 10,000 for titanium and polyetheretherketone (PEEK) hemicraniectomy implants, respectively. The vast majority of the Pakistani population are poor and underprivileged, and the trauma cohort who require this operation are actually those who could never meet these costs in their lifetime. Free-hand PMMA cranioplasty was utilized in virtually all cases nationally. After beginning our initial service, the total cost to manufacture an implant in consumables was US\$ 40. The printer we used was a locally assembled Chinese Prusa i3 clone. Thus, production cost was exponentially cheaper than

commercial rates, and in our experience, our clinical and aesthetic outcomes are the same, if not better. Naturally, when one intends to offer a service for the patient benefit rather than profit, affordability is one of the most important parameters, especially in the impoverished developing world. We would be delighted to know the exact specification of the printer used by Malikov et al, the cost of disposables and printing of each implant, and the context of this cost in their patient's socioeconomic demographic/health care system, and whether commercial options were as extortionate for their general public as it was for ours.

Once we began this service, we became a national referral center. The service began with a single neurosurgeon, without any formal IT training, experimenting, and printing these implants with an ambition to advance global neurosurgery. We now require the resources for a full-time service. This means the need for a departmental printer, arguably of a better spec to the bare minimum leisure 3D printer used at home, and capacity building by training clinical fellows and residents in the design process to meet the demands for national service in a timely fashion. It would be interesting to learn more about Malikov et al's exact workflow and cost breakdowns. Is the authors' patient-specific PMMA cranioplasty service in a public sector hospital? Do the patients have to pay out of their pocket for these implants? If this is a public sector service, has the author's volume of referrals

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increased, and if so, how are they coping with meeting the demands? Finally, it would be of great use to hear the authors' experience on the learning curve with these open-access software packages, which are arguably not as user-friendly as the purpose-built (but much more costly!) software. In our own experience, when began this service, we initially found even simple implant designing difficult, but within the space of 10 to 20 patients, we have been proficient in the design process of even complex orbital defects, including neurofibromatosis type 2 and plexiform tumors that require radical tumor resection and subsequent skull base reconstruction. Perhaps instead of paper-based publications/technical notes offering limited information, we should produce virtual tutorials and online workshops that teach viewers the design process in enough detail to equip them to begin such a service if required in their local setup. We

congratulate the authors on beginning this service in their country and wish them all the best in advancing global neurosurgery.

Conflict of Interest

None declared.

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