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Effect of head orthoses on skull deformities in positional plagiocephaly: Evaluation of a 3-dimensional approach☆

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Purpose: The positional non-synostotic plagiocephaly represents a cranial asymmetry affecting all 3 dimensions. The aim of this study was to evaluate volumetric indices to assess the efficiency in improving non-synostotic cranial asymmetries in treatment with head orthoses.
Material and methods: A total of 96 infants were included in this observational retrospective study. The cohort was further divided into subgroups according to age of helmet supply (younger/older than 7.5 months) and duration of therapy (less/more than 150 days). With 3-dimensional photogrammetry data sets, the skull volume was separated into quadrants and set in relation to each other to create an Anterior Cranial Asymmetry Index (ACAI) and a Posterior Cranial Asymmetry Index (PCAI) as 3-dimensional parameters.
Results: Treatment with head orthoses led to a significant reduction of ACAI ($p < 0.0001$) and PCAI ($p = 0.001$). Cranial asymmetry was more severe in the occipital region and significantly improved mainly during the first 75 days with a 40.08% decrease of PCAI value in the short-term therapy in the younger treatment subgroup ($p = 0.003$).
Conclusions: The introduced parameters sufficiently reproduce the improvement of asymmetry during helmet therapy, following the trend of already established parameters. Asymmetry was significantly improved in the occiput region, and helmet therapy was highly effective in younger infants and in the early treatment period.

1. Introduction

Positional plagiocephaly is a 3-dimensional cranial asymmetry that has been linked to infant positioning. The American Academy of Pediatrics (AAP) issued a recommendation in 1992 suggesting that infants should sleep on their back to prevent sudden infant death syndrome. In the aftermath, the incidence of positional plagiocephaly rose from 1 in 300 to 1 in 60 infants (Graham et al., 2005). According to recent data from Collett et al., even 1 in 5 infants show signs of positional plagiocephaly (Collett, 2014). Positional plagiocephaly is classified into lateral plagiocephaly that is marked by unilateral flattening of the occiput, a brachycephaly that exhibits a central flattening of the occiput, and a hybrid type that shows features of both (Argenta et al., 2004).

The diagnosis of positional plagiocephaly is usually established between the 4th and 8th week of life. The various treatment options are chosen depending on the individual dysfunction and the risk factors of the infant (Mulliken et al., 1999; Loveday and de Chalain, 2001; Persing et al., 2003; Willenborg, 2011; Steinberg et al., 2015). Methods of treatments actually comprise positioning techniques, physical and manual therapy (e.g. chirotherapy, atlas therapy, osteopathy). If these techniques fail to take effect up to the 6th month, children with persistent cranial asymmetry are recommended for wearing head orthoses (Dörhage, 2010). It has already been shown in the past that head orthoses are able to sufficiently improve cranial asymmetries in children when compared to those who did not undergo helmet therapy (Kim et al., 2013; Kluba et al.,

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2014a). In approximately one-fourth of all cases, complications such as slight bruising, erythema or other skin infection might occur, which are well treatable or do not require any treatment due to self-limitation (Wilbrand et al., 2012c). In most cases, an interdisciplinary approach is obligatory (Kluba et al., 2014b).

In order to objectify the extent of cranial asymmetry, a multitude of indices have been established in the past. All of them rely on the mathematical relationship of defined distances on the skull's axial cross-section, such as the Cranial Vault Asymmetry Index (CVAI), Cranial Index (CI), and Ear-Shift. Although the asymmetry of the skull affects 3 dimensions, all established indices are calculated in regard to a more or less arbitrarily determined and often difficult-to-reproduce 2-dimensional area.

The aim of this retrospective study was to evaluate two 3-dimensional parameters in positional plagiocephaly, considering that during therapy for cranial asymmetry the volume of the skull changes in the process of harmonization. Other influence factors such as patient age at the start of therapy and the duration of therapy should also be considered.

2. Material and methods

2.1. Patients and procedures

From 2009 to 2014, a total of 96 patients were able to be recruited in this retrospective observational study in the department of Oral and Maxillofacial Surgery at the Schleswig–Holstein University Hospital of Kiel.

Helmet therapy was initiated the earliest at the age of the 4th month and was ended not later than the 21st month in children with non-synostotic positional plagiocephaly.

In this cohort, 11 children were diagnosed with a unilateral plagiocephaly, whereas 85 children had a combined form of lateral and central plagiocephaly. Children with brachycephaly and synostotic plagiocephaly were excluded from this study.

All participants met all the criteria for therapy with head orthosis (Wilbrand et al., 2012a), and cases of medium (CVAI 7–12) to severe (CVAI >12) cranial asymmetries were included. Children younger than 7.5 months were included in the early-onset therapy group ($n = 48$), whereas children who were older than 7.5 months at the time of therapy initiation were in the late-onset therapy group ($n = 48$). The cohort was further subdivided according to duration of helmet therapy: short-term therapy was defined at a maximum of 150 days ($n = 46$) and long-term therapy at a maximum of 225 ($n = 50$) days of wearing a head orthosis. Patients with a short helmet therapy scheme were evaluated at the time of helmet provision (M1), after 75 days (M2), and at the end of helmet wear time (M3 = 150 days). An additional evaluation took place in long-term helmet therapy after 225 days (M4).

Helmets were purchased from Cranioform® (Cranioform AG, Alpnach, Switzerland) and were recommended to be worn for at least 23 h each day.

Skull asymmetry was assessed using 3-dimensional photogrammetry. The child was put on a seat surrounded by 20 cameras, creating a 3-dimensional data set, which then was processed with the software provided by the manufacturer (Cranioform® Analytics 3.0). All previously established 2-dimensional parameters and indices including head width and length, as well as transcranial diagonals A and B, Ear shift, Cranial Index, and the Cranial Vault Asymmetry Index were determined and illustrated by the software as previously published (Dorhage et al., 2016).

In order to assess the skull volume changes, the affected cranial area was defined as the cranial proportion above the axial plane formed by both the tragus and the subnasal. This volume was further separated into 4 quadrants, Q1 (anterior, left side) to Q4 (posterior, left side), according to a previously published definition (Meyer-Marcotty et al., 2014) (Fig. 1).

Based on these quadrants, the Anterior Cranial Asymmetry Index (ACAI) and the Posterior Cranial Asymmetry Index (PCAI) were established and calculated alongside the 2-dimensional parameters.

The 3-dimensional parameters display a relation of quadrant volumes in the anterior or posterior skull area in order to objectify the asymmetry and were defined as follows:

Anterior Cranial Asymmetry Index (ACAI)

$$\mathrm{ACAI} = \frac{\text{greater anterior quadrant} - \text{smaller anterior quadrant}}{\text{smaller anterior quadrant}} \times 100$$

Posterior Cranial Asymmetry Index (PCAI)

$$\mathrm{PCAI} = \frac{\text{greater posterior quadrant} - \text{smaller posterior quandrant}}{\text{smaller posterior quadrant}} \times 100$$

2.2. Statistical evaluation

The collected data were further evaluated with GraphPad Prism 6.0 (GraphPad Software, La Jolla, CA, USA). The data were aligned against the normal distribution by applying the Shapiro–Wilk test. Differences between groups were analyzed with analysis of variance (ANOVA) regarding the previously determined influence factors. p Values were further corrected after a post hoc Tukey test according to the Geisser-Greenhouse method. The level of significance was set at $p = 0.05$.

3. Results

3.1. ACAI

In all cases with lateral plagiocephaly and combined forms with brachycephaly and helmet therapy, ACAI values improved when comparing the first and the last assessments.

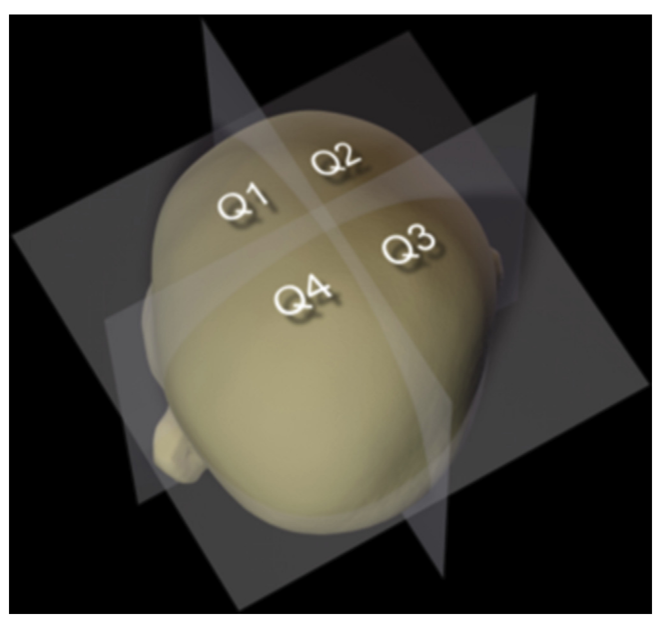

Fig. 1. Anterior Cranial Asymmetry Index (ACAI) and Posterior Cranial Asymmetry Index (PCAI) were calculated due to the definition of quadrants on the infant's skull.