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Research Paper
Imaging

Assessment of facial asymmetry before and after the surgical repair of cleft lip in unilateral cleft lip and palate cases

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Abstract. This study was performed to assess facial asymmetry in patients with unilateral cleft lip and palate (UCLP) before and after primary lip repair. Three-dimensional facial images of 30 UCLP cases (mean age 3.7 ± 0.8 months) captured 1–2 days before surgery and 4 months after surgery using stereophotogrammetry were analysed. A generic mesh – a mathematical facial mask consisting of thousands of points (vertices) – was conformed on the three-dimensional images. Average preoperative and postoperative conformed facial meshes were obtained and mirrored by reflecting on the lateral plane. Facial asymmetry was assessed by measuring the distances between the corresponding vertices of the superimposed facial meshes. Asymmetries were further examined in three directions: horizontal, vertical, and anteroposterior. Preoperatively, the philtrum and bridge of the nose were deviated towards the non-cleft side. The maximum vertical asymmetry was at the upper lip. The greatest anteroposterior asymmetry was at the alar base and in the paranasal area. The overall facial asymmetry improved markedly after surgery. Residual anteroposterior asymmetry was noted at the alar base, upper lip, and cheek on the cleft slide. In conclusion, dense correspondence analysis provided an insight into the anatomical reasons for the residual dysmorphology following the surgical repair of cleft lip for future surgical consideration.

Key words: 3D; cleft; face; analysis; image.

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Unilateral cleft lip and palate (UCLP) is the most common craniofacial deformity. Surgical repair of the lip and nose is usually performed in the early months of life. The ultimate goals of primary surgery are to improve facial aesthetics and function. However, facial appearance is not always completely restored, and residual facial asymmetry has been noted following the surgical repair of UCLP[1,2].

Objective assessment of the residual facial asymmetry is crucial to guide the

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primary surgical repair of cleft lip and palate. The vast majority of studies on cleft deformities have focused on the evaluation of postoperative asymmetry[3–8]; only a few studies have evaluated facial asymmetry before and after surgery[9–11]. In most of these studies, the analysis of facial morphology was based on a limited set of landmarks, which constrained the evaluation of the three-dimensional (3D) of the captured images.

One of the common methods for the evaluation of facial asymmetry is the mirror image technique in which the reflected 3D model of the face is superimposed on the original one. This allows a robust comparison between the right and left sides of the face. Facial asymmetry is then calculated by measuring the minimum linear distances between the surfaces of the original 3D model and its mirror image, and the disparities between the two images are usually displayed using a colour map. The main drawback of this method is that the distances between the nearest points of the two superimposed surfaces are measured irrespective of their anatomical correspondence, which underestimates the measurement of the asymmetry. Furthermore, the points of the superimposed surfaces may not be anatomically related, i.e., the pronasale of one 3D image may not be directly related to the pronasale of its mirror image.

The application of a facial surface mesh, consisting of thousands of mathematical points or 'vertices', provides a solution to this problem[12]. A generic mesh, which has a facial mask-like appearance, can be conformed to take the individual shapes of the 3D facial images, and dense correspondences can be established between the vertices of a group of facial Images[13]. The conformed mesh provides a comprehensive analysis of the spatial differences in facial morphology[14].

The assessment of facial asymmetry in UCLP cases before and after primary lip surgery using dense correspondence analysis has not been considered before. The aim of this study was to present a new approach to the evaluation of total and regional facial asymmetry in UCLP cases before and after primary lip repair.

Materials and methods

Ethical approval was obtained from the ethics and research and development committees. The sample consisted of the 3D facial images of 30 non-syndromic UCLP cases of Caucasian origin. For each infant, the 3D facial images were captured 1–2 days before primary surgery and about 4 months postoperatively, before any palatal surgery (Fig. 1). The mean age of the infants at the time of 3D facial image capture before surgery was 3.7 ± 0.8 months and after surgery was 8.4 ± 1.8 months.

All cases had undergone a modified Millard cheiloplasty and a McComb primary rhinoplasty, performed by the same surgeon. A professional photographer captured the images using the same imaging system 3dMDface System (3dMD Inc., Atlanta, GA, USA). This stereophotogrammetry system consists of two pods, each of which contains three stereo pairs of cameras that capture the face in 3D from ear to ear. The infants were seated on a raised infant seat, which was 1.5 metres away from the capture system. The images were captured while the infants were at rest and looking slightly above the midpoint of the camera pods for clear capturing of the nose. The capture time was 1.5 milliseconds; this short acquisition time was essential to avoid image distortion due to involuntary movement of the head during image capture. A 3D model of the face was constructed by processing the stereo pair of images using software designed for this purpose. The 3D facial model developed was saved in .obj file format.

Assessment of facial asymmetry

Facial asymmetry was analysed by the application of a generic mesh (Fig. 2a, b). This is a mathematical facial mask consisting of 7190 indexed points, or vertices. The vertices are mathematically represented and symmetrically distributed. The generic facial mesh was conformed to resemble the 3D characteristics of facial morphology (Fig. 2c–e). The conformation process allows the generic mesh to perfectly adapt or 'conform' to the 3D geometric morphology of the face, while maintaining the generic mathematical information through the indexed vertices, for analysis. Presurgical and post-surgical conformed meshes were created for each case. Procrustes analysis was applied to obtain an average preoperative mesh and an average postoperative mesh, which were used in the analysis. Procrustes analysis is mathematical translation, rotation, and superimposition of the images based on the correspondence between images. The av-

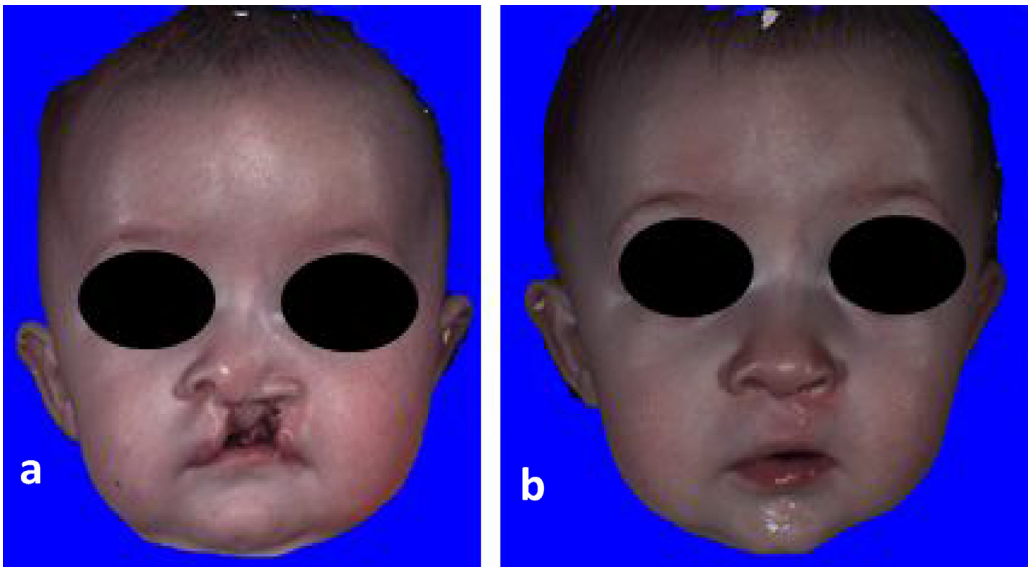

Fig. 1. 3D facial image of a cleft infant (a) before primary lip surgery, and (b) at 4 months after surgery.

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