Original Article

3-D analysis of facial asymmetry in children with hip dysplasia

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ABSTRACT

Objective: To determine whether facial asymmetry existed in patients with developmental dysplasia of the hip (DDH).

Materials and Methods: Subjects consisted of children between ages 5 and 10 years having DDH, and treated by the Von Rosen splint method. Three-dimensional (3-D) facial photographs were taken on all subjects using the 3dMDface system. Using RF6 PP2 software, anthropometric landmarks were plotted and used to calculate asymmetry based on 3-D coordinates in a reference framework.

Results: Of a total of 60 subjects with a mean age of 8 years (SD, 1.4 years), 30 had dysplasia of the left hip; 13, of the right; and 17 were bilateral. Twenty-seven subjects had upper face (UF) dominance values of 2 mm or more; of those, 26 were right-side dominant. Twenty-four subjects (40%) had a chin-point (CP) deviation of 2 mm or more; of those, 21 had right-side deviations. Statistically, UF and CP deviations were not significantly independent of each other ($P > .05$). Thirty percent of subjects had a posterior dental crossbite.

Conclusions: The results indicate that facial asymmetry exists in patients with DDH. (*Angle Orthod.* 2010;80:707–712.)

KEY WORDS: 3-D analysis; Facial asymmetry

INTRODUCTION

Developmental dysplasia of the hip (DDH), the etiology of which is multifactorial, is medically well known and usually diagnosed in infancy.[1] In the literature, there is very little regarding facial asymmetries in DDH children. It might seem reasonable to expect that craniofacial asymmetries would translate into concomitant dental asymmetries, and studies do exist showing statistically significant associations between facial and dental asymmetry,[2] suggesting an increased need for orthodontic therapy. Because some of these problems may require orthopedic correction during the growth period or surgical management later,[3] additional information on the development and detection of facial asymmetry is important in orthodontic treatment planning.

Measurement of facial asymmetry using three-dimensional (3-D) photography is a relatively new concept, with just a few studies exploring its capabilities[4–6] and no standard technique having yet been accepted. Past methods of study have included various 2-D photographs and radiographs. These records have proven useful but they are limited because of their 2-D representation of a 3-D structure. Three-dimensional photography seems to solve many of these dilemmas, as it is noninvasive and does not expose subjects to radiation. This technology allows accurate representation of facial soft tissue and morphologies,[7–9] and it can be used to compare[10,11] and predict orthodontic outcomes.[12–14]

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This study was designed to determine whether facial asymmetry exists in patients with DDH and to evaluate a method for the study of facial asymmetries and malocclusions in children born with DDH and treated with splint therapy.

MATERIALS AND METHODS

Subjects

The subjects recruited for this study had to meet the following inclusion criteria:

- Subjects were born during the years 1997–2001 in Northern Ostrobothnia.
- Hospital District of Oulu, Finland.
- Subjects had DDH.
- Subjects were treated by the Von Rosen method.

All children with previously diagnosed plagiocephaly or craniosynostosis were excluded from the study.

Imaging System

The imaging system used in this study was the portable 3dMDface System (3dMD, Atlanta, GA), an imaging system that combines stereophotogrammetry and structured light techniques.[12] This system uses a multicamera configuration, with three cameras on each side (one color and two infrared), that records high-quality, photo-realistic pictures. It is able to capture full facial images from ear to ear and under the chin in 1.5 milliseconds at the highest resolution. Manufacturer's stated accuracy is less than 0.5 mm, and the quoted clinical accuracy is 1.5% of total observed variance.[15] Three-dimensional surface images captured by surface acquisition systems are highly repeatable and precise.[16,17]

Images taken with the 3dMDface System were analyzed and viewed on a computer using the 3dMDpatient Software Platform.

Image Acquisition

Images were acquired with the subjects in their natural head position, which has proven to be clinically reliable.[18] The subjects sat on an adjustable chair with their face centered on a computer screen and were asked to keep the facial musculature as relaxed as possible.

Image Analysis

All images acquired were transferred to a reverse modeling software package, Rapidform 2006 Plus Pack 2 (RF6 PP2) (INUS Technology, Seoul, Korea) for analysis.[19] The software allows the surface data to be assessed as a collection of points interrelated by their positions along an x-, y-, and z-coordinate system. The 3-D evaluation methods described below were patterned after a recent study using the same software.[4]

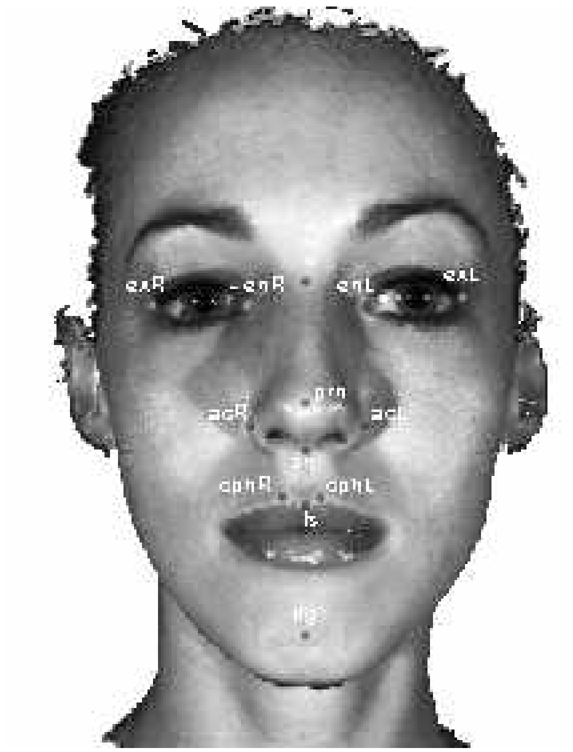

Figure 1. A sample illustrating the anthropometric landmarks used.

3-D Evaluation Methods

Each craniofacial image was oriented in the computer virtual space to have a natural head position before analysis. This was done by confirming the orientation of the interpupillary line to be parallel to the horizontal x-axis (from both a frontal and coronal view) and the orientation of the patient's line of sight parallel to horizontal (z-axis). Various anthropometric landmarks were chosen for analysis and were identified by marking them on the surface of the facial contour using the cursor. Anthropometric landmarks included five midline points (*n, prn, sn, ls, pg*) and four bilateral points (*ex, en, ac, cph*) (Figure 1 and Table 1).

Landmarks were chosen carefully so as to be easily identifiable and repeatable, and they appear as color points with reference coordinates. The surface shell was translated in the 3-D space so as to center soft tissue nasion (*n*) as point (0, 0, 0) in the x-, y-, z-coordinate system, Figure 2. The values of other points' coordinates therefore represent distances from *n* on the chosen axis in millimeters; their corresponding positive or negative value indicates directions (ie, positive x = left, positive y = up, positive z = anterior).

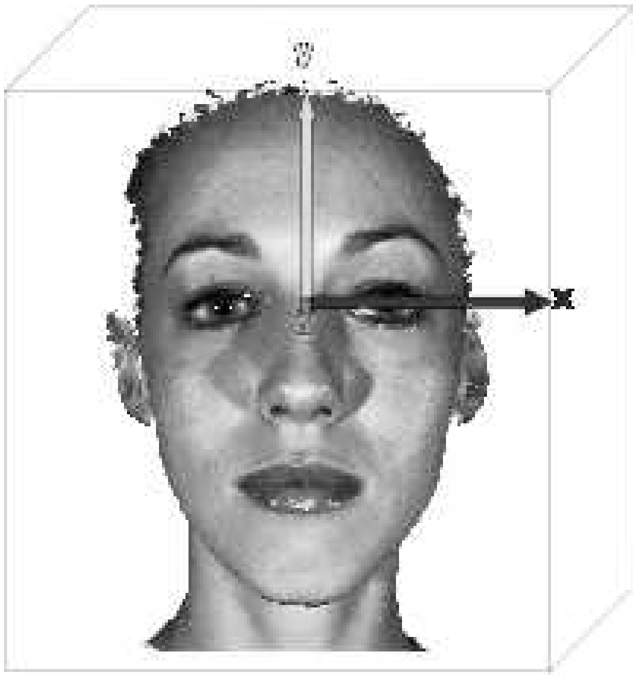

Figure 2. Illustration of the x-, y-, and z-coordinate system centered at landmark nasion. (z-axis is oriented perpendicular to the page).

Parameters Measured

The following three parameters were studied and evaluated:

UF dominance analysis

- All anthropometric landmarks except *pg* were considered in the upper two-thirds of the face (above the mandibular region) and were used to calculate the side of dominance of the upper face (UF). For these points, the more lateral (x-axis) the landmark, the more dominant is the landmark to that side of the face.
- For midline landmarks *(prn, sn, ls*), x-values were recorded, representing their deviation from the facial midline. By conventions set out in this study, a negative value for x represents a deviation toward the right side of the face. Theoretically, a perfectly symmetrical face would have an x-value of 0 for every midline point.
- For bilateral landmarks (*ex, en, ac, cph*), differences in the left and right x-values represent their degree of asymmetry in that plane of space. Theoretically, bilateral landmarks on a perfectly symmetrical face should have equal but opposite values for the x-coordinate (eg, right = −5 mm; left = +5 mm). Differences in corresponding x-values for bilateral landmarks were recorded. Negative values were assigned to all right-side dominant measures, and positive values for all left-side dominant measures.

Table 1. Definitions of Anthropometric Landmarks Used in This Study

Abbreviation	Landmark
N	nasion
En	endocanthion
Ex	exocanthion
T	tragus
Prn	pronasale
Ac	alar curvature
Sn	subnasale
Cph	crista philtri
Ls	labiale superius
Ch	cheilion
Pg	pogonion

- Finally, UF dominance was computed using these raw x-values for midline landmarks and differences in x-values for bilateral landmarks with the appropriate negative or positive sign assigned to correlate with the side of dominance. For each subject, x-values were summated and averaged to formulate a negative or positive value to represent a right or left dominance in the UF.

CP Deviation analysis. Chin deviation can be one of the most notable indicators of facial asymmetry, as laterality is most common on the lower one-third of the face.[20,21] CP deviation was measured by the x-value of landmark *pg,* which represents the deviation from the facial midline in millimeters. This was recorded for each subject, and a positive value represents a left deviation while a negative value represents a right deviation. Based on previous literature, a distance of less than 2 mm was considered to be within normal facial proportions of symmetry and therefore not significant.[21–23]

Dental occlusion analysis. Subjects underwent a clinical dental exam, which recorded the presence of posterior cross bites (left, right, or bilateral).

STATISTICAL ANALYSIS

Paired *t*-tests (SPSS 17.0, Chicago, Ill) were used to determine whether significant differences existed between UF and CP deviations in the x-direction of space by comparing UF and CP values in all subjects with

Pair 1: significant UF dominance values.
Pair 2: significant CP deviation values.

RESULTS

Subjects

A total of 60 out of 130 subjects voluntarily participated in the study. All were children between

Table 2. Results of the Side of DDH of Subjects Participating in the Study

	Subjects		
Side of DDH[a]	Male	Female	Total
Left	11	19	30
Right	2	11	13
Bilateral	7	10	17
Total	20	40	60

[a] DDH indicates developmental developmental dysplasia of the hip.

ages 5 and 10 years, and the average age of all subjects was 8 years (see Table 2 for breakdown). Ten measurements were randomly made on five subjects by two investigators to test inter- and intraobserver reliability. A *t*-test showed no statistically significant differences between operators.

Parameters Measured

UF dominance analysis. Using the average value from all UF landmarks, 27 subjects (45%) had a significant (2 mm or more) UF asymmetry in the x-dimension. Of these, 26 were right-side dominant and only 1 was left-side dominant (Table 3). Looking at the sample as a whole, the average UF dominance value was −1.5 mm, with a range from −4.6 mm to 9.7 mm. Without regard to right or left, by taking the absolute value of each number, the average asymmetry value for the UF was 1.8 mm.

CP deviation analysis. Regarding lower face asymmetry, 24 subjects (40%) had a CP deviation of 2 mm or more. Within this group, 21 had right-side chin deviations (87.5%) and 3 had left-side chin deviations (12.5%; Table 3). In all 60 subjects, the average chin deviation was −1.1 mm, ranging from −5.1 mm to 7.6 mm. Without regard to right or left, by taking the absolute value of each number, the average deviation of *pg* from the facial midline was 1.9 mm.

Dental occlusion analysis. Posterior dental cross bites were present in 18 of the 60 subjects (30%), with 7 being right, 5 left, and 6 bilateral (Table 3).

Statistical Analysis

Statistical analysis to determine whether significant differences existed between UF and CP deviations in the x-direction of space indicated that there were no statistically significant differences for UF vs CP (pair 1) and CP vs UF (pair 2) ($P > .05$). The results suggest that subjects in this study with a presenting asymmetry in either the UF or CP tended to be asymmetric on the same side in the corresponding parameter (Table 4).

Table 3. Results of the Three Parameters Measured

	Results of Parameters Measured		
	Significant (2 mm or more)		
Side	Upper Face Dominance	Chin-Point Deviation	Dental Cross Bite
Left	1	3	5
Right	26	21	7
Bilateral	n/a	n/a	6
Total	27	24	18

DISCUSSION

Until now, few studies have focused on analyzing facial asymmetries and malocclusions specifically within a population of DDH children. Vlimmeren,[24] in his review of diagnostic strategies for the evaluation of asymmetry in infants, stated that children with deformational plagiocephaly have an elevated risk of mandibular asymmetry, and cranial asymmetry was found in about 30% of infants with muscular torticollis. Studies exist showing statistically significant associations between facial and dental asymmetry.[2] Pirttiniemi et al.[22] found significant asymmetries of the facial skeleton and dental arches with muscular torticollis. The patients had a high prevalence of treated or diagnosed lateral malocclusions (50%) compared with the control group (12.5%), and they also had more dental arch asymmetry and midline deviation in the maxillary than in the mandibular arch.

In addition, a few reports in the literature link DDH to these asymmetric head and neck disorders. Watson studied the relation between the side of plagiocephaly, dislocation of hip, scoliosis, bat ears, and sternomastoid tumor.[25] Iwahara and Ikeda[26] reported that 14.8% of their patients with congenital muscular torticollis also had dysplasia of the hip, whereas Hummer and MacEwen observed 20%.[27] Cady[1] reiterated that the risk factors generally used for DDH are questionable physical exam, female sex, breech presentation, and positive family history, and added that there is some evidence that torticollis may be a risk factor as well.

Some studies even relate the side of the disorder (left or right) to the side of craniofacial asymmetry. For example, infants with posterior deformational plagiocephaly are characterized by having the ipsilateral ear and cheek anteriorly displaced, and mandibular asymmetry with deviation toward the unaffected side.[28,29] Kane et al.,[30] in a computer tomography study, reported a 3.8% larger hemimandibular volume, a 3.5% shorter ramal height, and a 3% longer mandibular body length on the ipsilateral side of the occipital flattening. Watson[25] related this to DDH, reporting that the flat temple in plagiocephaly and a unilateral congenitally dislocated hip tend to be on the same side.

Table 4. Results of Paired *t*-Test for Different Groupings[a]

		Paired Sample Test				
				95% Confidence Interval of the Difference		
		Mean	Std. Deviation	Lower	Upper	Sig. (2-tailed)
Pair 1	CP[b]1 - UF[c]1	0.08	1.18	−0.39	0.54	0.73
Pair 2	CP2 - UF2	−0.38	1.28	−0.92	0.17	0.17

[a] Pair 1 included the CP and UF values for all subjects with UF dominance values >2 mm (CP1−UF1). Pair 2 included the CP and UF values for all subjects with CP deviation values >2 mm (CP2−UF2).
[b] CP indicates chin point.
[c] UF indicates upper face.

The image analysis and 3-D evaluation methods used in this study mimicked techniques from a recently published report studying asymmetry using the RF6 software.[4] In addition, the use of anthropometric landmarks with the 3dMDface System have been proven valid and reliable.[31]

In our study, a careful inspection of the data found no strong relationship between the side of DDH compared with the side of UF dominance, the side of CP deviation, or the side of dental cross bite. Surprisingly, there was also no strong relationship between CP deviation and the presence of a posterior cross bite. Only 5 of the 24 significant CP deviations had concomitant posterior cross bites, which might influence the asymmetric mandibular position.

In this study, 45% of the study sample had significant (2+ mm) UF asymmetry; of those, 26 of 27 were right-side dominant. Additionally, 40% of the study sample had significant (2+ mm) CP deviations; of those, 21 of 24 were right-side deviations. Looking at the sample as a whole, both the average UF dominance (−1.5 mm) and the average CP deviation (−1.1 mm) were negative numbers. This reflects a majority of right-side facial tendencies in the study sample. The results also suggest that subjects in this study did not have upper or lower facial asymmetry independent from the other, as a presenting asymmetry in either the UF or CP tended to be asymmetric on the same side in the corresponding parameter.

According to a criterion used in previous studies, lateral deviation of 2 mm or more was employed as a critical value to separate asymmetry from symmetry.[31] Severt and Proffit[21] reported that, in patients showing dentofacial deformity including jaw deviation, laterality toward the left side was present in more than 85% of their sample. Our study of DDH children, however, showed quite the opposite, with 87.5% of the significant CP deviations being toward the right side. Perhaps this suggests something different occurring with subjects having DDH as compared with the general population.

Another interesting finding was the number of subjects with cross bites—30%. Two studies in 1990 and 2004[32,33] reported the incidence of cross bites in Finnish children to be 13% and 4%–10%, respectively. This information suggests a much higher prevalence of this malocclusion than that in the general population.

CONCLUSIONS

- The results indicate that facial asymmetry exists in patients with DDH.

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