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Innovative method to assess maxillary arch morphology in oral cleft: 3d-3d superimposition technique

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This study aimed to analyze the maxillary growth and development of children with oral clefts using the innovative method of 3D-3D superimposition technique. Children with unilateral complete cleft lip (UCL) and unilateral cleft lip and palate (UCLP) participated in the study. The impressions of the dental arches were executed 1 day before and 1 year after lip repair surgery. A 3D laser scanner digitized the dental models and the stereophotogrammetry system software analyzed the 3D-3D superimpositions in two groups of matches (same child, UCL and UCLP) and one group of mismatches (different individuals). The differences were evaluated by Root Mean Square (RMS) and expressed in millimeters (mm). Kruskal-Wallis test followed by post-hoc Dunn test and Mann-Whitney test were assessed to compare the groups (α=5%). RMS was 1.34 mm (± 0.37) in UCL group, 1.41 mm (± 0.32) in UCLP group, and 3.38 mm (± 1.28) in mismatches group. RMS was significantly greater in mismatches than in matches groups ($p<0.0001$). No statistically significant differences occurred between genders. The 3D-3D superimposition technique showed the maxillary development after lip repair surgery in the anterior region of the palate. Thus, it is suggested that the cleft amplitude and the palatal segments proportion influenced the morphological heterogeneity and, consequently, the development and maxillary growth of children with orofacial cleft.

Key Words: dental arch, cleft lip, cleft palate, imaging three-dimensional, innovation.

Introduction

Anthropologic analyzes of the dental arches are commonly performed by two-dimensional (2D) comparisons such as linear and angular parameters, silhouette, and surface (area) measurements. However, currently, devices are capable of scanning and virtually reconstructing the dental arches in three-dimensions (3D), taking the comparative analyzes of the anatomic structures to another level (1-8).

3D acquisition and reconstruction of the dental arches can be executed through optical equipment, such as either intraoral or fixe laser scanner. In newborn children with cleft lip and palate, the use of the intraoral scanner is difficult because the intraoral scanner point does not match the size of the mouth of these children; the scanner is unable to capture and process the light source projection in the cleft area; and involuntary or voluntary movements of the child make the scanning of the palate take longer. In these situations, the fixe laser scanner is the equipment of choice.

Thus, nowadays, it is possible to perform comparative analyzes by using 3D-3D superimposition through the use of devices capable of capturing and reconstructing the objects in three-dimensions. This has been largely used in forensic area for human identification (8, 9), but little in the human evolutive anthropometry (1). In evolutive anthropometry, 3D-3D superimposition may help to understanding the development of the dental arches with congenital alterations after a given treatment protocol. Notwithstanding, the literature lacks studies on the individuality of clefted dental arches through 3D-3D superimposition, by means of the quantitative and chromatic analyzes, at the first year of life. Thus, the aim of this study was analyzed the maxillary growth and development of children with oral clefts using the innovative method of 3D-3D superimposition technique.

Material and Methods

This study was submitted and approved by the Institutional Review Board under protocols number CAAE 77285417.0.3001.5441.

Healthy children with unilateral complete cleft lip (UCL) and unilateral cleft lip and palate (UCLP) enrolled in a craniofacial hospital (Hospital for Rehabilitation of Craniofacial Anomalies, University of São Paulo). All participants should be operated by the same plastic surgeon. Lip repair surgery (cheiloplasty) was carried out as to three months for all groups. Children with other congenital alterations, the rehabilitative treatment already initiated, and absent dental models were excluded from the study.

The sample size calculation was performed using a pilot study with Root Mean Square (RMS) standard deviation of 0.30 mm, with level of significance of 5%, test power of 80%, and a minimum clinically detectable difference of 0.28 mm. The minimum sample size of each group was calculated in 19 children.

The participants of the study were divided into three groups: UCL group – all children had unilateral complete cleft lip; UCLP group – all children had unilateral cleft lip and palate; mismatches group – children with unilateral cleft lip and palate. UCL and UCLP groups were denominated "matches groups", that is, the dental arch superimposition occurred for the same child. In the mismatches group, superimposition occurred between different children.

The impressions of the dental arches were executed before (T1 – presurgical) and after (T2 – postsurgical) cheiloplasty. The impression tray size was previously chosen according to the palatal dimension. To seal the vestibule bottom, wax was added to the tray. All children impressions were made with condensation silicon (Perfil, Vigodent S/A Indústria e Comércio, Rio de Janeiro, Brazil), mixed according to the manufacturer's instruction.

During the impression procedure, all children should be awakened and sitting on the mother/father's lap. The pediatric dentist was positioned behind the child's head. The pediatric dentist left hand was introduced on the child's mouth and with the aid of thumb the mouth was kept open. With the right hand, the pediatric dentist introduced the tray towards the palate, kept in position for a few seconds until the material's setting. After that, the tray was removed, the impression quality evaluated regarding the reliable copy of the palate, that is, from the anterior to the retromolar area of the cleft, and correct vestibule depth. In the laboratory, white orthodontic gypsum was casted (Pasom, Gold Star Brasil Ind. e Com., Mairiporã, Brazil). After the gypsum setting, the molds were cut with the aid of standardized templates (6, 7).

All dental casts were digitized through 3D laser scanner (3Shape's R700TM Scanner, Copenhagen K Denmark; Accuracy < 20 microns) connected to a computer. The scanner accuracy was tested by previous study (10). A non-destructive scanning lasts between 60 and 75 seconds. The dental cast was fixed onto a platform inside the device. During the scanning, the platform moved towards three mechanical axes (rotation of 360°, translation and inclination) so that the laser reached all the cast surface. Two cameras captured the reflected laser. The digitized dental model was obtained by the capture of the points of the dental cast surface by software (ScanItOrthodonticsTM, 3Shape A/S, Copenhagen K, Denmark). These points were automatically organized in triangle, forming a cloud of points. The digitized dental model was saved in Standard Triangle Language format (.STL) (6, 7, 10).

The analyzes of the 3D-3D superimposition were performed through stereophotogrammetry system software (Mirror imaging software, Canfield Scientific Inc., Fairfield, NJ, USA) into two phases. The first phase comprised the manual marking of the dental arches at T1 and T2 by contouring the vestibule bottom limited by the cleft and soft palate (11). Then, the automatic spatial alignment was performed between the dental molds to reach a better combination between their surfaces. This phase mathematically superimposes the smallest distance, point-by-point, between the molds. The software calculated the RMS related to the distance between the surfaces. Also, this procedure provided a chromatic map of the changes between the pre- and post-operative scanning (Figure 1). The green color indicates an unchanged area, while the colors blue, yellow, and red are discordant areas. The blue color indicates the positive difference, while the yellow and red colors, negative difference (8, 12, 13).

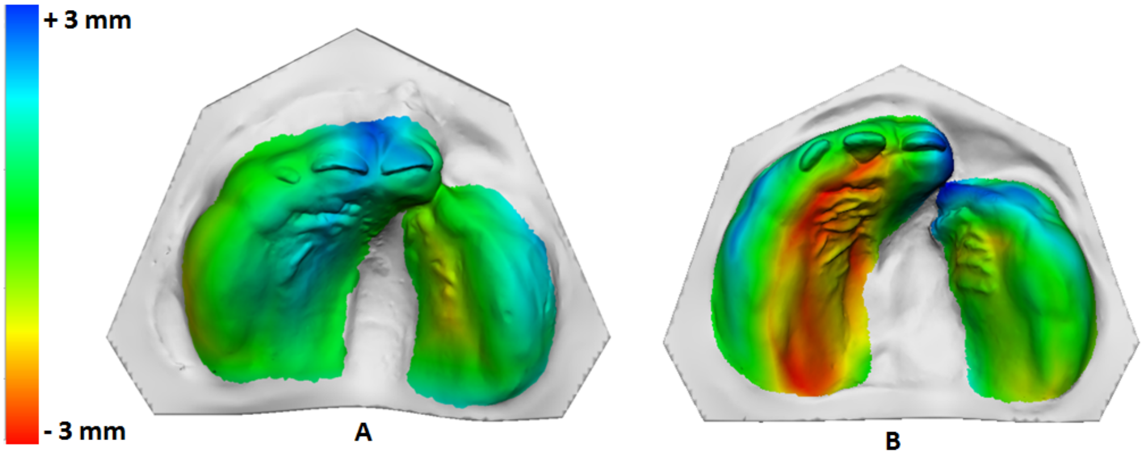

Figure 1 – Chromatic visualization of the superimpositions. A) Example of match. B) Example of mismatch.

The data were analyzed by GraphPad Prism software (Prism 5 for Windows - Version 5.0 – GraphPad software., Inc. San Diego, CA, USA). To test the normality, Shapiro-Wilk test was applied. Paired t test and Dahlberg formula evaluated the intraexaminer reliability, which was executed in 20 models, measured again after two weeks (1, 3). Kruskal-Wallis test followed by post-hoc Dunn test was applied to compare three groups independent sample groups, that is, UCL group, UCLP group and mismatches group. Mann-Whitney test was used to assess the differences between genders. The level of significance was α = 5%.

Results

The UCL group was composed by 21 children (10 boys and 11 girls), UCLP by 20 children (14 boys and 6 girls), and in the case of mismatches by 20 children (10 boys and 10 girls). At T1 and T2, children had 0.34 (± 0.07) and 1.28 (± 0.22) years-old, respectively. The intraexaminer reliability showed no statistically significant differences (p=0.874). Dahlberg formula indicated a random error of 0.020.

In UCL group, RMS was 1.34 mm (± 0.37), in UCLP it was 1.41 mm (± 0,32), and in the mismatches group it was 3.38 mm (± 1.28) (Figure 2). There were statistically significant differences between matches x mismatches (Kruskal-Wallis test followed by post-hoc Dunn test, p<0.0001).

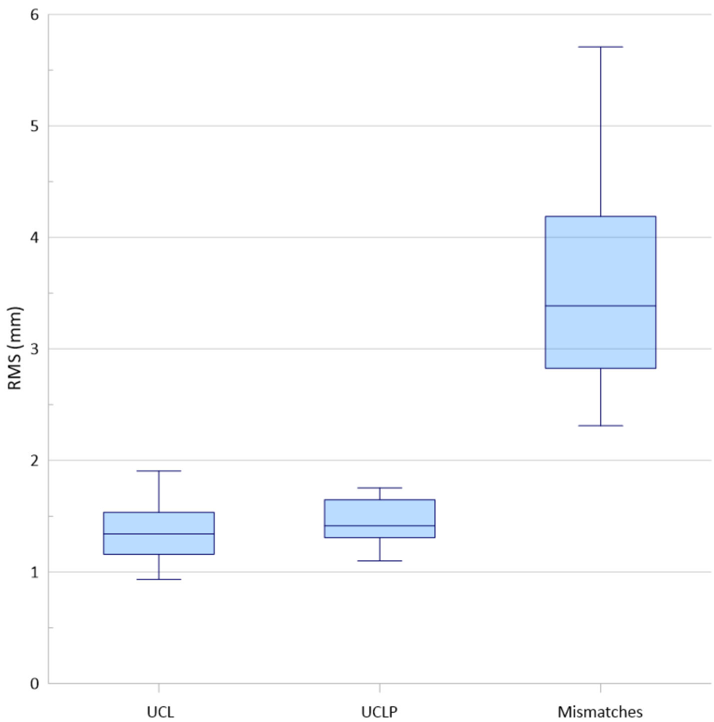

Figure 2 – Box plot of Root Mean Square (RMS) values of groups UCL, UCLP, and Mismatches.

In UCL group, boys had an RMS equal to 1.29 mm (± 0.31) and girls equal to 1.42 mm (± 0.44). In UCLP group, boys exhibited an RMS equal to 1.38 mm (± 0.42) and girls equal to 1.46 mm (± 0.24), while in the mismatches group, boys exhibited RMS equal to 3.41 mm (±1.12) and girls equal to 3.38 mm (± 1.55) (Figure 3). No statistically significant differences occurred between genders for each group (Mann-Whitney test, UCL p=0.860; UCLP p=0.536; mismatches p=0.970).

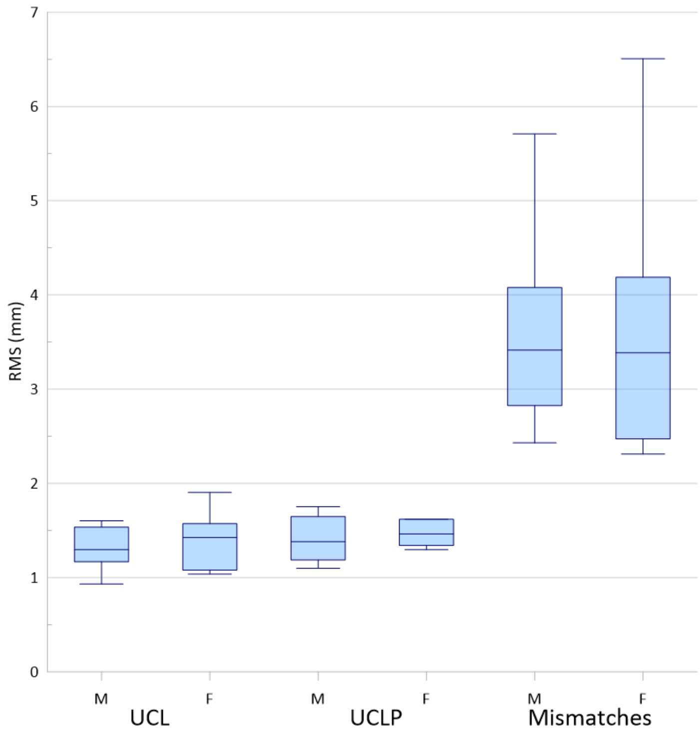

Figure 3 – Box plots of Root Mean Square (RMS) values between genders for each group: UCL, UCLP, and Mismatches (M: male; F: female).

Discussion

Commonly, dental arches of children with craniofacial anomalies are analyzed through digitized dental casts by transversal and longitudinal studies. The scientific articles have been applying similar methodologies to quantify linear measurements and palatal surface area with different purposes (1-7). The analyzes of the distance between the digitized palatal surfaces is a novel approach in Pediatric Dentistry for children with oral clefts. Thus, this is the first study to evaluate whether 3D-3D superimposition analyzed anthropometrically children with oral clefts the first years of life, before and after lip repair surgery.

The intergroup comparison revealed a significantly greater RMS value for the group of mismatches than for the groups of matches (UCL and UCLP). The results of this study suggested that the dental arch anatomy had little influence on the morphometric analyzes in case of matches. However, further studies are necessary to verify this assumption at other phases of the rehabilitative treatment in the same cleft phenotypes because the 2D analyzes of the linear measurements and palatal surface area showed different outcomes (2-4). Visually, the chromatic maps of UCL and UCLP groups indicates a positive growth (blue) as well as unchanged areas (green) of the dental arches in the anterior region of the alveolar edge, possibly related to the bone remodeling due to the eruption of the central incisors. However, in the mismatches group, the chromatic maps showed disagreement on the surfaces by colors blue, yellow, and red.

The intragroup comparison of the genders showed no statistically significant differences ($p<0.05$). The difference of the measurements between boys and girls has been discussed in the literature because studies on children with oral clefts indicate either significant differences (14) or similar results (15). The lack of literature consensus may be related with either the number of participants or the methodology used in the morphometric analyzes. Although this present study attempted to assure homogeneous groups concerning to gender, UCLP group had more boys than girls. This would be probably because UCLP affects more males than females, as described in other anthropometric studies (3-5, 11).

In craniofacial anomalies, 3D-3D superimposition is commonly applied to analyze the face regarding the influence of involuntary facial expressions (16), pre- and post-surgical asymmetry (17, 18) and growth (17, 19). Concerning the analyzes of the digitized models, some studies analyzed the chromatic map of the dental arches of children with oral clefts but not quantitatively described RMS (20-22).

We highlight that the smallest point-to-point distances between the superimposed molds showed negative and positive values and if only the arithmetic mean values are considered, the results would be the mean values of the distances. RMS is a more complete approach because it evaluates the mean square root of the point-to-point distances between the digital casts, that is, all values are positive (23). From that point of view, RMS calculation is an advantage of this present study because it proposes a novel analyzes for anthropometric studies of dental arches before and after surgery.

The clinical impact of RMS can be analyzed by two perspectives: biological and forensic anthropology of the dental arches. The biological analyzes of the RMS showed the three-dimensional growth of the palate of children submitted to cheiloplasty. Generally, the evolutive analyzes of the palate have been performed by 2D anthropometry, although the dental arches are anatomic structures with three-dimensions (height, depth, and width). The 2D analyzes may not provide the real palate growth. In this context, a positive RMS value greater than zero indicated 3D growth of the dental arches (1). Moreover, the statistical similarity between UCL and UCLP groups exhibited that 3D growth occurred in both groups comparably. According to previous studies, the 2D analyzes would show different outcomes (2-4).

In forensic anthropology, RMS quantitative values may contribute for human identification studies. The palatal superimposition of the same child (matches group - UCL and UCLP) revealed the smallest RMS values. The rationale behind this fact is the many coincident anatomic areas of the superimposition even when the scanning occurred at different time periods, but in the same child. On the other hand, the mismatches group showed RMS value 2.5 times greater than the other groups, because the anatomic discrepancy between different children. Although the superimposition of these individuals occurred using the same criteria (gender and cleft side), it is clear that each individual has intrinsic characteristics. Thus, the statistically significant differences among UCL group, UCLP group, and mismatches group indicated that RMS is a parameter that would help in forensic analyzes for "ante mortem" and "post mortem" recognition of people (8, 9, 12, 13).

The limitations of this present study include the absence of groups underwent active or passive pre-cheiloplasty orthopedics and pre- and post-palatoplasty comparisons. Thus, further studies are necessary considering other cleft types before and after bone graft surgery and the phases before and after orthodontic treatment to delineate better rehabilitative protocols.

The 3D-3D superimposition technique showed the maxillary development after lip repair surgery in the anterior region of the palate. In this study presented the existence of anatomical variability in the same phenotype. Thus, it is suggested that the cleft amplitude and the palatal segments proportion influenced the morphological heterogeneity and, consequently, the development and maxillary growth of children with orofacial cleft.

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Resumo

O objetivo deste estudo foi analisar o crescimento e desenvolvimento maxilar de crianças com fissuras orais por meio de um método inovador da técnica de sobreposição 3D-3D. Participaram do estudo crianças com fissura unilateral completa de lábio (FL) e fissura unilateral de lábio e palato (FLP). As moldagens dos arcos dentários foram realizadas 1 dia antes e 1 ano após o reparo cirúrgico labial. Um scanner a laser 3D digitalizou os modelos dentários e o software do sistema de estereofotogrametria analisou as sobreposições 3D-3D em dois grupos correspondentes (mesmo indivíduo, FL e FLP) e um grupo não-correspondente (indivíduos diferentes). As diferenças foram avaliadas pelo Root Mean Square (RMS) e expressas em milímetros (mm). O teste de Kruskal-Wallis seguido do teste post-hoc de Dunn e teste de MannWhitney foram avaliados para comparar os grupos (α=5%). RMS foi de 1.34 mm (± 0.37) no grupo FL, 1.41 mm (± 0.32) no grupo FLP e 3.38 mm (± 1.28) no grupo não-correspondente. RMS foi significativamente maior no grupo não-correspondente ($p < 0.0001$). Não houve diferenças estatisticamente significativas entre os gêneros. A técnica de sobreposição 3D-3D evidenciou o desenvolvimento da maxila após a cirurgia labial na região anterior do palato. Assim, sugere-se que a amplitude da fenda e a proporção dos segmentos palatinos influenciam na heterogeneidade morfológica e, consequentemente, no desenvolvimento e crescimento maxilar de crianças com fissura orofacial

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