DEVELOPMENT OF THE PALATE IN PATIENTS WITH COMPLETE UNILATERAL CLEFT LIP AND PALATE FOLLOWING CHEILOPLASTY WITH PRIMARY PERIOSTEOPLASTY: 3D GEOMETRIC MORPHOMETRIC STUDY

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Abstract
The aim: (1) to analyze the growth of cleft palate in patients with complete unilateral cleft of the lip and palate (cUCLP) after cheiloplasty with primary periosteoplasty, and (2) to compare the results with published data of younger cUCLP patients after neonatal cheiloplasty.
Materials and methods: The study deals with the longitudinal growth changes of the palate, including alveolar segments and its variability within the analysed group of 14 patients with cUCLP. Twenty eight dental plaster casts obtained from each patient in the two examinations (before cheiloplasty and before palatoplasty) were used for the analysis. The first dental plaster cast was taken from patients with an average age of 8.5 months, while the average age for second continuous casting was 4.5 years. Dental casts were scanned using a 3D laser scanner and then analysed, using methods of geometric morphometrics.
Results: Palatal morphology did not differ significantly between the sexes, but a statistically significant growth of palate was detected. A detailed colour-coded map identified the most marked growth at the anterior and posterior ends of both segments. Growth insufficiency of the smaller upper jaw segment after cheiloplasty with periosteoplasty was detected.
Conclusion: The reconstructed lip of both compared groups (neonatal and later cheiloplasty) exerts a natural formative effect on the actively growing anterior parts of split segments, which grow towards each other. But on top of that, neonatal cheiloplasty has many other benefits (wound healing, feeding facilitation, socialization), and so it is the most common surgical approach in the Czech Republic now.

Keywords: *orofacial cleft; cheiloplasty with periosteoplasty; neonatal lip suture; geometric morphometrics; growth of palate*

INTRODUCTION

Orofacial clefts not associated with a defined syndrome are among the most frequent congenital anomalies. Currently, the incidence of cleft defects in the Czech Republic is approximately 1.8 per 1000 live births (Peterka et al. 2000). This defect severely deforms the face aesthetically, significantly complicates food intake and breathing, and un-operated defects may negatively affect the development of speech. Intellect is mostly unaffected. Treatment begins early after birth, ends in adulthood and is multi-disciplinary. Treatment involves the co-operation of a team of specialists (plastic surgeon, neonatologist, phoniatrist, logopaedist, clinical psychologist, orthodontist, prosthetics specialist and maxillofacial surgeon). Cleft defects render socialisation of patients significantly more difficult. Patients are stigmatised by post-surgical scars and typical deformities of the face (Smahel et al. 1998), by less intelligible speech, and often by a certain degree of deafness (Borský et al. 2007).

Primary suture of the lip with or without periosteoplasty from the 3rd to 10th month is preferred by approx. 2/3 of the institutions dealing with cleft defects worldwide. Cheiloplasty can also be performed during the first week of life (neonatal cheiloplasty), and nowdays, it is the most common surgical approach in the Czech Republic. It was found that patients looked very well after surgery (nose and lip). The scars matured much more quickly than in children who were operated on according to the classical protocol (Živicová et al. 2017), and they were hardly visible after 8 months. Our preliminary results are very encouraging, and their evaluation shows that it will be probably necessary to conduct minor cosmetic corrections at a later age in approx. 25% of the patients who underwent this early surgery (Borský et al. 2012).

The question is whether classic operation protocol cheiloplasty results in a worse or the same outcome as the neonatal cheiloplasty. We evaluated the isolated influence of cheiloplasty with primary periosteoplasty on maxillary growth during preschool age. We compared maxillary morphology of the same UCLP patients before cheiloplasty (8.5 months) and before palatoplasty (4.5 years) using three dimensional methods of virtual anthropology.

The aim of our study was to evaluate the growth of maxillary segments in cUCLP patients (aged 0.75–4.5 years) after primary cheiloplasty with periosteoplasty, and to determine whether classic cheiloplasty has any negative effect on the growth of the maxilla during the observed period. We compared our morphometric data with published data on cUCLP patients operated upon using the neonatal cheiloplasty at a younger age (Hoffmannová et al. 2016).

MATERIALS AND METHODS

This study was based on geometric morphometric analysis of plaster models of the maxillary alveolar arch and palate of 14 patients with cUCLP (7 girls and 7 boys). Patients were of Czech origin and all surgery was performed at the Clinic of Plastic Surgery of the Faculty Hospital Královské Vinohrady, in Prague from 1971 to 1985 by the same method. Lip surgery was performed according to Tennison, with primary periosteoplasty at an average age of 8.5 months (range from 3 to 10 months). Palatoplasty by pushback with two flaps and pharyngeal flap surgery was performed at an average age of 4.5 years (range from 3.0 to 5.9). After surgery, the patients underwent long-term orthodontic treatment (Kuderová et al. 1996). Two plaster casts were taken of each patient, the first before cheiloplasty (T0) and the second before palatoplasty (T1).

The plaster casts were scanned using laser scanner Roland LPX-250 (Roland DG, Hamamatsu, Japan) with a lateral resolution of 200 µm. Rawscan data were processed using Pixform reverse engineering software (Roland DG). This procedure included cleaning, merging of multiple scans, hole-filling, removing unneeded parts, decimating and smoothing (Fig. 1). Our sample of UCLP patients comprised both left- and right-sided clefts. The scans of right-sided clefts were flipped horizontally and evaluated as left-sided clefts because the sample has to be homogenized for further 3D shape analysis.

Fig. 1. Data processing using Pixform reverse engineering software. The figures from the left show raw and processed dental models of a UCLP patient with and without clefted gap; first row patient in T0 (before cheiloplasty), second row the same patient in T1 (before palatoplasty).

Geometric morphometric analysis was performed using MorphoStudio v 3.0 and Morphome3cs v 2.0 software. At first, dense correspondence analysis (DCA) was used to convert the models to the same number of triangular faces (Hutton et al. 2001). In the first step, a set of hand-placed landmarks was situated on each evaluated palatal surface. Generalised Procrustes analysis (GPA) was used to register these landmarks. The transformations obtained from GPA on landmarks were then applied on the surface models, resulting in a rigid alignment of these meshes. The centroid size of each virtual model was recorded for future analysis (more details in Bejdová et al. 2012).

Palatal variability was analysed using principal component analysis (PCA). Above that this method was used to explore the mean morphological differences between palatal shape before cheiloplasty and palatal shape before palatoplasty. The shape variables reduced to the first two principal components were plotted in a scatter plot. The mean growth direction in the space of the first two principal components was calculated: where n is the number of specimen pairs and xi and yi are the principal component (PC) scores of the i-th individual after and before surgery, respectively (Hoffmannová et al. 2016). The colour coded maps were used to visualize the effect of first principal component (PC1) on growth of the palate. The parametric and permutation Hotteling *T*-square tests on the PCA scores were used to test the sexual dimorphism of investigated palatal surfaces. To assess the statistical significance of palatal growth changes, the paired Hotteling *T*-square test was performed on the PCA scores.

RESULTS

Principal component analysis (PCA) on the respective form variables was used to define palatal surface variability of patients with cUCLP. The broken-stick method indicated that the first 4 principal components (PCs) should be kept for statistical processing. Next, with parametric and permutation versions of Hotelling T2 tests on PC scores, we found that the palatal means did not differ significantly between sexes in T0 ($p = 0.28$) and also in T1 ($p = 0.72$) age categories. Further testing was focused on cleft age groups comparison. Paired Hotelling's T2 test detected statistically significant differences between T0 and T1 age categories ($p < 1.00e\text{-}04$).

Surface differences of the maxillary segments between the two age groups were visualised using the first two principal components – PC1 and PC2 (Fig. 2). Out of the total form variability, PC1 explained 51.09%, and PC2, 9.09%. Each specimen appears twice in the plot, at age T0 and at age T1. Projections of each specimen at T0 and T1 into the first two principal components were plotted in a scatterplot. Overall, the variation of maxillary form was slightly greater in the younger group (T0). The effect of PC1 and PC2 on the form of the maxillary segments was visualised using synthetic computed morphologic forms of the palate (Fig. 2, below the x-axis). Mostly size was manifested in PC1. An increase in PC1 score from negative to positive values translates into an enlargement of maxillary segments. The mean of the T1 group was shifted toward positive scores of PC1, which would indicate that the maxillary segments were larger and with a smaller anterior cleft gap in T1 than in T0. They are relatively longer, higher and more divergent in posterior area.

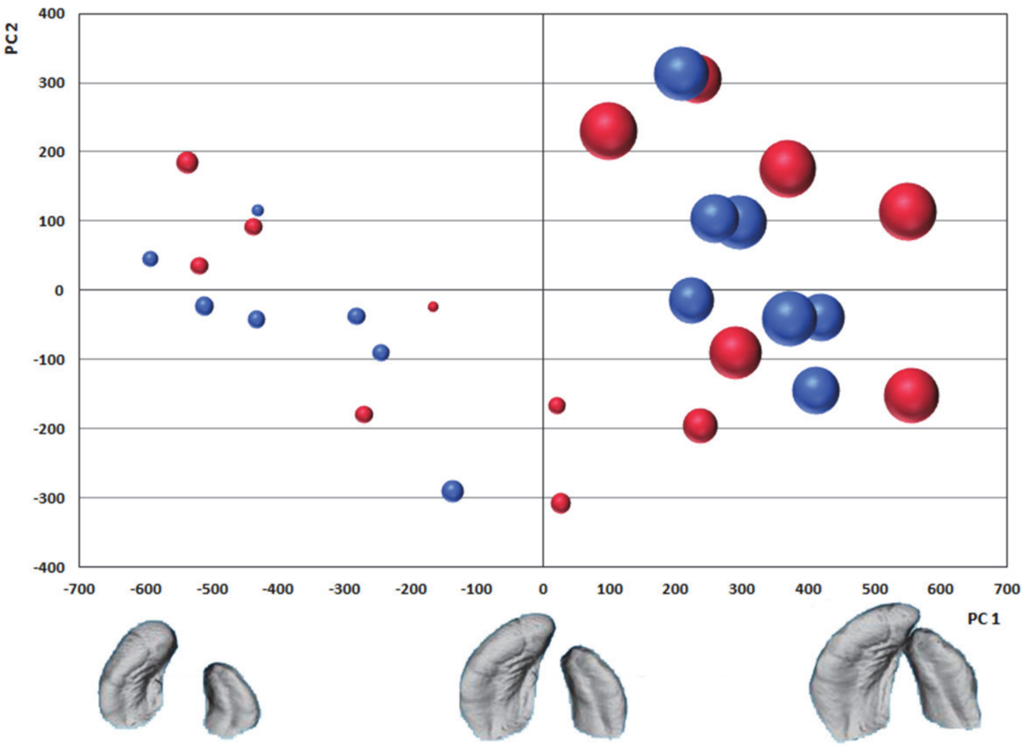

Fig. 2. PCA scatterplot of ULCP patients in time T0 and T1 together. The x-axis is the first component (PC1) and the y-axis is the second component (PC2). The size of bubbles represents the age of an individual patient; red bubbles are girls, blue bubbles are boys. Below the graph synthetic computed morphologic forms of the palate within PC1 were created. The pictures show palatal configurations from negative (left) to positive (right) values corresponding with PC1 palatal variability.

The growth of the maxillary segments in the cUCLP patients between cheiloplasty and palatoplasty (PC1) was visualized by a colour-coded map and was not uniform. Areas of the greatest growth were marked red (Fig. 3A). The results show a major growth pattern located at the anterior and posterior ends. Growth of the maxillary segments was generally more pronounced on the greater segment with premaxilla. Both separated segments were growing in size, prolonging and converging in the anterior ends of the segments. On the contrary, the posterior ends of both segments show divergence.

Fig. 3B shows the growth of maxillary segments between cheiloplasty and palatoplasty too, but in another sample of cUCLP patients operated on at a different age (neonatal cheiloplasty in first week of life) and using different surgical protocol (Hoffmannová et al. 2016). In comparison with our sample (Fig. 3A), the maxillary segments after neonatal surgery were growing in all directions (especially on the outer perimeter of the palate) and both segments with the same intensity. The anterior cleft width was reduced too.

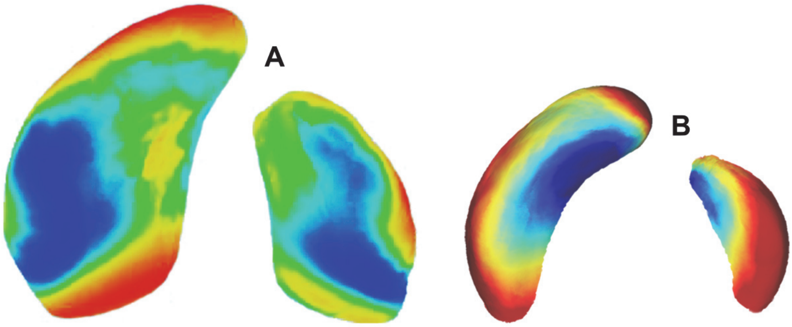

Fig. 3. Colour-coded maps visualise the effect of first principal component (PC1) which correspond with growth of the palate. Red and yellow areas increase outward with age, while blue areas increase inward (green areas remained unchanged). A – the growth of the maxillary segments after cheiloplasty with periosteoplasty (aged from 8.5 to 4.5 years); B – the growth of the maxillary segments after neonatal cheiloplasty (aged from 4 days to 10 months).

DISCUSSION

Cleft of the lip and palate may develop because of hypoplastic growth of the maxillary and palatal segments, failure of the palate to elevate above the tongue, excessively wide head and for other reasons. The aetiology of abnormal facial morphology in orofacial clefts may thus be multifactorial (Ross 1987). Hypoplasia could be the cause or the effect of other factors, and many authors confirmed that an intrinsic tissue deficiency in the palate/maxilla of unilateral complete cleft lip and palate patients exists (Ye et al. 2012, Cao et al. 2017).

Surgical therapy was supposed to have a crucial influence on the facial development of cleft patients. It is remarkable that transverse palatal collapse and anterior cross-bite are two major clinical problems. Lip surgery could have a similar restricting or even constricting effect on the growth of the palate (Kramer et al. 1992). Our group of cUCLP patients underwent lip surgery according to Tennison with primary periosteoplasty. Primary periosteoplasty at the time of lip repair was used to induce bone formation in the alveolar cleft, thereby obviating the need for later bone grafting (Jabbari et al. 2017). The main goal of our study was to evaluate their development of palate before palatoplasty.

The normal round palatal morphology at birth was changed in the third month of life thanks to the more intensive sagittal than transversal growth in this period. A similar increase was found also in cleft patients and was situated mainly in the posterior region of the palate (Kramer et al. 1992). Posterior growth of the palate was described also in the later period of preschool age (Honda et al. 1995). This finding is consistent with our results, but we also observed growth localized at the anterior ends of maxillary segments. This was in accordance with Huang et al. (2002) in patients operated upon at 3 months of age. The growth intensity in our sample was much less pronounced on the clefted side. A similar growth pattern was confirmed after neonatal cheiloplasty, but the growth intensity was higher and more symmetric in the first year of their life (Hoffmannová et al. 2016, 2018).

The anterior cleft gap was reduced during the investigated period between 0.75 and 4.5 years of life. This molding effect has been described many times before (e.g. Mazaheri et al. 1993) and its cause is that alveolar segments in some cases come into contact with each other. In our study we used geometric morphometry for studying palatal morphology directly from their geometric representation. These methods enable a better representation of shape than traditional linear measurements and allow the visualization of growth differences between two ages on the basis of colour coded maps (Hoffmannová et al. 2016).

We can conclude that the reconstructed lip of both compared groups (neonatal and later cheiloplasty) exerts a natural formative effect on the actively growing anterior parts of split segments, which grow towards each other. On the other hand, undeniable benefits of early neonatal cleft lip repair are very good wound healing (Živicová et al. 2017) and feeding facilitation (Weatherley-White et al. 1987, Cohen et al. 1992). Moreover, socialization of the children proceeded normally from the very beginning, as in the cases of those without a cleft. This is very important from the aspect of all – mother, child and their mutual and social relationships.

CONCLUSION

The aim of our study was (1) to analyze the growth of clefted palate in cUCLP patients (age interval 0.75–4.5 years) after cheiloplasty with primary periosteoplasty, and (2) to compare the results with published data of younger cUCLP patients after neonatal cheiloplasty.

1. Palatal morphology did not differ significantly between sexes in both of the evaluated ages (0.75 and 4.5 years), thus palatal growth in girls and boys was evaluated together.
2. Statistically significant differences between palatal morphology in both ages were detected, their inter-individual variability did not overlap.
3. The palates were growing especially at the anterior and posterior ends of both maxillary segments. The anterior cleft gap was reduced, the posterior ends of both segments showed slight divergence.
4. Growth insufficiency of the smaller upper jaw segment after cheiloplasty with periosteoplasty was detected.
5. The maxillary segments in the first year of life after neonatal surgery were growing in all directions, while clefted palate after cheiloplasty with periosteoplasty grew at the anterior and posterior ends of both segments. This can be caused by various factors, such as timing of cheiloplasty, futher therapy (periosteoplasty), different ages of the compared groups of patients.
6. Data of the compared group suggest that the neonatally reconstructed lip exerts a natural formative effect on the actively growing anterior parts of split segments, which grow towards each other.

CONFLICT OF INTERESTS

The authors have no conflict of interests to disclose.

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