The Professional Medical Journal
www.theprofesional.com

REVIEW PROF-4138

DOI: 10.17957/TPMJ/17.4138

BONE FLAPS:

CRYOPRESERVATION VERSUS INTRACORPOREAL PRESERVATION OF CRANIAL BONE FLAPS; A COMPREHENSIVE REVIEW OF LITERATURE.

Atiq Ahmed Khan[1], Muhammad Imran[2], Syed Ijlal Ahmed[3], Shiraz Ahmed Ghouri[4], Alizay Rashid Khan[5], Muhammad Osama Farooqi[6], Majid Chandio[7]

1. FCPS
Associate Professor of Neurosurgery,
Civil Hospital, Dow University of Health Sciences, Karachi, Pakistan.
2. FCPS
Associate Professor Neurosurgery,
Civil Hospital, Dow University of Health Sciences, Karachi, Pakistan.
3. MBBS
Honorary Researcher,
Civil Hospital, Dow University of Health Sciences, Karachi, Pakistan.
4. FCPS
Assistant Professor Neurosurgery,
Civil Hospital, Dow University of Health Sciences, Karachi, Pakistan.
5. Medical Student,
Dow University of Health Sciences, Karachi, Pakistan.
6. Medical Student,
Dow University of Health Sciences, Karachi, Pakistan.
7. Resident,
Civil Hospital, Dow University of Health Sciences,
Karachi, Pakistan.

Corresponding author:
Syed Ijlal Ahmed
Honorary Researcher,
Civil Hospital,
Dow University of Health Sciences,
Karachi, Pakistan.
syedijlalahmed@ymail.com

Article received on:
01/06/2017
Accepted for publication:
25/08/2017
Received after proof reading:
08/09/2017

ABSTRACT: Cranioplasty is the surgical repair of a bone deformity of the skull. Autologous bone grafts are preferred more since the cranial bone flaps will not be subject to rejection by the host and they lower the entry of foreign materials into the body. Preservation of cranial bone flaps is done in numerous ways, namely cryopreservation after a decompressive craniectomy, intracorporeal preservation and cranioplasty with subcutaneously preserved autologous bone grafts. The method of preserving cranial bone flaps using cryopreservation has many advantages; it is a safe, simple and an effective method for autologous bone grafts. The cryopreservation is also associated with higher infection rates and bone resorption as complications when compared to intracorporeal preservation. Intracoporeal preservation technique has many advantages, particularly that this surgery is easy, safe and cost-effective. The duration of the operation is short. The autologous bone flaps are not subject to rejection and there is no need for intra-operative bone shaping. Therefore on the basis of review of literature authors concluded that intracorporeal preservation is better than cryopreservation of cranial bone flaps, in terms of efficacy and complications.

Key words: Cranioplasty, Decompressive craniectomy, Cryopreservation, Intracorporeal preservation, Cranial bone flaps.

Article Citation: Khan AA, Imran M, Ahmed SI, Ghouri SA, Khan AR, Farooqi MO, Chandio M. Bone flaps; Cryopreservation versus intracorporeal preservation of cranial bone flaps; a comprehensive review of literature. Professional Med J 2017;24(9):1259-1264. **DOI:** 10.17957/TPMJ/17.4138

INTRODUCTION

Cranioplasty is the surgical repair of a bone deformity of the skull. There are many kinds of cranioplasties. It may be performed for protection of the skull, to improve neurological function and brain metabolism, for aesthetic purposes and to reduce headaches which may occur as a result of some injury.[1] The materials commonly used include plexiglass, methacrylate, titanium mesh and autologous skull flaps. Synthetic materials used for cranial bone defect reconstruction have shown more favorable outcomes as compared to auto grafts. Different synthetic materials ensured different survival rates.[2] Metals were the choice of material for cranioplasty since antiquity but currently autologous bone grafts are preferred more since the cranial bone flaps will not be subject to rejection by the host and they lower the entry of foreign materials into the body.[3] Cranioplasty is performed within 2-3 hours and the recovery period ranges from 1-2 weeks. The incidence of complications related to cranioplasty with cranial bone flaps ranges from 0-46%.[4] Wound infection and bone resorption are the main complications associated with cranioplasty, especially if the skull defects and deformities are large. Cranioplasty methods are also associated with surgical and aesthetic risks, hemorrhage, hydrocephalus, fluid under the scalp and seizures.[1]

A bone flap is 'a portion of cranium removed but left attached to overlying muscle-fascial blood supply', as defined by Medical Dictionary for the Health Professions and Nursing.[5] Bone flaps will either be replaced or not, depending upon the type of surgery being performed. A craniotomy is a type of surgery in which part of the bone from the skull is surgically removed to expose the

brain. The bone flap is removed on a temporary basis and then replaced after the surgery has been done.[6] On the other hand, in craniectomy, the bone flap is not replaced.[7] The preservation of cranial bone flaps is carried out in a wide variety of ways, each of which have their own benefits and drawbacks.

Decompressive craniectomy is a surgery in which part of the skull will be removed to allow a swelling of the brain to expand. It is used to manage major strokes, malignant edema and intracranial hypertension. It also improves cerebral perfusion pressure and cerebral blood flow. However, meningitis and brain abscess may occur.[8]

Preservation of cranial bone flaps is done in numerous ways, namely cryopreservation after a decompressive craniectomy, intracorporeal preservation and cranioplasty with subcutaneously preserved autologous bone grafts.

The purpose of this review was to compare the cryopreservation technique with intracorporeal technique for the preservation of cranial bone flaps, in terms of complications and success rates.

Review of Literature

Literature search strategy

The literature databases used for search were Medline, Science direct, EMBASE, PUBMED and Google Scholar.

Inclusion Criterion of studies

Studies directly related to the preservation of cranial bone after decompressive craniectomy and to the two methods of it, intracorporeal and cryopreservation were included in the review. The type of articles selected were case reports, cohort, surgeon general's report, retrospective studies and follow up patient databases. The data was extracted and compared for technique of management and best preservation method and the complications.

Review of Evidence

There is an ongoing controversy in medical literature as to whether cryopreservation or intracorporeal preservation is the better means of preserving cranial bone flaps. Both techniques are feasible and efficacious for the storage of bone flaps.

Cryopreservation or cryoconservation is a process where organelles, cells, tissues, extracellular matrix, organs or any other biological constructs susceptible to damage caused by unregulated chemical kinetics are preserved by cooling to very low temperatures (typically −80 °C using solid carbon dioxide or −196 °C using liquid nitrogen).[9]

The method of preserving cranial bone flaps using cryopreservation has many advantages; it is a safe, simple and an effective method for autologous bone grafts.[10,11] Delayed cranioplasty using autologous bone flaps undergone cryopreservation, frozen with glycerol gave clinical and aesthetic results which were satisfactory.[10] In a study by T Beez, Et al. performed the surface analysis of the cyroconserved skull bone after decompressive craniectomy concluded that that the bone flap didn't alter the surface up to 8 months proving the reliability of the method.[12] Very Low incidence rates of infection and severe bone resorption are seen with cryopreserved autologous bone flaps stored in povidone-iodine solution.[11] Cranioplasty performed at least 14 days after initial craniectomy; helps minimize the chances of any infections from the surgery.[13]

Although, this method has many advantages but it is also followed by some major post operative complications and in some cases requiring the need of reoperation. In a study, one case was found where there was mild resorption of bone flaps although there was no infection or a need for reoperation for the complications during the follow-up periods.[10] Surgical site infection (SSI) and bone flap resorption have been seen to be the most frequent complications in patients with re-implantation of autologous cryopreserved bone flaps after decompressive craniectomy, statistically shown SSI developed in about 12.8% patients and bone resorption occurred in 4.3%.[14] Cryopreserved bone flap resorption has been seen to be associated with bone flap location. Also, the fragmented bone

flaps or those implanted in patients undergone Ventriculo-peritoneal shunts showed a higher incidence of bone resorption causing bone flap collapse.[11] In a retrospective analysis by LH Stieglitz et al [15]100 patients were reimplanted with a cryopreserved autologous bone flap. Out of 92 patients who followed up, Minor resorption was seen in 19 patients, Major resorption leading to surgical revision and replacement was seen in 28 patients. Factors like long surgical time, proper use of antiseptic solutions, the presence of VPS, number of operations and other medical comorbidities might play a role in developing post operative complications,[16] as well as the delayed reimplantation of cryopreserved bone flap can lead to the complication of resorption.[15]

A study on the pediatric patients showed complications in the cranioplasty following decompressive craniectomy for traumatic brain injury. It was noticed that patients of age 2.5 years or younger were having a greater risk of bone flap resorption than the older children, around 50% patients experienced bone flap resorption.[17] The incidence of complication is linked to patients age in many cases and is more frequent in children than adults.[15]

Intracorporeal preservation is a way of preserving cranial bone flaps. The flaps are stored in subcutaneous pouches in the abdominal wall.[18] Preservation of bone flaps is also done in the thigh and between abdominal fat and muscle layers.[19,20] Preservation is feasible under the skin of the left lower abdomen, specifically.[1]

This preservation technique has many advantages, particularly that this surgery is easy, safe and cost-effective. The duration of the operation is short. The autologous bone flaps are not subject to rejection and there is no need for intra-operative bone shaping.[1] Bone union is also possible. There is a negligible infection rate linked with subcutaneous preservation which is a subtype of intracorporeal preservation. It promotes viability of the bone flaps and is also responsible for good cosmetic results.[21,22] Subcutaneously, preserved bone flaps retain their osteogenic potential and is a simple option for the storage of bone flaps during a decompressive craniotomy.[23]

Cranioplasty and intracorporeal preservation is generally performed because of cranial defects and traumatic injuries to the head. In children, who are younger than 3 years of age, congenital anomalies and growing skull fractures are common predispositions to cranioplasty. Cranioplasty serves cosmetic purposes but also provides relief to psychological drawbacks.[24] Classically, cranioplasty material must fit the cranial defect, be inexpensive, easy to shape and work with, resistant to infections and must not become dilated with heat.[25]

However, there are a few complications associated with this technique. The bone flaps can be absorbed and shrink, so their size will not match the size of the bone window. Wound healing disorders may occur leading to further operations, with the need for artificial bone implantation.[26] In children, there is a high rate of complications related to cranioplasty after a decompressive craniectomy. This is because children are highly susceptible to bone resorption and this risk increases if cranioplasty is delayed for a time period of 6 weeks or more after decompressive craniectomy has been performed.[27] The reimplantation of autologous bone has a high complication rate.[28] Autoclaved autologous bone reimplantation has a low rate of surgical site infection, but with a very significant rate of bone flap resorption.[29] However, long time span of cranioplasty can be risk factor for acute autologous bone flap infection.[30] The development of bone flap necrosis [31,32] and the Aseptic bone flap resorption is also a major concern in long-term follow-ups after cranioplasty.[33]

Bone flap reimplantation should ideally be done between the 2nd and 3rd months after the craniotomy has been performed. Absorption can be avoided if the reimplantation time is less than 6 weeks.

There are a few points to consider when deciding which preservation technique should be carried

out. Cranioplasty following decompressive craniectomy is associated with a high rate of complication,[16,34] having surgical site infection and bone flap resorption as the two most common complications.[3] This varies from patient to patient. A study suggests that implant material, early surgery and method of flap preservation have no effect on the rate of cranioplasty infections.[35]

In a study by Cheng-Hesin et al.[36] of 110 patients received a cranioplasty of subcutaneous pocket preserved bone flap and 180 received cryopreserved bone flap cranioplasty. Surgical site infection occurred in 18.2% patients in SP compared to 11.1% patients in CP and bone resorption was found to be higher in CP group than in the SP group. It was concluded that SP and CP, both might effective and safe method for the storage bone flap regardless of whether the etiology is TBI or non-TBI. The method employed also depends upon the surgeon's level of experience and personal preference. The technique used also depends by and large upon the equipment which is available.

In another article, patients with traumatic brain injury (TBI), subcutaneous preservation of bone flaps may be the more suitable option. Whereas, for patients of non-TBI etiology, subcutaneous preservation or cryopreservation are equally effective.[37]

A study was conducted in which cryopreservation has been known to exhibit a low infection rate (2.3%), low rate of bone absorption (2.3%) and no cosmetic problems whereas the procedure of subcutaneous preservation showed no complications at all. The cryopreservation operation had an average duration of 146 minutes, whereas the subcutaneous preservation operation was completed in an average time of 130 minutes.[38]

CONCLUSION

The two methods of preservation of the cranial bone flap, Cryopreservation and Intracorporeal preservation, after decompressive craniectomy showed a wide variety of outcomes. Both methods prove to produce good results and yet have some complications in some cases.

Intracorporeal preservation was found to be associated with lesser complication rates as compared to cryopreservation.

Additionally, some other methods like Rapid closure technique have shown to be feasible and safe in decompressive craniectomy. It has also shown to reduce the surgical time significantly without increased complication rates. Cranioplasty performed following Rapid closure decompressive craniectomy procedure is also found to be safe, fast, feasible and doesn't impaired by Rapid closure decompressive craniectomy technique.[39]

REFERENCES

1. Wang Wx, Jiang N, Wang Jw, Kang X, Fu Gh, Liu Yl. **Bone formation in subcutaneous pocket after bone flap preservation.** Clinical case reports. 2016; 4(5):473-6.

2. Piitulainen JM, Kauko T, Aitasalo KMJ, Vuorinen V, Vallittu PK, Posti JP. **Outcomes of cranioplasty with synthetic materials and autologous bone grafts.** World neurosurgery. 2015; 83(5):708-14.

3. Brommeland T, Rydning PlN, Pripp AH, Helseth E. **Cranioplasty complications and risk factors associated with bone flap resorption.** Scandinavian journal of trauma, resuscitation and emergency medicine. 2015; 23(1):75.

4. El Ghoul W, Harrisson S, Belli A. **Autologous cranioplasty following decompressive craniectomy in the trauma setting.** British journal of neurosurgery. 2015; 29(1):64-9.

5. . Farlex; 2012. **Medical Dictionary for the Health Professions and Nursing**

6. Youngson RM. **Surgery Book: An Illustrated Guide to 73 of the Most Common Operations.** Macmillan; 1997.

7. Pickrell KD. **Miller-Keane encyclopedia and dictionary of medicine, nursing, and allied health.** Hospitals & Health Networks. 2003; 77(8):70.

8. AlbanÃ¨se J, Leone M, Alliez J-R, Kaya J-M, Antonini Fo, Alliez B, et al. **Decompressive craniectomy for severe traumatic brain injury: evaluation of the effects at one year.** Critical care medicine. 2003; 31(10):2535-8.

9. Pegg DE. **"Principles of cryopreservation".** Methods in Molecular Biology Clifton, NJ. 2007; 368:39–57.

10. Takeuchi H, Higashino Y, Hosoda T, Yamada S, Arishima H, Kodera T, et al. **Long-term follow-up of cryopreservation with glycerol of autologous bone flaps for cranioplasty after decompressive craniectomy.** Acta neurochirurgica. 2016; 158(3):571-5.

11. Zhang J, Peng F, Liu Z, Luan J, Liu X, Fei C, et al. **Cranioplasty with autogenous bone flaps cryopreserved in povidone iodine: a long-term follow-up study.** Journal of Neurosurgery. 2017:1-8.

12. Beez T, Sabel M, Ahmadi SA, Beseoglu K, Steiger H-J, Sabel M. **Scanning electron microscopic surface analysis of cryoconserved skull bone after decompressive craniectomy.** Cell and tissue banking. 2014; 15(1):85-8.

13. Morton RP, Abecassis IJ, Hanson JF, Barber J, Nerva JD, Emerson SN, et al. **Predictors of infection after 754 cranioplasty operations and the value of intraoperative cultures for cryopreserved bone flaps.** Journal of neurosurgery. 2016; 125(3):766-70.

14. Sundseth J, Sundseth A, Berg-Johnsen J, Sorteberg W, Lindegaard KF. **Cranioplasty with autologous cryopreserved bone after decompressive craniectomy. Complications and risk factors for developing surgical site infection.** Acta neurochirurgica. 2014; 156(4):805-11.

15. Stieglitz LH, Fung C, Murek M, Fichtner J, Raabe A, Beck Jr. **What happens to the bone flap? Long-term outcome after reimplantation of cryoconserved bone flaps in a consecutive series of 92 patients.** Acta neurochirurgica. 2015; 157(2):275-80.

16. Paredes I, CastaÃ±o-LeÃ³n AM, Munarriz PM, MartÃnez-Perez R, Cepeda S, Sanz R, et al. **Cranioplasty after decompressive craniectomy. A prospective series analyzing complications and clinical improvement.** Neurocirugia. 2015; 26(3):115-25.

17. Bowers CA, Riva-Cambrin J, Hertzler DA, Walker ML. **Risk factors and rates of bone flap resorption in pediatric patients after decompressive craniectomy for traumatic brain injury: clinical article.** Journal of Neurosurgery: Pediatrics. 2013; 11(5):526-32.

18. Shoakazemi A, Flannery T, McConnell RS. **Long term outcome of subcutaneously preserved autologous cranioplasty.** Neurosurgery. 2009; 65(3):505-10.

19. AÃ§ikgÃ¶z B, Ã–zcan OE, Erbengi A, Bertan V, Ruacan Å, AÃ§ikgÃ¶z HGk. **Histopathologic and microdensitometric analysis of craniotomy bone flaps preserved between abdominal fat and muscle.** Surgical neurology. 1986; 26(6):557-61.

20. Nakajima T, Tanaka M, Someda K, Matsumura H. **Subcutaneous preservation of free skull bone flap taken out in decompressive craniectomy (author's transl).** No shinkei geka Neurological surgery. 1975; 3(11):925-7.

21. Baldo S, Tacconi L. **Effectiveness and safety of subcutaneous abdominal preservation of autologous bone flap after decompressive craniectomy: a prospective pilot study.** World neurosurgery. 2010; 73(5):552-6.

22. Movassaghi K, Ver Halen J, Ganchi P, Amin-Hanjani S, Mesa J, Yaremchuk MJ. **Cranioplasty with subcutaneously preserved autologous bone grafts.** Plastic and reconstructive surgery. 2006; 117(1):202-6.

23. Singla N, Singh SP, Gupta SK, Karthigeyan M, Radotra BD. **Histopathology of subcutaneously preserved autologous bone flap after decompressive craniectomy: a prospective study.** Acta neurochirurgica. 2014; 156(7):1369-73.

24. Aydin S, Kucukyuruk B, Abuzayed B, Aydin S, Sanus GZ. **Cranioplasty: review of materials and techniques. Journal of neurosciences in rural practice.** 2011; 2(2):162.

25. Blake DP. **The use of synthetics in cranioplasty: a clinical review.** Military medicine. 1994; 159(6):466.

26. Wachter D, Reineke K, Behm T, Rohde V. **Cranioplasty after decompressive hemicraniectomy: underestimated surgery-associated complications? Clinical neurology and neurosurgery.** 2013; 115(8):1293-7.

27. Piedra MP, Thompson EM, Selden NR, Ragel BT, Guillaume DJ. **Optimal timing of autologous cranioplasty after decompressive craniectomy in children: clinical article.** Journal of Neurosurgery: Pediatrics. 2012; 10(4):268-72.

28. Martin KD, Franz B, Kirsch M, Polanski W, von der Hagen M, Schackert G, et al. **Autologous bone flap cranioplasty following decompressive craniectomy is combined with a high complication rate in pediatric traumatic brain injury patients.** Acta neurochirurgica. 2014; 156(4):813-24.

29. Mracek J, Hommerova J, Mork J, Richtr P, Priban V. **Complications of cranioplasty using a bone flap sterilised by autoclaving following decompressive craniectomy.** Acta neurochirurgica. 2015; 157(3):501-6.

30. Huang Y-H, Yang T-M, Lee T-C, Chen W-F, Yang K-Y. **Acute autologous bone flap infection after cranioplasty for**

postinjury decompressive craniectomy. Injury. 2013; 44(1):44-7.

31. DÃ¼nisch P, Walter J, Sakr Y, Kalff R, Waschke A, Ewald C. **Risk factors of aseptic bone resorption: a study after autologous bone flap reinsertion due to decompressive craniotomy: Clinical article.** Journal of neurosurgery. 2013; 118(5):1141-7.

32. Schwarz F, DÃ¼nisch P, Walter J, Sakr Y, Kalff R, Ewald C. **Cranioplasty after decompressive craniectomy: is there a rationale for an initial artificial bone-substitute implant? A single-center experience after 631 procedures.** Journal of Neurosurgery. 2016; 124(3):710-5.

33. Schuss P, Vatter H, Oszvald Ãg, Marquardt G, ImÃ¶hl L, Seifert V, et al. **Bone flap resorption: risk factors for the development of a long-term complication following cranioplasty after decompressive craniectomy.** Journal of neurotrauma. 2013; 30(2):91-5.

34. Gooch MR, Gin GE, Kenning TJ, German JW. **Complications of cranioplasty following decompressive craniectomy: analysis of 62 cases.** Neurosurgical focus. 2009; 26(6):E9.

35. Yadla S, Campbell PG, Chitale R, Maltenfort MG, Jabbour P, Sharan AD. **Effect of early surgery, material, and method of flap preservation on cranioplasty infections: a systematic review.** Neurosurgery. 2011; 68(4):1124-30.

36. Cheng C-H, Lee H-C, Chen C-C, Cho D-Y, Lin H-L. **Cryopreservation versus subcutaneous preservation of autologous bone flaps for cranioplasty: comparison of the surgical site infection and bone resorption rates.** Clinical neurology and neurosurgery. 2014; 124:85-9.

37. Inamasu J, Kuramae T, Nakatsukasa M. **Does difference in the storage method of bone flaps after decompressive craniectomy affect the incidence of surgical site infection after cranioplasty? Comparison between subcutaneous pocket and cryopreservation.** Journal of Trauma and Acute Care Surgery. 2010;68(1):183-7.

38. Lee BS, Min KS, Lee MS, Kim YG, Kim DH. **Comparison with subcutaneous abdominal preservation and cryoconservation using autologous bone flap after decompressive craniectomy.** Korean Journal of Neurotrauma. 2012;8(1):21-5.

39. GÃ¼resir E, Vatter H, Schuss P, Oszvald Ãg, Raabe A, Seifert V, et al. **Rapid closure technique in decompressive craniectomy: Clinical article.** Journal of neurosurgery. 2011; 114(4):954-60.

AUTHORSHIP AND CONTRIBUTION DECLARATION

Sr. #	Author-s Full Name	Contribution to the paper	Author=s Signature
1	Atiq Ahmed Khan	Principal idea, Proof reading,	
2	Muhammad Imran	Literature Search & interpretatish	
3	Syed Ijlal Ahmed	Principal idea, Literature Search manuscript writing	
4	Shiraz Ahmed Ghouri	Literature Search	
5	Alizay Rashid Khan	Literature Search & Manuscript writing	
6	Muhammad Osama Farooqi	Literature Search, Medical artity	
7	Majid Chandio	Literature Search	