COUNTERMEASURES TO THE EFFECTS OF GRAVITY ON THE SKULLS OF HUMAN INFANTS.

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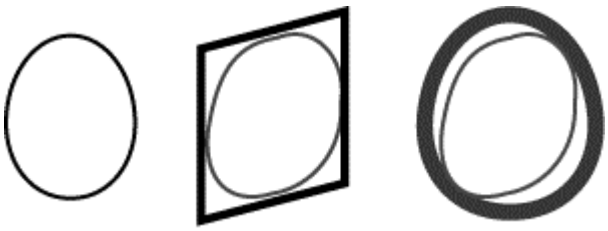
The effects of altered gravity on the skeleton have been studied mainly in weight-bearing bones, so few gravitational biologists know how Earth's gravity shapes the skulls of human infants. Skull deformations due to prolonged exposure to the *g* vector in one direction are well-known to craniofacial experts, and include brachycephaly, a flattening of the back of the skull, and posterior deformational plagiocephaly (PDP), in which the infant's skull, viewed from the top, has the shape of an oblique oval, which can be enclosed in a parallelogram (Teichgraeber et al., 2002; Fig. 1A, 1B). This shape results from a flattening of either the left or right occipito-parietal region of the skull, causing bossing, or bulging, of the contralateral occipital region and the ipsilateral frontal bone. The ipsilateral ear and malar eminence, or cheekbone, are displaced anteriorly as are the eye and the temporomandibular joint (TMJ).

PDP is associated with a number of factors related to intrauterine constraint: loss of amniotic fluid, premature and multiple births, the birthing process itself and postnatal positioning. Some infants have a torticollis, a shortened muscle affecting head positioning. Recalcitrant cases require surgery, and increased levels of TGF β2 and β3 have been found in affected sutures (Lin et al., 1997).

An infant's skull is designed to be deformed, being composed of plates of intramembranous bone connected by tough fibrous membranes or sutures, a construction allowing for compression of the infant's head during birth and postnatal growth of the bones. In craniosynotosis, sutures fuse prematurely, resulting in a malformed skull requiring surgery. Fusion of the lambdoid suture between the occipital and parietal bones, like PDP, results in bossing of the contralateral occipital region. The frontal bossing, however, is on the contralateral side, and the ear and malar eminence are not displaced (Habal et al., 2003).

PDP includes a facial asymmetry, continuing into adulthood, due to rotation of the cranial base and the resulting anterior displacement of the TMJ and consequent asymmetric mandibular growth (St. John et al., 2002).



A. B. C.

Figure 1: *A. Normal head shape. B. Parallelogram shape of head of infant with PDP. C. Thick line indicates how DOC helmet therapy changes growth of regions of the skull.*

Disturbingly, a number of developmental anomalies are associated with PDP (Habal, et al., 2003). Delays in both cognitive and psychomotor development have been noted and auditory processing disorders affecting speech and cognition have been found. CT scans have revealed an accumulation of fluid in the frontal region of the cranium.

In light of these problems in infants with PDP, the increase in incidence from 1 in 300 to 1 in 10 since 1992 is alarming (Teichgraeber et al., 2002). In 1992, the American Academy of Pediatrics urged parents to place sleeping infants on their backs to prevent Sudden Infant Death Syndrome. The message was reiterated in 1994 in the AAP's "Back to Sleep" campaign. As a result, the incidence of SIDS decreased by 45%, but craniofacial centers were inundated with parents seeking treatment for children with misshapen skulls. In 1995, the Division of Pediatric Surgery at the University of Texas Medical School in Houson treated two infants with PDP; in 1996, they treated 54 (Teichgraber et al., 2002).

Some pediatricians advocate a wait and see attitude, but craniofacial specialists prefer early intervention, while the skull still has sufficient growth potential to correct the deformations (Teichgraber et al., 2002). In some cases, the problem can be corrected with repositioning the infant during sleep, so that the head does not rest on the flattened portion of the skull. Increased tummy time, in which the infant is placed prone under parental supervision, also alleviates pressure on the occipital region, and encourages head raising, thus strengthening the neck muscles. If a torticollis is involved, physical therapy is required to stretch the infant's muscles in order to reposition the head. Time spent in car seats, carriers or swings should be limited.

Simple countermeasures are not always successful in skull reshaping, and in these cases a molding helmet such as Dynamic Orthotic Cranioplasty (DOC) is used (Fig. 1C). The custom molded DOC helmet consists of a semi-rigid styrene shell and inner polyurethane liner, and relieves pressure on the flattened part of the skull allowing growth in that region. Parts of the skull that developed bossing or bulging are constrained by the helmet, and growth in those areas thus restricted. DOC helmet treatment has disadvantages; the helmet must be worn 23 hrs/day,requires weekly monitoring/adjustment, and is costly. Sometimes, the helmet does not correct the deformation, and surgery is required.

A study of 125 patients treated with DOC helmet therapy (Cranial Technologies, Inc., Tempe, AZ) at the UT School of Medicine found that asymmetries of the cranial vault (CV) and the cranial base (CB) were significantly reduced (41.6% and 40.2%) by treatment (Teichgraber et al., 2002). Orbitotragial (OT) asymmetry was improved by 18.7%. Recently, the question of retention of improvement was addressed by re-examining these children 5 years after their treatment.

MATERIALS AND METHODS

14 male and 14 female patients from the previous study were re-examined. 79% had right side flattening. Mean start age for treatment was 6.7 months, and mean treatment time was 6.2 months. 7.1% were born prematurely, 3.6% were from breech births, and 3.6% from multiple births. 7.1% had a torticollis. These percentages are similar to those in the general population. Skull measurements used anthropometric landmarks (Figure 2): frontozygomatic point (FZ)-suture of frontal and zygomatic bones, midpoint of outer edge of eye orbit; euryon (EU)-most lateral point on the side of the cranium-from EU to EU is the widest portion of the skull; exocanthion (EX)-where eyelids meet in outer corner of eye; tragus point (TR)-notch in ear cartilage in front of ear; inion point (IN)- the most prominent point on the external occipital protuberance in the median sagittal plane. CV asymmetry was the distance from left FZ point to right EU point minus the distance from the right FZ point to the left EU point. Orbitotragial depth asymmetry was the distance from right EX point to right TR point minus the left EX point to the left TR point. CB asymmetry was IN point to right TR minus IN to left TR. Asymmetries were compared to those immediately post treatment. Facial asymmetry and malocclusions were also tabulated.

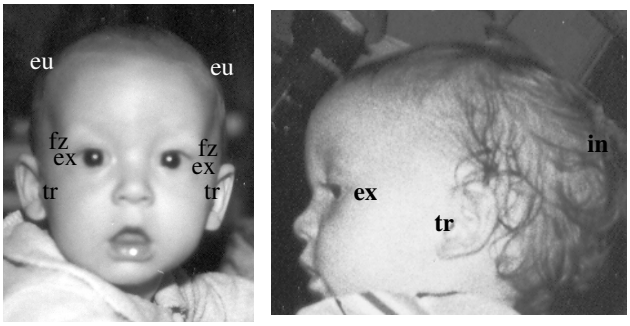


Figure 2: *Points for anthropometric measurements.*

RESULTS

Measurements of asymmetry immediately after treatment and 5 years later are shown in Table 1. Only the % change in CB asymmetry was significant.

Table 1: A*symmetry changes 5 years posttreatment.*

Measurement	Asymmetry (mm)		% Change
Cranial Vault	5.57	6.89	+23.7% (n.s.)
Orbitotragical Depth	2.89	2.25	-22.2% (n.s.)
Cranial Base	3.64	8.11	+122.5% (p< .004)

In terms of facial asymmetry, 19 of 28 (67.86%) had chin point deviation to the unaffected side. Deviation of the midline was observed in 67.86%, with upper and lower jaws not necessarily congruent. Posterior dental crossbites were noted in 17.89% of the sample. Molar relationships were examined in 17 patients, and the incidence of Class II (lower molar posterior to upper) and Class III (lower molar anterior to upper) relationships was greater than normal.

DISCUSSION

DOC helmet therapy effectively corrects cranial asymmetry, especially CV and CB, but after 5 years, significant relapse in CB occurs, and may include jaw asymmetries leading to misaligned teeth, TMJ problems, and esthetic concerns. Reasons for relapse are unknown, but likely involve skull growth patterns. CB asymmetry is based on IN, the middle of the back of the head, and improves with DOC helmet treatment because cranial flattening improves. The ear (TR) remains forward due to the rotated CB, the anterior portion of which continues growing, increasing the posttreatment asymmetry. Less than 5% of the general population has noticeable facial asymmetry.

Since CB asymmetry recurs, producing facial asymmetries and malocclusions, greater efforts at prevention of PDP are needed, including increased awareness on the part of pediatricians, family members and other caregivers. Parents must realize that the shape problem of their baby's skull may not resolve with time, and needs to be addressed with repositioning from an early age.

The AAP 1992 recommendations on sleep position allowed side sleeping, but in October, 2005, side sleeping was recommended against, a change that is likely to cause a further increase in PDP and makes the need for education even more urgent. The cure for PDP is prevention, and the key to prevention of PDP is education.

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