Positional plagiocephaly is defined as the product of dynamic distortion of the infantile cranium secondary to the application of pre- and post-natal forces. Most commonly, this abnormal head shape can be attributed to deformation that occurred in the womb, secondary deformational forces caused by sleep and daytime supine positioning, premature birth, or prolonged positioning due to unilateral tightness or weakness of the sternocleidomastoid muscle. During the last 10 years there has been an increase in the number of referrals to craniofacial clinics and the number of infants diagnosed with positional (i.e., nonsynostotic) plagiocephaly. The practicing orthotist needs to understand the cause, natural progression, anatomic features, and developmental implications of positional plagiocephaly to provide a comprehensive and effective orthotic treatment program for young infants. (J Prosthet Orthot. 2003;15:37–45.)

KEY INDEXING TERMS: positional plagiocephaly, cranial remolding orthoses, cranial sutures, craniosynostosis, supine positioning, cranial anatomy, cranial deformation.

American Academy of Pediatrics and the initiation of the “Back to Sleep” program. By recommending back and side sleeping positions, as opposed to the traditional prone sleeping position, this program decreased the incidence of sudden infant death syndrome (SIDS) by almost 40%. This reduction in the SIDS rate has been reproduced worldwide in countries that began similar programs to encourage parents to place their infants on their backs to sleep, and it is expected that this recommendation will continue.

Nighttime positioning combined with the additional time infants spend supine during the day in infant carriers, car seats, strollers, and supine play positions, places today’s infants at a greater risk for the development of positional plagiocephaly. In a study of more than 7600 infants under 6-months-old in the Netherlands who were seen for scheduled postnatal visits, 8.2% of the children presented with either asymmetric flattening of the occiput or the forehead. In a follow up study, 50% of these infants continued to demonstrate reduced neck range of motion and flattening of the skull at 2 and 3 years of age.

REVIEW OF CRANIAL ANATOMY

The functions of the skull include protection for the brain, eyes, and organs of hearing and balance. It also provides attachment points for the muscles that move the eyes, jaw, and head. The shape and structure of these bones are affected by genetic, metabolic, and mechanical factors because deformation or misalignment of one unit affects the alignment and shape of adjoining structures. Under normal circumstances, the growing brain determines the size and shape of the cranium and symmetrical growth can be expected.

The skull of the infant has nine bones of the neurocranium that include: two frontal bones, two parietal bones, one occipital bone, two temporal bones, and two sphenoid bones.
These free-floating bone structures are separated by fibrous sutures, allowing the head to distort in its passage through the birth canal and also accommodating the rapid brain growth that begins immediately after birth. Fontanelles (i.e., “soft spots”) are present at all angles of the parietal bones with the anterior and posterior fontanelles being the largest and most easily palpable on the young infant. Closure of the cranial sutures and fontanelles occurs at various times through infancy, childhood, and adulthood.

(Figure 2). The viscerocranium consists of 14 facial bones and it is important to note that the alignment and orientation of these structures are interdependent with the alignment and orientation of the neurocranium. For example, flattening of the right occipital area is commonly noted with positional plagiocephaly and leads to anterior displacement of the right ear; bossing of the right forehead; misalignment of eyes, cheeks, and jaw; and contralateral bossing of the left posterior occipital region. As Pruzansky states: “The skull is a community of bones...if one member of this community is affected adversely, inevitably other parts will suffer.” Eighty-five percent of postnatal skull growth occurs within the first year, creating the ideal window of opportunity for directed growth treatment procedures for the deformed skull.

Positional plagiocephaly results from three primary pro-
cesses: (1) abnormalities in brain shape—such as microcephaly and macrocephaly; (2) premature fusion of the suture(s)—such as craniosynostosis; or (3) prenatal or postnatal external constraint such as in-utero positioning, multiple births, early descent into the pelvis, congenital muscular torticollis, etc.

HISTORICAL OVERVIEW OF CRANIAL REMOLDING PROCEDURES

Intentional cranial deformation has been practiced for thousands of years with predictable results. Many cultures throughout the world understood the concept of directing neurocranial growth during the first year of life through the application of externally applied forces. Methods of cranial remolding included the application of wooden boards, tight wrapping of cloth or bark, and manual reshaping techniques. Based on these historical concepts of directing “normal” cranial development into deviated shapes and forms, the ability to direct deviated cranial shapes toward “normal” with the use of an external orthosis was developed.

Orthotic treatment for positional plagiocephaly was first introduced in 1979 (Figure 3) when Clarren et al. hypothesized that “...if the pressure of a rapidly growing brain against a flat surface would flatten the skull, then pressure against a concave surface would round it back again”. This concept of remodeling deviated head shapes was shown to be an effective, noninvasive treatment for young infants with positional plagiocephaly.

Clarren et al.’s study provided the groundwork for the development of many future design variations. Orthotic treatment programs have evolved during the last 23 years to address this growing patient population. Cranial remolding orthoses are now used as the primary treatment for positional plagiocephaly and as a post-surgical adjunct in the treatment of craniosynostosis. Intentional cranial remolding is defined as the product of dynamic control of the normal infantile cranial growth through the application of externally directed force(s).

ABNORMAL HEAD SHAPE

For the newborn, many factors affect the degree of cranial symmetry, including intrauterine compression forces (i.e., large or multiple fetuses) and extrauterine compression forces (i.e., prominent lumbar spine or small maternal pelvis). Breech presentations and prolonged vertex presentations create many different types of dysmorphology as various parts of the body are constrained within the maternal pelvis. The common vertex descent places the baby’s right occipital area in contact with the maternal ilium anteriorly and the left frontal area in contact with the maternal sacrum posteriorly (left occiput anterior [LOA] position). Because 85% of vertex presentations occur in this manner, this specific positioning pattern may account for the predominance of right occipital flattening in infants with positional plagiocephaly. It is important to note that positional plagiocephaly or cranial asymmetry is unique to each infant. While common head shapes can be identified, each infant’s head shape is the result of specific pre- and postnatal factors that influence cranial size, shape, and growth.

HEAD SHAPE TERMINOLOGY

There are several characteristic head shapes that can be classified according to a specific pattern of deformity. The literature is confusing in this regard, because the head shape terminology is used for infants with positional plagiocephaly, and for infants with the less prevalent condition of plagiocephaly with synostosis. Plastic surgeons often identify head shape as it relates to the area of frontal bossing while neurosurgeons have traditionally identified head shape based upon the posterior area of flattening. Non-synostotic plagiocephalic head shapes are identified or named similar to craniosynostotic head shapes, although the cranial sutures are unaffected. For example, a premature infant often presents with a scaphocephalic head shape but without synostotic closure of the sagittal suture. An infant with flattening of both the right and left occipital areas is identified with a brachycephalic head shape that can be the result of bilateral coronal or lambdoidal synostosis, or have all sutures open and patent. For the purposes of this discussion, the head shapes described relate to infants with nonsynostotic or positional plagiocephaly.

The general term positional plagiocephaly usually refers to a head shape that has unilateral occipital flattening, anterior progression of the ear on the same side as the flattening, and varying degrees of ipsilateral forehead bossing (Figure 4). In effect, the continuous pressure on one side of the cranium causes all the bones on the same side to progress forward—creating asymmetry and sometimes a realignment of the facial structures as well.

The term (positional) brachycephaly refers to a head shape that is short and wide. The back of the head is flattened, and the anterior-posterior (A-P) and medial-lateral (M-L) dimensions of the cranium (i.e., cephalic index) are distorted (Figure 5). Infants with this head shape often have a prominent or bossed forehead and increased height of the cranial vault in addition to the flattened occiput. While brachycephalic head shapes may not exhibit a great deal of asymmetry, the deformity in this head shape is related to disproportion of the cranial structures. Anthropometric data indicates that in most normal skulls, the cephalic index (or M-L to A-P ratio) is approximately 78%, but this percentage is much higher in brachycephalic head shapes.

An infant with scaphocephaly has a head shape that is long and narrow (Figure 6). Premature babies have softer skulls than full-term infants, and extended time in a side-lying position in neonatal intensive care units often exacerbates the head distortion. This prolonged positioning predisposes them to a head shape with a very low cephalic index in that M-L measurement is significantly less than the A-P measurement. In addition to their softer skulls, these infants are developmentally premature and do not develop head righting and
neck extension at the same time as full-term infants. The long and narrow head shape places neck muscles at a mechanical disadvantage, and the deformity tends to perpetuate itself. This head shape is also seen in full-term infants that present with breech positioning. The reduced space limits M-L growth of the cranium and results in a cephalic index that is much lower than the normal 78%.

CRANIOSYNOSTOSIS AND SURGICAL CONSIDERATIONS
The second most common group of infants with plagiocephaly is infants diagnosed with craniosynostosis presenting as early closure of one or more cranial sutures. The incidence of this deformity is 1 in 10,000 live births, and is roughly 0.2% as common as the incidence of positional plagiocephaly. Complex presentations of craniosynostosis involve early fusion of two or more cranial sutures.

In any case, infants with asymmetrical head shapes will undergo definitive diagnostic testing to identify the cause of the deformation. Craniosynostosis is often identified initially by physical examination and verified by x-ray, computed tomography (CT) scan, or magnetic resonance imaging (MRI). Infants with craniosynostosis are contraindicated for cranial remolding orthoses until the affected suture(s) have been surgically addressed. Several articles written by plastic surgeons and neurosurgeons provide more definitive ways to diagnose the two conditions, and inappropriate and unnecessary surgeries have since been avoided. Most surgical procedures for correction of craniosynostosis are performed between 3 and 9 months of age, and orthoses can be used postoperatively for protection of the surgical site and/or continued remodeling.

PATIENT EVALUATION PROCESS
It is difficult to assess and relate the complexity of cranial deformations simply by viewing single dimensional films. A thorough patient history and “hands on” clinical examination of the patient’s head, neck, and torso are required. Relevant information to be discussed with the infant’s caregiver(s) during the initial interview is listed in Table 1.
The infant’s head should be examined from all angles. Manual examination of the cranial sutures is performed, noting any areas of ridging and/or prominence of the cranial bones. Generally, craniosynostosis of the metopic and sagittal sutures presents with palpable ridges; however, the lambdoid or coronal sutures rarely present palpable ridges and are identified by other clinical features. Abnormal soft spots, ear orientation and alignment, facial alignment and symmetry, and head control and positioning should also be examined. Neck tightness or preferential posturing should be referred to physical therapy for further evaluation and stretching exercises.

At least five measurements are obtained to document the initial head shape and degree of asymmetry:\[19\],

1. Head circumference: Obtained at the equator, brow level, parallel to the floor.
2. Oblique transcranial (right): Diagonal distance from the right frontozygomatic arch to the contralateral parieto-occipital area. (Anatomical landmarks: right frontozygomaticus to contralateral euryon, fz right-eu left.)
3. Oblique transcranial (left): Diagonal distance from the left frontozygomatic arch to the contralateral parieto-occipital area. (Anatomical landmarks: left frontozygomaticus to contralateral euryon, fz left-eu right.)
4. Cranial width: At widest point, proximal to ears. (Anatomical landmarks: euryon to euryon, eu-eu.)
5. Cranial length: At widest point, mid-brow to occipital area. (Anatomical landmarks: glabella to opisthocranion, g-op.)

These measurements should be repeated at each visit to quantify structural alignment changes secondary to the directed translational movements of the cranial bones.

Five photographs are used to qualitatively document the beginning and end of treatment outcomes. Additional photographs are recommended throughout the course of the treatment program. The five views are:

1. Frontal view: Includes entire head, face, and proximal shoulder region.
2. Superior view: Includes top view of head with ears visible, if possible.
3. Posterior view: Includes entire back of head and proximal shoulder region.
4. Lateral view (right): Includes entire head, profile view.
5. Lateral view (left): Includes entire head, profile view.

A useful way to clinically document change is through the use of a flexible ruler. A 24-inch flexible ruler is placed around the infant’s skull at the equator. The midline of the nose, occiput, and ears are marked on the ruler with a grease pencil. The flexible ruler is laid on a piece of paper and the inside of the shape is traced to document the overall head shape and orientation of the nose, occiput, and ears. During each follow up visit, this tracing is taken at the same level, and over time, the tracing can be used to demonstrate change in the cranial growth pattern.

The information gathered during the initial patient evaluation is used to document and quantify asymmetrical head shapes. Many insurance companies are reluctant to cover cranial remolding orthoses without a letter of medical necessity and additional documentation. A detailed report should be forwarded to the referring physician, physical therapist, and third party payer. Photographs and tracings are often helpful additional information.

For more than 20 years, cranial facial specialists have attempted to find a way to differentiate infants with positional plagiocephaly on a scale of mild to severe.\[20,21\] Generally, there has been agreement that mild cases should be treated with aggressive repositioning techniques, therapy if indicated, and followed closely to detect any increase in the deformity. Infants with moderate to severe positional plagiocephaly after 3 months of age are referred for therapy if indicated and are generally managed with a cranial remolding orthosis. Given the difficulty of measuring infants and the disparity among techniques, developing a common assessment tool has been difficult.

The development of laser scanning technology in the last decade has raised interest in the use of this technology to quantify and document infant head shapes. A noninvasive...
A cast or three-dimensional image of the infant’s head is acquired. The model is modified to full or partial symmetry, depending upon the severity of the condition, design of the orthosis, and protocols of the treating orthotist. Mild and moderate asymmetries may be modified to full symmetry while severe deformations may require progressive adjustments to the inner surface of the orthosis to obtain full symmetry throughout the course of the treatment program. Orthotic designs including chinstraps are likely to be less intimate at the initial fitting, allowing for normal growth to follow the internal contours of the orthosis. To date, there is no evidence that any one orthotic design provides better outcomes than another. Symmetrical growth is achieved by consistent evaluation and adjustments to the orthosis based upon the child’s head shape and growth patterns.

Translational movements of the cranial bones are to be expected and frequent evaluation will ensure total contact over prominent areas and provide areas of relief over depressed areas. Circumferential growth is accommodated by the removal or recontouring of material and additional material may be strategically added to provide total contact and to stabilize the orthosis on the infant’s head. It is extremely important for the orthosis to be thoroughly cleaned each day to prevent bacterial build-up and problems with scalp rashes. Air holes are commonly added to help dissipate heat as well as to assist in the evaluation of the fit of the cranium to the inner surface of the orthosis.

Generally, infants between the ages of 4 and 6 months will require a 10- to 16-week treatment program to obtain desirable results. Follow up visits every 2 to 3 weeks ensure...
optimum fit of the orthosis and allow for greater control of directed growth. Older infants generally require a longer treatment program because cranial growth begins to slow toward the end of the first year. By the end of the second year, cranial growth is greatly reduced although benefits have been noted in young toddlers. Discontinuation of the orthotic treatment program occurs at the discretion of the medical team and the family when a desirable degree of symmetry or improvement is obtained.

CONTRAINDICATIONS
There are important contraindications for the use of cranial remolding orthoses. The first of these, craniosynostosis, is discussed above. Hydrocephalus is an increase in the cerebral spinal fluid in the brain, producing fluctuating volume of the head and increased intracranial pressure. Unless this pressure and fluid are controlled—most commonly with a shunt—an orthosis should not be used. If the hydrocephalus is controlled, a cranial remolding orthosis may be used with careful monitoring of the skin and shunt. The orthosis should not place any pressure on the shunt. Children less than 3 months of age with positional plagiocephaly should begin treatment with active repositioning, physical therapy, and stretching exercises if torticollis is present. Often, aggressive repositioning is successful in shifting the infant off the flattened areas, and the head begins to assume a more symmetric shape. Infants at this young age also lack the head control to manage the weight of the cranial orthosis. The brains and skulls of infants older than 24 months have finished growing and no longer have the pliability and plasticity necessary to create a change in shape. Cranial remolding orthoses are therefore contraindicated after 2 years of age.

TREATING TORTICOLLIS
It has been estimated that 80–85% of all infants with positional plagiocephaly present with some degree of torticollis caused by an asymmetrical tightness of the sternocleidomastoid muscle. Torticollis is the third most common musculoskeletal deviation in the newborn after dislocated hips and clubfeet. The overall management of positional plagiocephaly requires the coordinated treatment of torticollis to prevent the child from continuing to rest on the same area of posterior cranial flatness, and to develop bilateral head, neck, and trunk symmetry.

Treatment of torticollis is provided before, during, and after the orthotic treatment program. Young infants under 3 months of age receive passive stretch to the sternocleidomastoid, upper trapezius, and ipsilateral trunk muscles. Specific handling and positioning instructions are provided and supervised “tummy time” is used to provide active and passive stretch to the neck musculature. By the time the child reaches 4 to 6 months of age, it becomes difficult to maintain the desired repositioning because the infant develops greater strength and control. Stretch and massage to the affected muscle is provided and the cranial orthosis may be removed during these exercises. Therapy will continue to monitor the head righting response, encourage age-appropriate developmental exercises, and emphasize head and neck mobility, equal weight bearing, and midline activities. The child is monitored for symmetric development until unsupported walking is attained. Occasionally, a cervical orthosis may be needed to augment the orthotic treatment program.

Cervical orthoses block lateral flexion to the affected side and...
prevent the head from rotating to the opposite shoulder. Usually the orthosis is worn before orthotic treatment is initiated or whenever the cranial orthosis is not in place.

**LONG-TERM CONSEQUENCES OF POSITIONAL PLAGIOCEPHALY AND TORTICOLLIS**

There are documented long-term consequences of untreated torticollis with positional plagiocephaly. Strabismus and other ocular problems have been documented and are of varying severity depending on the extent of the asymmetry in head shape.\(^{25}\) Ocular and vestibular impairment may occur as the child tries to compensate for the head's abnormal orientation in space.\(^{26}\) Headaches and temporal mandibular joint (TMJ) dysfunction have been reported among older patients diagnosed with positional plagiocephaly. A study by Kane et al.\(^1\) found that infants with plagiocephaly without synostosis had mandibles that were asymmetrical beyond the normal range. Torticollis and plagiocephaly create upper body asymmetry that can prevent symmetrical neck extension and bilateral propping and rolling to the involved side. Later, the asymmetry can affect crawling, reaching, and sitting activities. Children with this type of asymmetry often exhibit muscle tone that closely parallels children with hemiplegia.\(^{27}\)

Two recent studies suggest that infants diagnosed with positional plagiocephaly may require more services in school than their matched siblings, and a higher percentage of these infants score below the mean on developmental tests.\(^{28,29}\)

Once the torticollis and positional plagiocephaly are resolved, the child's symmetrical positioning allows more normalized movement patterns.

**SUMMARY**

Cranial remolding techniques have been used for thousands of years to control and direct the pathway of skull growth. This process uses total contact over areas where growth is to be curbed, and allows space in areas where growth is to be encouraged to promote the desired head shape. In 1998, the Department of Health & Human Services Food and Drug Administration (FDA) classified cranial remolding orthoses as Class II medical devices requiring special clearance for the manufacturing process. The ability to manufacture cranial remolding orthoses requires testing of the product, annual registration, consistent designs and features, proof that the materials used do not create skin breakdown, good manufacturing practices, labeling information, and prohibitions against misbranding and adulteration. At this time, 17 groups have received clearance from the FDA to manufacture cranial remolding orthoses.

This is in sharp contrast to protective helmets that do not require special clearance from the FDA because they do not involve remolding of the cranium. Protective helmets do not require frequent follow up visits and are generally used for a short time postoperatively to protect the surgical site or long-term to protect the cranium from trauma. Conversely, an infant treated with a cranial remolding orthosis is seen on a regular basis—weekly for the first few weeks, and then bimonthly throughout the course of the treatment program. These regular visits ensure that the infant’s head has sufficient space for continued growth, and adjustments are made to ensure that the head is developing into a more symmetrical shape.

Unlike other areas of orthotics, where progress can be slow, cranial remolding orthoses for infants with positional plagiocephaly create positive outcomes within 2–4 months of treatment. The orthotist is able to use the rapid period of growth to create greater cranial, facial, and core symmetry and to enhance the infant’s ability to attain good visual tracking, overall skeletal alignment, and developmental skills. Early intervention and consistent follow up are the keys to providing effective orthotic care with measurable change.

**REFERENCES**


