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Outcome analysis after helmet therapy using 3D photogrammetry in patients with deformational plagiocephaly: The role of root mean square

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Summary Deformational plagiocephaly (DP) is a multifactorial non-synostotic cranial deformity with a reported incidence as high as 1 in 7 infants in North America. Treatment options have focused on non-operative interventions including head repositioning and the use of an orthotic helmet device. Previous studies have used linear and two dimensional outcome measures to assess changes in cranial symmetry after helmet therapy. Our objective was to demonstrate improvement in head shape after treatment with a cranial molding helmet by using Root Mean Square (RMS), a measure unique to 3D photogrammetry, which takes into account both changes in volume and shape over time. Three dimensional photographs were obtained before and after molding helmet treatment in 40 infants (4—10 months old) with deformational plagiocephaly. Anatomical reference planes and measurements were recorded using the 3dMD Vultus® analysis software. RMS was used to quantify symmetry by superimposing left and right quadrants and calculating the mean value of aggregate distances between surfaces. Over 95% of the patients demonstrated an improvement in symmetry with helmet therapy. Furthermore, when the sample of infants was divided into two treatment subgroups, a statistically significant correlation was found between the age at the beginning of treatment and the change in the RMS value. When helmet therapy was started before 7 months of age a

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greater improvement in symmetry was seen. This work represents application of the technique of RMS analysis to demonstrate the efficacy of treatment of deformational plagiocephaly with a cranial molding helmet.

Introduction

Deformational plagiocephaly (DP) is a non-synostotic cranial deformity described as flattening of an infant's head as a result of extrinsic factors such as intrauterine constraint, multiple births, preferential head positioning and congenital muscular torticollis. Since the advocacy of supine sleep positioning for infants to reduce the incidence of Sudden Infant Death Syndrome (SIDS), the incidence and prevalence of DP are on the rise: in 2003 Persing et al. reported that the prevalence of deformational plagiocephaly was in the range of 5%–48% of healthy newborns.[1] More recently in 2005 Losee et al. reported an incidence of 1 in 7, noting that the true incidence of DP at an early age is probably still underestimated.[2]

Treatment options for DP have focused on non-operative interventions including head repositioning and the use of an orthotic helmet device. Numerous non-randomized cohort and single group studies suggest a significant improvement in shape and symmetry with the use of an orthotic helmet device[3–5]; however, systematic reviews of the literature have shown many pitfalls in the methodology of these studies. Reviewed case series lacked a comparison group and comparative studies lacked randomization of participants to intervention groups. Considerable biases were also present. For example, outcome measures were neither standardized nor validated; conflicts of interest with orthotic companies were not disclosed, sample size was not justified, and substantial information was often not provided by the authors of these studies. Documentation of the effectiveness of treatment requires a durable, reproducible and rapid method to quantify head shape and asymmetry. To date, a reliable standardized outcome measurement for DP is lacking.[3,4,6,7]

Plagiocephalometry and spreading calipers use differences in linear measurements to provide documentation regarding changes in cranial shape but they are limited to the transverse plane and do not take into account asymmetry relative to circumference, volume or overall shape of the cranium. In order to overcome these limitations, measuring techniques have been developed that take into account the three dimensional nature of cranial deformities and the change in head shape over time. Recent technologies such as laser surface scanning and 3D photogrammetry have provided a potential solution to these difficulties. Digital data sets can be acquired rapidly and non-invasively, while simultaneously being archived for future analysis. Improvements in head shape after treatment with an orthotic device have been verified using a three dimensional non-invasive laser scanner[8–10] and 3D photogrammetry is capable of greater precision when compared with direct anthropometry.[11–14]

Our study aims to analyze the effect of helmet therapy with 3D photogrammetry by looking at changes in both volume and overall shape of the cranium over the duration of treatment. Root mean square (RMS) is a measurement unique to 3D photogrammetry, which takes into account both changes in volume and shape. It is the statistical measure of the magnitude of a varying quantity; the mean value of aggregate distances between surfaces (measured in millimeters). In our study, we used the root mean square value to quantify symmetry before and after helmet treatment in children with deformational plagiocephaly.

Materials and methods

In a retrospective analysis, 40 infants (23 males, 17 females) with DP referred to our institution were included in this study. Subjects were between four and 10 months of age at the time of referral. All patients in this study underwent treatment with an orthotic helmet device. Infants were classified into two groups: right posterior plagiocephaly and left posterior plagiocephaly. Patients with brachycephaly (posterior symmetrical flattening of the cranium and/or a cephalic index equal or greater than 95%) were excluded from the analysis.

The cranial molding orthosis used at the Hospital for Sick Children facilitates the development of normal cranial symmetry by inducing prominent areas of the skull to be retained passively while flattened areas grow into the hollow spaces of the device. The device is made of a hard outer shell with a foam lining. Each helmet is custom made based on anthropometric measurements and a plaster moulage of the infant's head. Adjustments to each cranial molding device were carried out based on established departmental guidelines, on a monthly basis, to maintain consistency in fit criteria.

All patients underwent 3D photography at the beginning and at the completion of molding helmet treatment. All images were captured between January 2010 and November 2011. A 3D photograph of each infant was acquired using a multicamera system (3dMD; Cranial System, Atlanta, GA). The full 360-degree 3D photograph was generated with the 3dMD system using a 5 pod, 20 camera configuration and a capture speed of 1.5 ms, which allows errors arising from the movement of infants to be avoided. All children were wearing a one-ply open face stockinet over their head to eliminate extraneous data. Markers were placed on the sellion and each tragion of the reconstructed image to define the anatomical reference planes, which were then used for quadrant placement and volume calculations. Standard anthropometric parameters for head length, width and head diagonals were collected, using the 3dMD Vultus® analysis software, according to landmark