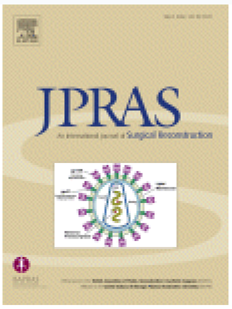
http://www.sciencedirect.com.ezproxy.lib.usf.edu/science/article/pii/S1748681507003531?

ELSEVIER

Journal of Plastic, Reconstructive & Aesthetic Surgery

Volume 61, Issue 4, April 2008, Pages 413–418



The effect of tissue expansion on skull bones in the paediatric age group from 2 to 7 years

- M.M. El-saadi,
- M.A. Nasr
- Faculty of Medicine, Zagazig University, Zagazig, Sharkia, Egypt
- http://dx.doi.org.ezproxy.lib.usf.edu/10.1016/j.bjps.2007.06.024, How to Cite or Link Using DOI
- Permissions & Reprints

Summary

Tissue expansion has gained wide application in the reconstruction of scalp defects in adults and children. However, the main concern in the use of scalp expansion in the paediatric population has been the risk of skull deformation.

This study shows the application of 40 expanders in 32 patients in different skull areas in the paediatric age group from 2 to 7 years. The effect of expansion on the skull was studied by CT imaging (pre-expansion, post-expansion and 3 months after expander extraction). The post-expansion CT showed multiple bony changes as well as changes at suture lines.

Keywords

- Tissue expansion;

- Paediatric tissue expansion;
- Mechanical effect on bone;
- Cranial bone;
- Expanders;
- Bone resorption

The use of tissue expanders in plastic and reconstructive surgery is now well established for large defects in adults and children. Neumann[1] published his clinical experience when he expanded a patient for auricular reconstruction using a subcutaneous balloon. Radovan[2] and Austed[3] popularised and refined this technique. Since this early work, tissue expansion has been investigated thoroughly and has gained widespread acceptance. Intra-expander pressures as high as 41 to 103 mmHg were recorded after saline filling. After about 6 h, the intra-expander pressure gradually decreased to less than 32 mmHg. If the intra-expander pressure exceeds 32 mmHg for more than 6 h, skin necrosis can occur.[4] Previous studies focused only on soft tissue response to mechanical expansion. A few studies have investigated the effect of tissue expansion on the bone.[5]

It has been observed that bone is composed of the minimal quantity of osseous tissue that will withstand the usual functional stresses applied to it.[6] During development abnormal external forces can distort cranial morphology, as is evident by the bizarre shapes of skulls produced by pressure devices on children's skulls in some tribal societies.[7]

There is evidence that mechanical stimulation activates osteocytes to produce anabolic factors, which recruit new osteoblasts from the periosteum. Using this concept it is possible to explain local bone gain as a result of local overuse.[8]

Klein-Nulend et al.[9] state that mechanical loading that produces microdamage, observable only at greater than ×1000 magnification, will interfere with the integrity of the lacuno-canalicular network, disrupting the communication between osteocytes and the bone surface. This will abolish active suppression of osteoclasts by osteocytes, thereby allowing resorption to begin. Resorption of microdamaged bone will then lead to (local) overuse and stimulation of bone formation. Bone formation will continue until a new steady state of normal loading (use) is reached.

Oleski et al.[10] reported cranial bone mobility as a result of an external force visualised by a plain X-ray. Jeremy and Hyun-Duck[11] observed significant suture widening in response to mechanical force. Andrew[12]analysed the stress direction across the suture surface and suggested that there is a very clear transfer of tension and compression through these sutures.

The studies of the mechanical effect of tissue expansion focused only on soft tissue response but few studies have investigated the effect on bone. These studies demonstrated bone apposition at the periphery of the expanders which was a fibrous structure in conjunction with the capsule of the expanders. This reaction was felt clinically and was seen intraoperatively as a ridge at the edge of the expander. It was mediated by periosteal reaction and showed osteoblastic activity, proved histologically by Colonna et al.[13]and Schmelzeisen et al.[5] They also claimed bone resorption under the expanders in the form of bone thinning (resorption and remodelling) occurred. This reaction was mediated by osteoclastic activity. Outer table erosion (resorption) of the skull secondary to tissue expansion was reported in an 18-month-old child by Paletta et al.[14] Full thickness bone erosion was reported by Fudem and Orgel[15] in a child of 5 years of age due to neglection of an expander in the scalp for 22 weeks.

At 9 months postoperatively, in most cases, a complete normalisation was confirmed by computed tomography.[13]

Patients and methods

This study involved the application of 40 expanders in 32 patients (15 males and 17 females) in different skull areas in paediatric age group 2–7 years during the period from May 2003 to January 2006 at the Plastic Surgery Department of Zagazig University Hospital (Table 1 and Table 2). Four patients underwent re-expansion with 3 month intervals. All expanders had soft bases and remote valves and were implanted subglially and inflated twice a week for 6–10 weeks. Computed tomography (CT) (Hi–Speed, General Electrics Sytec machine) was used for this study (pre-expansion, post-expansion and 3–6 months after reconstruction). We reduced the CT radiation dose as much as possible by limiting the field of CT examination to the expander area and its surroundings, increasing the slice thickness and increasing the table speed. CT aids in certain functions such as 3D reconstruction, measuring and densitometric studies. Bone thickness and the length of the line perpendicular to the surface of the expander and extended from the inner table of the bone under the centre of the expander to the inner table of the opposite bone were both measured. Photographs of patients pre- and postoperatively were taken (Fig. 1). Sometimes, photographs of intraoperative bone changes were also taken (Fig. 2).

Table 1. Age and sex of patients

Age	Sex		Total no. Patients	No. of expanders
	Male	Female		
2–3y	4	7	11	12
3–5y	6	5	11	15
5–7y	5	5	10	13
Total	**15**	**17**	**32**	**40**

Table options

Table 2. Indication for expansion

Indications	Patient No.	No. of expanders
Burn scars	18	24
Post-traumatic scars	9	10
Hemangiomas	2	3
Large congenital nevi	3	3
Total	**32**	**40**

Table options

Figure 1.

Figure options

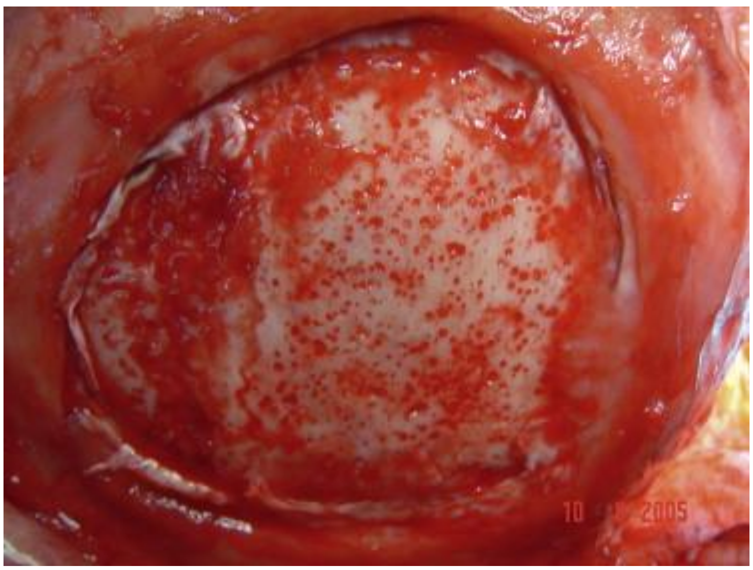


Figure 2.

Figure options

Results

All cases passed without major complication or failure. However, thinning of the skin at the centre of the expanded area with minimal exposure of the expander occurred at the end of the expansion period in three cases.

The post-expansion CT showed different bony and suture changes. These changes can be classified into five categories (Table 3):

1.

Bone apposition occurs at the periphery of all expanders (Fig. 2).

2.

Bone reaction under the surface of 30 expanders in the form of:

a.

Bone thinning (resorption and remodelling) under 26 expanders (Fig. 3).

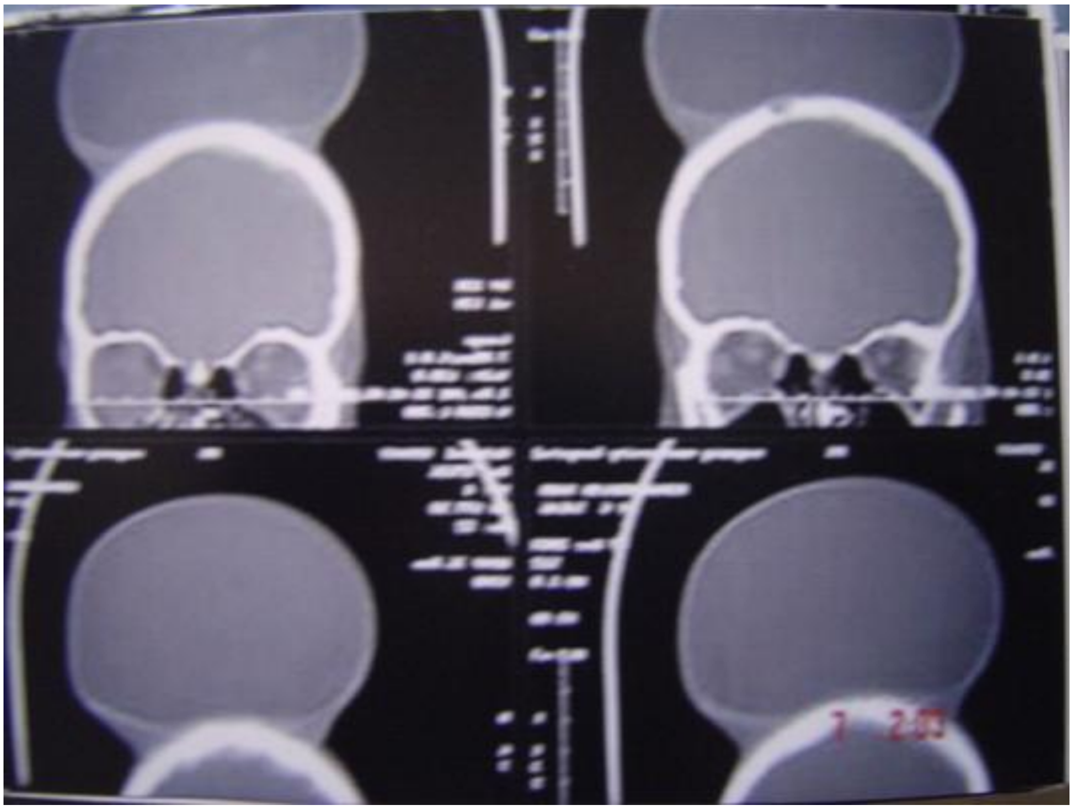


Figure 3.

Figure options

b.

Erosion (resorption) of the outer table under four expanders (Figure 4, Figure 5 and Figure 6).

Figure 4.

Figure options

Figure 5.

Figure options

Figure 6.

Figure options

3.

Inward displacement of the area of bone under the expander with maximum at its centre. This was visualised under 21 expanders (Figure 3 and Figure 7).

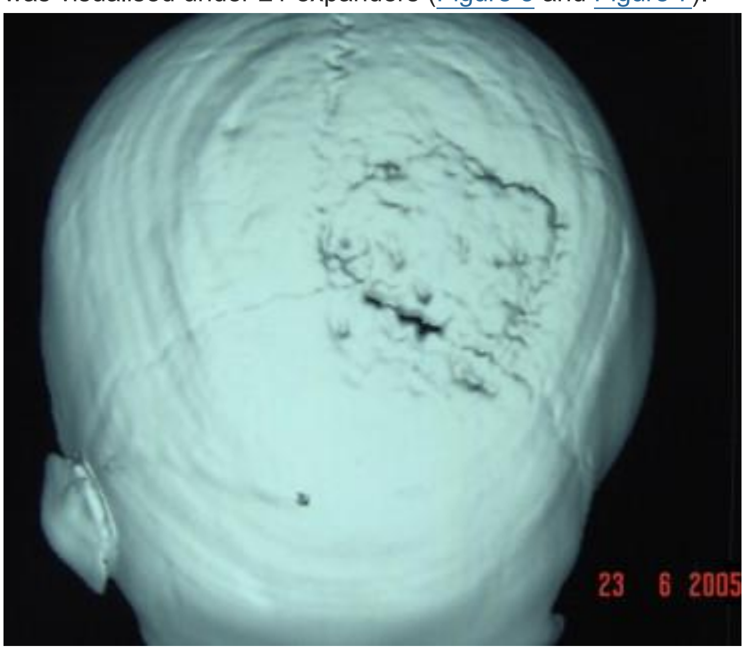


Figure 7.

Figure options

4.

Suture widening under eight expanders (Fig. 6).

5.

In one case, there was erosion away from the expander (Fig. 8).

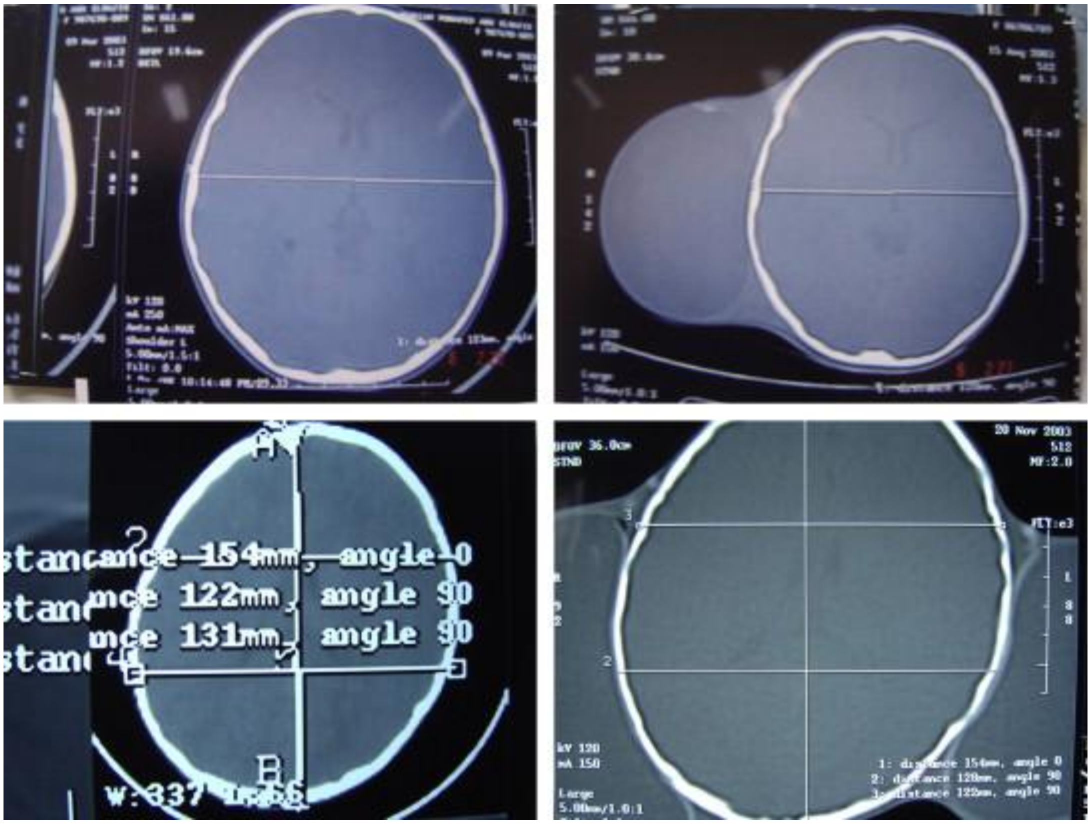


Figure 8.

Figure options

Table 3. Post-expansion CT changes

Post-expansion CT. changes	No.	%
Bone apposition	40	100
Bone reaction under the expander	30	75
Thinning	26	65
Outer table erosion	4	10
Full thickness erosion	0	0
Inward bone displacement	21	52.5
Suture widening	8	20
Erosion away from the expander	1	2.5

Table options

These changes, in general, have significance in the 2–3-year-old age group and to those who have post-traumatic scars (Table 4 and Table 5).

Table 4. Post-expansion changes in relation to the age

Post-expansion changes	Bone apposition		Bone reaction under the expanders						Inward bone shift		Suture widening		Erosion away from the expander		Mean %
			Thinning		Erosion		Total								
Age	No	%	No.	%	No	%	No	%	No	%	No	%	No.	%	
2–3 years	12	100	9	75	3	25	12	100	9	75	3	25	0	0	50
3–5 years	15	100	10	67	1	7	11	74	8	53	3	20	0	0	41
5–7 years	13	100	7	54	0	0	7	54	4	31	2	15	1	7.5	34.5
Total	40	100	26	65	4	10	30	75	21	52.5	8	20	1	2.5	42

Table options

Table 5. Post-expansion changes in relation to the indications

Post-expansion changes	Bone apposition		Bone reaction under the expanders						Inward bone shift		Suture widening		Erosion away from the expander		Mean %
			Thinning		Erosion		Total								
Indications	No	%	No	%	No.	%	No.	%	No.	%	No	%	No	%	
Burn scars	24	100	17	71	2	8	19	79	14	58	5	21	0	0	43
traumatic scars	10	100	7	70	2	20	9	90	5	50	2	20	1	10	45
Heman-giomas	3	100	1	33	0	0	1	33	1	33	1	33	0	0	33
congenital nevi	3	100	1	33	0	0	1	33	1	33	0	0	0	0	28
Total	40	100	26	65	4	10	30	75	21	52.5	8	20	1	2.5	37

Table options

Discussion

Klein-Nulend et al.[16] and Burger and Klein-Nulend[8] were the first to describe the response of the bone to mechanical stimulation in vitro and the mechanism of that response. Their findings were bone resorption and thinning that were visualised histologically.

Oleski et al.[10] reported cranial bone mobility in response to mechanical force in 12 patients visualised by plain X-ray (Fig. 9).

Figure 9.

Figure options

Few authors used CT imaging in recording cranial bone changes in response to mechanical stress exerted by expanders. Schmelzeisen et al.[5] in their experimental study on 19 growing pigs, found cranial bone changes in the form of bone apposition and bone thinning. Colonna et al.[13] in their clinical study on 10 patients (six adults and four children) used CT for visualisation of cranial bone changes. They found:

1. Bone apposition at the periphery of the expander in all cases.

2. Bone thinning under the expanders in all cases. They claimed that this change was intense in younger children.

In our study, we used post-expansion CT and 3D facilities for visualisation of cranial bone changes in 32 children with 40 expanders. Changes in the cranial bone could be summarised as follows:

1. Bone apposition in all cases.

2. Bone thinning under 65% of the expanders, mainly in the younger age group.

3. Bone erosion of the outer table under 10% of expanders occurred in children between 2 and 5 years.

4.

Full thickness bone erosion was not recorded. However in their case report Fudem and Orgel[15] reported full thickness erosion in a child of 5 years old with an expander neglected for 22 weeks.

5. Inward displacement of the area under 21 expanders was maximal at the centre.

6. Bone erosion of the outer table remote from the expander was detected in one case.

7. Widening of suture under eight expanders (20%) visualised in the 3D study and was found mainly in the younger age group. This observation was recorded by Jeremy and Hyun-Duck[11] in their experimental study on young growing rabbits subjected to intermittantly applied compression forces.

Cranial bone changes as well as changes at suture were followed up 3 months after expander extraction and showed complete normalisation. This finding agreed with Colonna et al.[13] who noted the same result by doing CT 9 months after expander extraction.

References

1.
   - 1
   - C.G. Neumann
   - **The expansion of an area of skin by progressive distension of the subcutaneous balloon**
   - Plast Reconstr Surg, 19 (1957), pp. 124–130
   - View Record in Scopus
     |
     Full Text via CrossRef
     | Cited By in Scopus (204)

2.
   - 2
   - C. Radovan
   - **Tissue expansion in soft-tissue reconstruction**
   - Plast Reconstr Surg, 74 (1984), pp. 482–490
   - **Full Text** via CrossRef

3.
   - 3

- E.D. Austed
- **The origin of expanded tissue**
- Clin Plast Surg, 14 (1987), pp. 431–433
-

4.

- 4
- G.H. Sasaki, J.E. Berg
- **Tissue expansion of the head and neck**
- C.W. Cumming, J.M. Fredrickson, L.A. Harker (Eds.) *et al.*, Otolaryngology Head & Neck Surgery (3rd ed.), Mosby, St Louis (1997), pp. 573–598
-

5.

- 5
- R. Schmelzeisen, R. Schimming, V. Schwipper *et al.*
- **Influence of tissue expanders on the growing craniofacialskeleton**
- J Craniomaxillofac Surg, 27 (1999), pp. 153–159
- Article
  |
  PDF (4828 K)
  |
  View Record in Scopus
  | Cited By in Scopus (8)

6.

- 6
- H.S. Geoffrey
- **Bone development and growth**
- H.S. Geoffrey (Ed.), Craniofacial Development. Section 1, BC Decker, London (2001), pp. 67–74
-

7.

- 7
- K.B. Barry
- **Skull and mandible**
- S. Susan (Ed.), Gray's Anatomy (39th ed.), Elsevier Churchill Livingstone, Philadelphia (2005), pp. 455–513
-

8.

- 8
- E.H. Burger, J. Klein-Nulend
- **Mechanotransduction in bone – role of the lacuno-canalicular network**
- FASEB J, 13 (1999), pp. S101–S112
- View Record in Scopus
  | Cited By in Scopus (409)

9.

- 9
- J. Klein-Nulend, J.G. McGarry, M.G. Mullender *et al.*
- **A comparison of strain and fluid shear stress in stimulating bone cell responses – a computational and experimental study**
- FASEB J, 29 (2004), pp. 54–63
-

10.

- 10
- S.L. Oleski, G.H. Smith, W.T. Crow
- **Radiographic evidence of cranial bone mobility**
- Cranio, 20 (2002), pp. 34–38
- View Record in Scopus
  | Cited By in Scopus (10)

11.

- 11
- J. Jeremy, N. Hyun-Duck
- **Growth and development: hereditary and mechanical modulation**
- Am J Orthod Dentofacial Orthop, 125 (2004), pp. 676–689
-

12.

- 12
- C. Andrew
- **The mechanics of cranial motion**
- J Bodywork Movement Ther, 9 (2005), pp. 177–188
-

13.

- 13
- M. Colonna, M. Cavallini, M. Signorini *et al.*
- **The effect of scalp expansion on the cranial bone: a clinical, histological and instrumental study**
- Ann Plast Surg, 36 (1996), pp. 255–262
- View Record in Scopus
  |
  Full Text via CrossRef
  | Cited By in Scopus (12)

14.

- 14
- C.E. Paletta, B. John, S. Sameer
- **Outer table skull erosion causing rupture of scalp expander**
- Ann Plast Surg, 23 (1989), pp. 538–542
- View Record in Scopus
  |
  Full Text via CrossRef
  | Cited By in Scopus (7)

15.

- 15
- G.M. Fudem, M.G. Orgel
- **Full thickness erosion of the skull secondary to tissue expansion for scalp reconstruction**
- Plast Reconstr Surg, 82 (1988), pp. 368–372
- **Full Text** via CrossRef

16.

- 16
- J. Klein-Nulend, A. Van der Plas, C.M. Semeins *et al.*
- **Sensitivity of osteocytes to biomechanical stress in vitro**
- FASEB J, 9 (1995), pp. 441–445
- View Record in Scopus
  | Cited By in Scopus (378)

Corresponding author.