

Cranioplasty

Last updated: October 22, 2024

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References:

H. Richard Winn “**Youmans Neurological Surgery**” 6th ed. (2011), ch. 338

TIMING

- previous infection** – 6 months should pass after all infection has cleared.
 - military penetrating injury** – 12 months
- no previous infection** – after brain edema subsided (usually > 6 weeks; skull edges ossify – less risk of autologous bone flap resorption);
 - TBI edema subsides fast; MCA stroke edema persists longer.
 - “R. Chestnut protocol” – **at least 6 months** before cranioplasty.
 - cranioplasty can be performed at **around 34 days** after DC for TBI (pros: ventriculomegaly occurred less frequently, 6-month GOS score was better in the early cranioplasty group)

How early can we perform cranioplasty for traumatic brain injury after decompressive craniectomy? A retrospective multi-center study. Na Rae Yang et al. World Neurosurgery 2017 October 31

Timing of Cranioplasty in Military Penetrating Injuries

- incidence of postcranioplasty complication was greatly increased (56%) among patients who had a **complication (e.g., infection or CSF leak) during initial care** + complications increased among patients whose cranioplasty was performed **less than 1 year** after injury (20%) versus more than 1 year after injury (4%); in cases without initial complications, there did not appear to be any difference in infection rate as a function of timing of cranioplasty.

Rish BL, Dillon JD, Meirrowsky AM, et al. Cranioplasty: a review of 1030 cases of penetrating head injury. Neurosurgery. 1979;4:381–385

ADVANTAGES OF EARLY REPLACEMENT

- Reduced incidence of **scalp contraction** (which can contribute to wound dehiscence) H: plastics can implant scalp expanders.
- Reduced **temporalis atrophy** (which can contribute to temporomandibular joint complaints and cosmetic asymmetry)
- Resolution of the **syndrome of the trephined**. see p. Op320 >>

4. Early replacement before the development of **severe encephalomalacia** eliminates the potential **dead space under the flap** postoperatively (risk for EDH, pneumocephalus, and fluid collections).
5. Provides **cerebral protection** during the phases when patients are most at risk - starting to walk again but are still likely to experience imbalance, incoordination, and orthostatic hypotension.
6. **Lower risk** of developing **hydrocephalus** – but only in TBI patients!

Davide Nasi, Mauro Dobran. Can early cranioplasty reduce the incidence of hydrocephalus after decompressive craniectomy? A meta-analysis. Surg Neurol Int . 2020 May 2;11:94.

- there is study that showed postoperative hydrocephalus rates were **significant higher** in the early (< 3 mos) cranioplasty group [RR=2.67, 95%CI (1.24, 5.73), p<0.05]
Hao Xu. Early cranioplasty vs. late cranioplasty for the treatment of cranial defect: A systematic review. Clin Neurol Neurosurg . 2015 Sep;136:33-40. doi: 10.1016/j.clineuro.2015.05.031. Epub 2015 May 29.

7. Cranioplasty, regardless of timing, is associated with significant **neurological improvement**; postcranioplasty neurological outcome is significantly improved in the early cohort (< 90 days) and has greater magnitude of change.

JG Malcolm et al. Early Cranioplasty is Associated with Greater Neurological Improvement: A Systematic Review and Meta-Analysis. Neurosurgery. 2018 Mar 1;82(3):278-288.

8. Early cranioplasty can **reduce** the **duration of operation**.

Hao Xu. Early cranioplasty vs. late cranioplasty for the treatment of cranial defect: A systematic review. Clin Neurol Neurosurg . 2015 Sep;136:33-40. doi: 10.1016/j.clineuro.2015.05.031. Epub 2015 May 29.

- using dural substitute and anti-adhesion barriers during index surgery may be helpful as well.

PLANNING

IMAGING

- **CT** – make sure brain has room to go back into skull (sometimes, brain bulges due to low atmospheric pressure).
- check if **CTA** was ever done (for pseudoaneurysms).

CT PROTOCOL FOR CUSTOM FLAP ORDERING

Scanning Guidelines

- Stabilize the patient. The patient must remain completely still through the entire scan. If patient movement occurs the scan should be restarted to achieve the best implant fit.
- The scan should include 2cm above and below the defect area. For cranial defects, please include entire defect plus 2cm above and below the area of interest. If the mandible and the maxilla are desired in separate models, use a bite jib between the teeth. Otherwise the mandible and maxilla will be fused in one model.
- Gantry tilt should be set to 0 and Standard Algorithm format should be used.
- Please archive DICOM uncompressed image data to accepted archive media listed for your scanner.
- Important position or details should be noted as well as an asymmetrical element of the patient to indicate left and/or right

BONE FLAP

NATIVE BONE FLAP

(always verify with OR if available; uncommon in military victims):

- stored **frozen** (theories that too much freezing destroys substances and transplanted flap is rapidly resorbed) – thaw and soak in Betadine solution.
- stored **implanted in abdominal wall** – high chances that *autoresorption* happened.

SYNTHETIC ALTERNATIVES

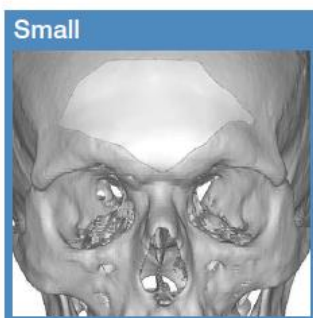
(advantage of filling in the temporal craniectomy defect and providing a strut for the temporalis muscle, which often results in better cosmesis):

- Methylmethacrylate** (e.g. DePuy) – mix well powder with solvent, apply on defect and mold (Dr. Broaddus - place layer of cotton to prevent heat transfer to brain), pour water when starts to get hot, trim with drill when solid, fix to skull with plates and screws.
- Medpor** (Stryker – they also give sterile real skull model – can be used intraop for bone edge dissection whenever skull defect is of difficult shape)
N.B. **Medpor cannot be flashed** if becomes unsterile (therefore, Stryker ships two identical sterile implants packed separately)
- PEEK (polyetheretherketone)** – custom skull flaps are made by: see p. Op140 >>
- PEKK (polyetherketoneketone)** – claims of less bacterial adhesion and encapsulation.
- PMMA** – porous, hydrophilic.
- Titanium**

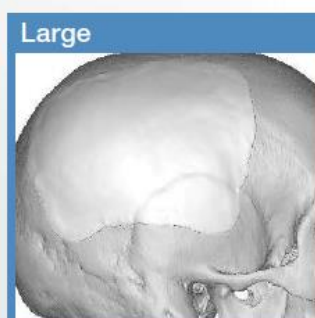
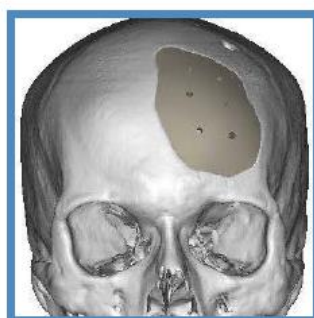
Custom made flap better fills bone voids!

If using custom implant to fill the void of craniectomy done at the same procedure (e.g. removing parts of skull involved in chronic osteomyelitis and then filling the gap with custom 3D implant), it may be much faster to cut bone using **neuronavigation** (need to load volumetric DICOM from implant manufacturer) – trace with sterile pencil on the skull where bone cuts need to be made (especially important if using complex shaped implants such as for craniofacial areas)

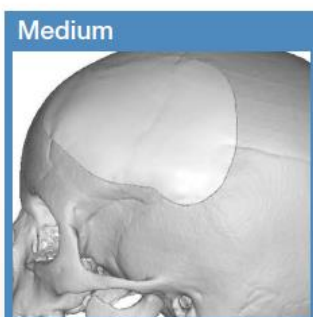
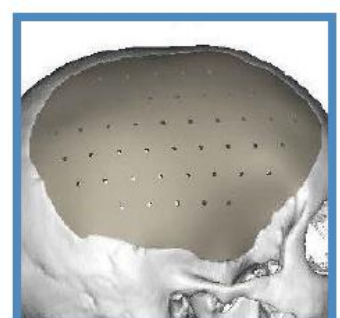
Companies often price their implants based on size:



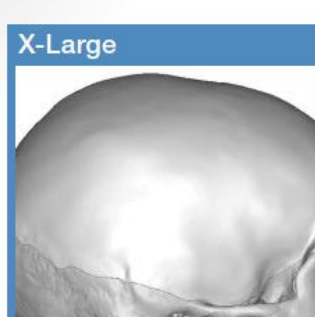
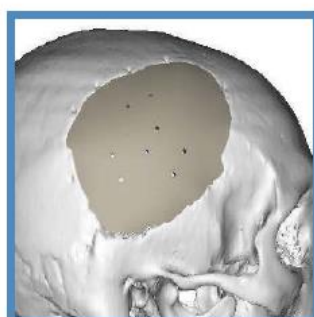
Up to approximately 6 x 6cm surface area (squash ball size)



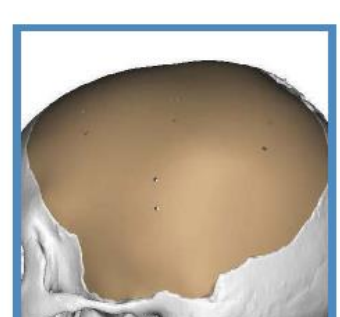
Up to approximately 12 x 12cm surface area (CD size)



Up to approximately 9 x 9cm surface area (tennis ball size)



Greater than 12 x 12cm surface area (larger than a CD)



PEEK vs. Titanium

Rosinski et al. A Retrospective Comparative Analysis of Titanium Mesh and Custom Implants for Cranioplasty. Neurosurgery January 86:E15–E22, 2020

PEEK - **infection** rates are higher (27% vs. 0%); importantly, none of the patients who received custom implants and developed cranioplasty infection had a craniectomy for osteomyelitis or epidural abscess.

Titanium mesh – worse **cosmesis** and postsurgical **discomfort** - can be managed nonsurgically; one of the most common complications in the titanium group, **CSF leak** (11.1%), did not occur in the PEEK group.

Virtual Surgical Planning (Stryker)

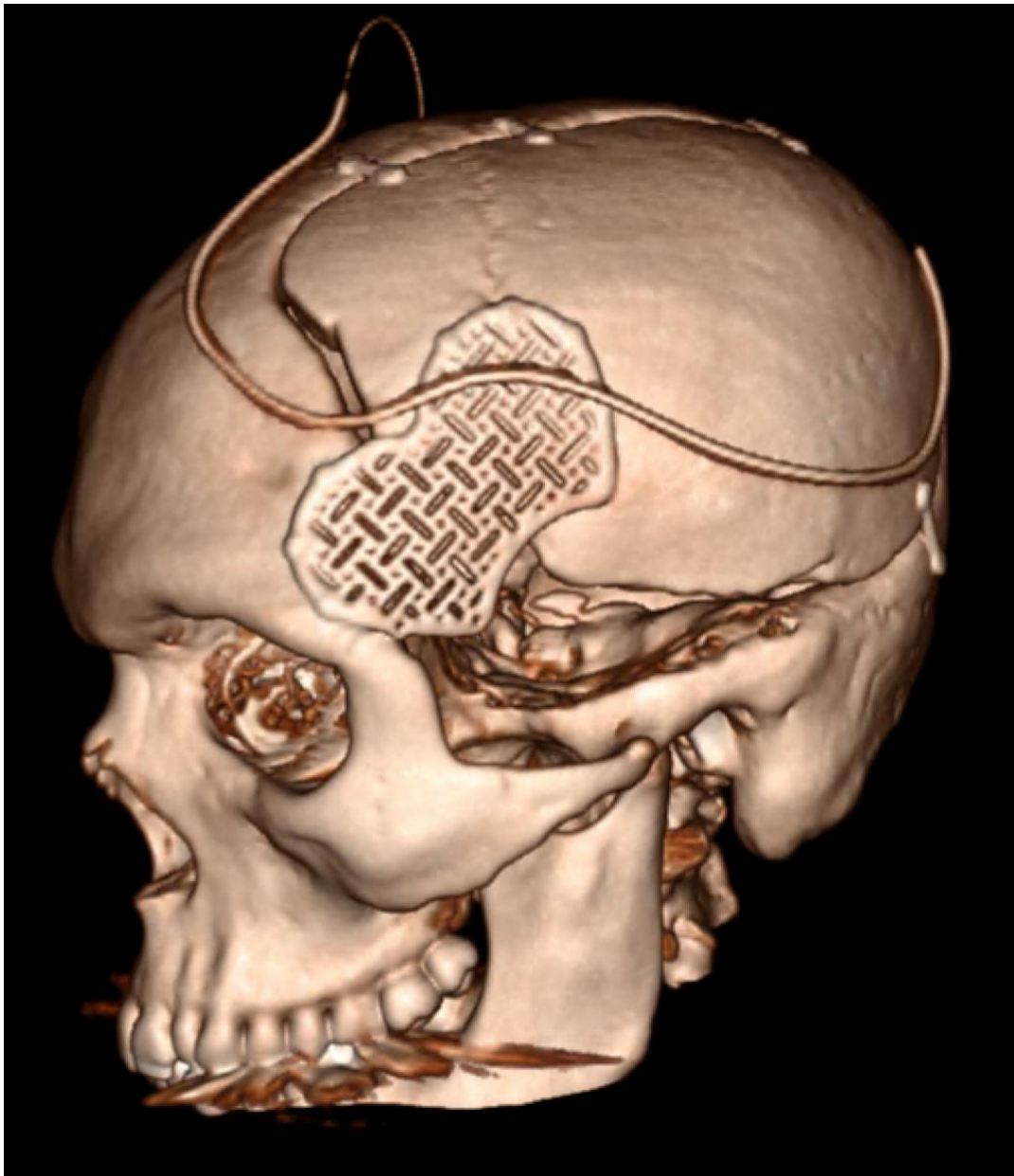
- plan your craniectomy (e.g. for skull tumor)
- Stryker will manufacture **implant** to fit the new (planned) defect + will give a **cutting guide** to help with the craniectomy.

PREOP

- always use **Foley** (in case patient needs mannitol intraop!); may not for **Dr. Graham**.
- may load with **AED** for 7 days.

TECHNIQUE

- inject local **anesthetic with epinephrine** early (additional hemostasis – less need for coagulation) – use robust **control syringe!**
- use sharp dissection with **Metzenbaum scissors** (insert scissors underneath and along incision between scalp flap and bone → cut with **knife**)
- use **bipolar cautery** for hemostasis (**Bovie** worsens incision healing, plus, transmits too much heat to the underlying brain – increased risk of postop seizures).
- dissect temporalis **muscle from dura** (risk of durotomies and bleeds a lot; **Dr. Collins** believes it decreases postoperative headaches from muscle pulling on dura).
- there is frequently a **ridge of scar tissue** at the perimeter of the bone flap that may be shrunken back with bipolar cautery or excised – gives extra mL of room to fit bone flap in.
- unintentional durotomies repaired with 4-0 silk running sutures.
- may tack dura to bone flap centrally with sutures (careful if there is significant encephalomalacia)
- may cover dura with Surgicel.
- fix flap to skull edges with **plates and screws**.
 - **advance flap anteriorly-superiorly** for cosmetic reasons (may need to drill off the sphenoid wing ridge on the bone flap for better accommodation).
 - avoid plates on the **path of legs of glasses**
 - **smoothen bone edges** with drill to improve contour.
 - **Dr. JRC** uses HydroSet
- **fix temporalis muscle** to new flap with sutures, screws (must go through muscle fascia).
 - if there is significant temporalis atrophy, may place a mesh to fill the void and attach the muscle:



- leave **drain** over flap (subgaleal) on suction.
- 1 g of **VANCOMYCIN** powder.
- use **running vertical mattress** for skin closure (e.g. 3-0 Monocryl) – scar edges tend to invert so mattress helps to keep skin edges aligned.

Difficulty closing scalp without tension: perform partial* thickness galeal incisions in # fashion – helps to stretch scalp.

- if this is anticipated preop, consult plastic surgery to implant **tissue expander** for several weeks.
*partial - to avoid damaging galeal vessels

POSTOP

- regular floor or ICU.
- likely home next day (unless drain output is high – make sure it is not CSF).

COMPLICATIONS

1. **Infection** (15-20%) – no matter what type of bone flap is used (autologous stored in abdomen vs. synthetic vs. autologous frozen).
N.B. cranioplasty is the neurosurgical procedure with the highest infection rates!
 - some experts culture autologous bone flap before reimplantation.
 - some experts soak autologous bone flap in the Betadine before reimplantation.
2. Hemorrhage
3. Cerebral **swelling** → **herniation** (lethal cases exist!)
4. **Resorption** of the autologous bone flap; risk is increased: kids, irradiated contaminated bone flaps, fragmented bone flaps, abdominal bone flap storage.

Vilcinis "Neurotraumatologija" 1999

KAUKOLĖS KAULŲ DEFEKTAI IR JŲ PLASTIKA

Kaukolės kaulų defektai lieka po išpaustinių, skeveldrinių lūžių šalinimo, šautinių, durtinių sužalojimų, dekompresinių kraniektomijų, osteomielito.

Indikacijos kranioplastikai yra kosmetinės, apsauginės, o taip pat dėl trepanacijos sukeltų nemalonių pojūčių. Išvaizdos pagerinimas gali turėti įtakos ir psichosocialinei adaptacijai. Pakartotinių traumų apsauga ypač svarbi kariams, policijos, pramonės, darbuotojams, sportininkams, ligoniams sergantiems epilepsija. Trepanaciniam sindromui būdingi veržiantys, pulsuojujantys galvos skausmai, ypač keičiantis aplinkai: atmosferos slėgiui, temperatūrai (netoleruoja saulės, karščio). Be to šie ligoniai jaučia svaigimą, nuovargį, nemigą, negalėjimą susikoncentruoti, nerimą, depresiją. Tokie simptomai galimi ir be kaukolės kaulų defekto po smegenų sukrėtimo ir tai vadinama "postkomociniu" ar "potrauminiu" sindromu. Esant plačiam kaukolės defektui po dekompresijos tiesioginis atmosferos slėgis sąlygoja pusrutulio kolapsą ir gali sąlygoti neurologinį pablogėjimą. Gi po kranioplastikos šiems ligoniams neretai pagerėja neurologinė būklė.

Kranioplastiką rekomenduojama atlikti išnykus intrakranijinės hipertenzijos požymiams, nes ankstyva operacija gali pagerinti neurologinių simptomų atsistatymą. Tai siejama su smegenų kraujotakos pagerėjimu po kranioplastikos. Operacija atidedama po infekcinių komplikacijų - paprastai 6 mėn.

Reikalavimai kranioplastikos medžiagoms:

- lengvai modeliuojama, priderinant prie kaukolės formos
- lengvai sterilizuojama
- stiprumas, atitiktų kaulo
- lengvo svorio
- pralaidi rentgeno spinduliams ir nejautri magnetiniame lauke
- pigi

Optimalu panaudoti to paties žmogaus kaulą, pvz., išsaugant, konservuojant kaulinį lopą. pašalintą, atliekant dekompresiją, panaudojant greta esančio kaukolės kaulo išorinę plokštelę ar šonkaulį, klubakaulio sparno fragmentą. Šio kaulo prigijimą blogina: bloga jo fiksacija prie defekto kraštų, kietojo dangalo pakeitimas fascia lata ar lavono dangalu, defekto kaulinių kraštų užvaškavimas, plonas, menkai vaskuliarizuotas skalpas.

Ieškota optimalios aloplastinės medžiagos. Dar prieš 3000 metų prieš mūsų erą Peru rastos auksinės ir sidabrinės plokštelės, savo dydžiu atitinkančios trepanacines kaukolės angas. Vėliau buvo naudojamas tantalas, nerūdijantis plienas, titanas, cirkonis, aluminis. Jų nepatogumas, kad yra geri temperatūros laidininkai, apsunkena rentgenologinius tyrimus.

1940 m. Kleinschmidt pasiūlė kranioplastikai naudoti **metylmetakrylatą**, kuris greitai tapo labai populiarus ir iki šiol naudojamas. Operacijos metu sumaišomi polimero milteliai su monomero tirpikliu, masė gerai išmaišoma, kad tirpiklio perteklius išgaruotų, nes jis veikia citotoksiškai. Defekto sritis užliejama šia mase, kad gerai priglustų prie kaulo defekto kraštų. Modeliavimui skirta apie 5 min, o po 15 minučių įvyksta egzoterminė polimerizacija ir plokštelė sukietėja. Tada ji fiksuojama prie kaukolės kaulų kraštų. Protokrilo ir kitų aloplastinių medžiagų nerekomenduojama naudoti kai yra pažeistas kaktinis antys - prieš tai būtina atlikti jo plastiką.

Paskutiniu metu kranioplastikai pradėtos naudoti keraminės medžiagos - trikalcio fosfatas, hidroksiapatitas, kurioms būdinga osteogenezės stimuliacija, t.y. jos palaipsniui rezorbuojasi ir sukaulėja.