Three Dimensional Assessment of Midface Asymmetry in Patients with Unilateral Cleft Lip and Palate Using Cone Beam Computed Tomography

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Abstract: Patients with unilateral clefts (UCLP) at the mixed dentition stage exhibit remarkable facial asymmetries that affect orthodontic and surgical decisions as well as treatment outcomes. Exact delineation of the extent and location of this asymmetry is critical for successful management. Cone beam computerized tomography (CBCT) offers detailed three dimensional (3D) assessment of the maxillofacial skeleton. However, a comprehensive 3D analysis of patients at the orthodontic age prior to alveolar cleft grafting has not been described using CBCT. The purpose of this prospective study was to analyze midface asymmetry in 3D planes of postero-anterior (PA) and axial views in patients with complete UCLP in mixed dentition stage, prior to orthodontic preparation for alveolar cleft grafting using CBCT. CBCT scans of 20 non-syndromic children (13 boys, 7 girls; mean age, 9.8 years $\pm$1.5 years) with repaired complete UCLP were collected. Specific landmarks applicable for PA and submentovertex radiography, as well as to conventional CT were selected to conduct 3D analysis of the midface. Numerous vertical, horizontal, transverse and sagittal measurements were made on PA and axial views respectively. Images were digitized on screen by the same investigator; points were set with respect to constructed reference lines. Obtained values were mainly compared using Paired t-test. Errors of the method and intra-observer reliability were measured. Obtained results revealed that there was significant intra-observer agreement denoting high reliability of measurements. In PA view; there were significant differences between nasal cavity, maxillary dento-alveolar vertical and horizontal measurements and molar point vertical measurments. In axial views; there were significant differences between pyriforme, maxilloalveolare and maxillary sinus total length sagittal measurements as well as difference in means of malare, pyriforme, maxilloalveolare and nasal chamber width transverse measurements. The ANS and nasal tip were shifted to the non-cleft side in 80% and 70% of cases respectively; the nasal septum was shifted towards the cleft side in 75% of cases. Within the limitations of this study it can be concluded that CBCT is an excellent method for 3D assessment of midfacial structures. Most asymmetries and deformities in the eight to 12-year-old patients with repaired complete UCLP were in the nasal chamber, maxillary dento-alveolar complex, maxillary sinus and malar prominence regions. Those results are of clinical importance to the maxillofacial surgeon and the orthodontist to develop a customized treatment plan for each patient in order to achieve successful outcomes.
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1. Introduction

Craniofacial morphology of children with cleft lip and palate (CLP) is different from that of normal children due to morphogenetic pattern and adaptive changes, **Bishara et al, (1985)**. Individuals with complete unilateral CLP (UCLP) show remarkable asymmetries of midface and lower facial structures that have been linked to suboptimal results of CLP therapy. For comprehensive management, it is vital to recognize the exact location, extent and severity of the related dental and midfacial deformities, Williams **et al, (2001)**.

Asymmetry of the nasomaxillary complex in UCLP has been studied utilizing conventional radiography including lateral, postero-anterior (PA) and submentovertex radiographs. Adults with UCLP showed significant differences in nasal cavity width and maxillary depth in comparison to patients with incomplete clefts, **Smahel and Berjcha, (1983)** as well as differences in maxillary dental arch, nasal septum and anterior nasal spine deviation, **Mølsted and Dahl, (1990)**; **Prusansky and Aduss, (1990)**, **Kyrkanides et al, (1996)**. Limitations associated with cephalometric radiographs render it difficult to reliably assess deeper craniofacial structures, **Ono et al, (1992); Yune, (1993)**.

Computerized tomography (CT) scans with three-dimensional (3D) reconstruction and cone beam CT (CBCT) are relatively recent diagnostic tools for the craniofacial region, **Lamichane et al, (2009)**. Findings and measurements obtained from CT are accurate, reproducible, offer greater and more reliable assessment of deeper anatomic structures than conventional radiography, **Kragskov et al, (1997)**. In axial CT, significant asymmetries in dentoalveolar and nasomaxillary complex were reported but none in deeper midface regions, **Suri et al, (2008)**. However, the routine use of CT in everyday clinical practice is limited by the greater radiation exposure, metallic artifacts and artifacts due to patient motion during scanning, **Li et al, (2011)**.

CBCT is currently considered a more comprehensive, cost effective method for diagnosis and treatment planning due precision, high resolution, true 3D images and a 1:1 perspective, relatively quick scans and low radiation exposure. Moreover, all necessary radiographs are collected in one scan which facilitates data acquisition, handling, storage and duplication. There has been a tendency to substitute traditional orthodontic and surgical planning imaging by 3D imaging using CBCT**, Sukovic, (2003).**

The maxillary complex was outlined through lateral views obtained from CBCT scans and compared to conventional lateral cephalograms and dental models, **Schneiderman et al, (2009)**. The individual measurements obtained from CBCT had a mean intra-rater reliability of 0.95, which offers the base for larger scale prospective studies to evaluate dimensional and positional data in patients with CLP utilizing CBCT.

Until now, there are only a few reports on the use of CBCT in subjects with CLP, **Miyamoto and Nakajima, (2010).** Moreover, a comprehensive analysis of patients at the orthodontic age prior to alveolar cleft grafting has not been described using CBCT. The purpose of this prospective study was to analyze midface asymmetry in 3D planes using PA and axial CBCT views in patients with UCLP in mixed dentition stage, comparing cleft to non-cleft sides, prior to orthodontic preparation for alveolar cleft grafting.

2. Materials and Methods:

This is a prospective study, including 20 children (13 boys and 7 girls) with UCLP (14 left and 6 right) in mixed dentition phase, ranging in age from 8 to 12 years (mean = 9.8 years $\pm$1.5 years). The patients were selected from the outpatient clinic of Orthodontic Department and Cleft-Care Clinic affiliated to the Oral and Maxillofacial Surgery Department, Faculty of Dentistry, Ain Shams University. Selection was determined according to the following inclusion criteria: 1. Non-syndromic complete unilateral cleft of the lip, alveolar process and secondary palate, 2. None of the patients had received presurgical maxillary orthopedics, tooth extraction and/or bone grafts, 3. None of the patients had previous orthodontic treatment, and 4. Medically free except for the CLP deformity.

CBCT scans were acquired for all of the patients as a routine assessment prior to orthodontic preparation for alveolar cleft grafting. All images were acquired using *i-CAT® scanner* (Model 17/19 series; *Imaging Sciences International, Hatfield, PA*). The Patient was positioned as described in i-CAT operations manual. Specifically, seated in erect posture with chin on chin support and guided to close in centric occlusion with lips in relaxed posture. To approximate the Frankfurt plane horizontal, the patient was asked to tilt his/her head such that the line from the center of the tragus to the bottom of the orbit was parallel to the floor. The vertical and horizontal laser-positioning guides were used to guide the proper orientation and position of each patient. A scout view was obtained at first and adjustments were made to ensure that the patient was correctly aligned before the final image acquisition. The scans were made at (18.54 mA), (120 KVp), with a single 360° rotation and a total scan time of (8.9 sec). Upon scan completion, the projection data were reconstructed with i-CAT software to create a data set with a voxel size of 0.125 mm in X, Y and Z directions as seen in the *Preview screen* shown in **figure 1**.

For each patient, data for assessment of asymmetry were acquired from CBCT scans for PA cephalometric and axial views analyses. The contralateral noncleft side measurements of each individual were considered as patients own internal control, **Grayson et al, (1983).** Measurements were as follows:

I. Postero-anterior view analysis:

MPR screen was used to synthesize the PA cephalograms from CBCT scans. *The Maximum intensity projections (MIP)* were used to optimally visualize anatomic details where, the 3D images are generated by projecting on the visualization plane the voxel with the highest intensity from the view point to the plane of projection. The synthesized cephalometric images were digitized on screen by the same investigator. The measurements of both the cleft side and the none-cleft side were measured directly using the software of the CBCT machine**, de Moraes, (2011).** Four bilateral landmarks were digitized on each PA radiograph. The landmarks as demonstrated by **Yen (1960); Subtenly, (1970)**; **Grummons et al, (1987)** were as follows **(figure 2A)**; skeletal points: latero-orbitale lo, lo' (lo for the cleft side and lo' for the noncleft side) and nasal point na, na' (na for the cleft side and na'for the noncleft side), dentoalveolar points: jugular point ju, ju' (ju for the cleft side and ju' for the noncleft side) and molar point mo, mo'(mo for the cleft side and mo' for the noncleft side).

The line connecting lo and lo' (LOL') was used as the reference line for vertical measurements. The reference line for transverse measurements (LOM) was drawn perpendicular to LOL' at the midpoint of lo and lo' **(figure 2B,C).** The following measurements were assessed on each PA cephalometric view **(figure 2B,C)**: Horizontal asymmetry: Measured as the perpendicular distances of na and na', ju and ju', mo and mo' from LOM respectively. Vertical asymmetry: Measured as the perpendicular distances of na and na', ju and ju', mo and mo' from LOL' respectively.

II. Axial views analysis:

MPR screen was used to synthesize the axial views from CBCT scans **(figure 3).** The method of analysis for assessing sagittal and transverse symmetry was developed by using concepts from cephalometric analysis with PA cephalograms, **Grummons et al, (1987)**, submentovetrex radiographs, **Forsberg, (1984),** multiplanar analysis, **Grayson et al, (1983)** and some points applicable for CT, **Schniderman et al, (2009).** Reference lines for transverse and antero-posterior analysis were based on cranial base landmarks. For transverse analysis, a cranial base midsagittal construct was drawn as the line of best fit, joining the bisectors of lines across plotted points representing the centroids of bilateral neurovascular foramina on the cranial base (foramina ovale, foramina spinosa), carotid canal, occipital condyles and lateral limits of foramen magnum, and unpaired central points which included median axis of spheno-occipital synchondrosis, basion and opsithion. For antero-posterior analysis, the inter-spinosal fit line was drawn perpendicular to the mid-sagittal construct, connecting or best fitting the two foramina spinosa **(figure 3A).**

Anatomic landmarks representing midfacial anatomy were selected and plotted by locating them on the series of different axial views for each subject. The following measurements were assessed in axial views; including *paired measurements* where sagittal measurements were recorded for the antero-posterior position of supraorbital margin, malare, pyriforme and maxilloalveolare on each side as related to the interspinosal fit reference line. The total length of the maxillary sinuses measured midway between the maximum and minimum extents; the maximum extent was measured on axial views just below the globe of the orbit, and the minimum just above the teeth. Transverse measurements were recorded for the mediolateral position of malare, zygion, pyriforme and maxilloalveolare on each side as related to the midsagittal construct. The total width of the maxillary sinuses measured midway between the maximum and minimum extents; the maximum extent was measured on axial views just below the globe of the orbit, and the minimum just above the teeth. The nasal chamber widths defined as the transverse dimensions of the right and left nasal chambers measured from the medial to lateral walls. **(figure 3 B-F).**

Moreover; *unpaired measurements* included the location of the anterior nasal spine (ANS) with respect to the midsagittal construct, shift of the nasal septum, recorded on the basis of the mean shift of the lower part of the nasal septum, and perpendicular plate of the ethmoid on either side of the midsagittal construct and shift of the nasal tip relative to the midsagittal construct **(figure 4).**

Statistical Analysis:

The collected data from various views were tabulated using Excel software program. Data were statistically analyzed utilizing a PASW Statistics 18.0® (Predictive Analytics SoftWare) for Windows. ® computer software program, IBM Company, Chicago, IL, USA. The following tests were carried out:

All measurements were repeated after one week by the same investigator for the PA and the axial views analyses by randomly selecting five images from each analysis to determine the error of the method using Dahlberg's method, **Houston, (1983).** Cronbach's alpha reliability coefficient; was used to measure intra-observer reliability (agreement). This normally ranges between 0 and 1. The closer Cronbach's alpha coefficient is to 1.0, the higher the reliability.

Descriptive statistics were calculated for each variable including; mean standard deviation, maximum and minimum values (range). Paired t-test was used to compare between cleft and non-cleft sides. Spearman's correlation coefficient was used to determine significant correlations between degrees of asymmetry. Qualitative data were presented as frequencies and percentages. Chi-square (x^2) test was used for studying the comparisons between different qualitative variables. The significance level was set at $P \leq 0.05$.

3. Results:

Measurement error and intra-observer reliability:

The error of the method for PA and axial views analyses is shown in table 1. The reliability analysis is presented in table 2, showing statistically significant intra-observer agreement regarding all measurements, denoting high reliability of measurements when repeated.

I. Postero-anterior view analysis:

As shown in table 3 and figure 5, there were statistically significant difference between nasal cavity, maxillary dento-alveolar and molar point vertical measurements. In the horizontal level there was statistically significant difference between mean nasal cavity and maxillary dento-alveolar measurements. There was a statistically significant positive (direct) correlation in horizontal asymmetry between nasal cavity and molar point as well as between maxillary dento-alveolar and molar point (Table 4).

II. Axial views analysis:

As shown in table 3 and figure 6, there were statistically significant differences between values of pyriforme, maxilloalveolare and maxillary sinus total length sagittal measurements. Assessment of transverse asymmetry showed statistically significantly lower means of malare, pyriforme, maxilloalveolare and nasal chamber width measurements.

The mean and standard deviation values of ANS were 2.9 ± 1 with a minimum of 1.3 and a maximum of 4.8. The majority of cases; 80% and 70% had shift of ANS and nasal tip to the non-cleft side respectively, while 75% had shift of nasal septum to the cleft side. Results of qualitative assessment of unpaired measurements are shown in figure 7.

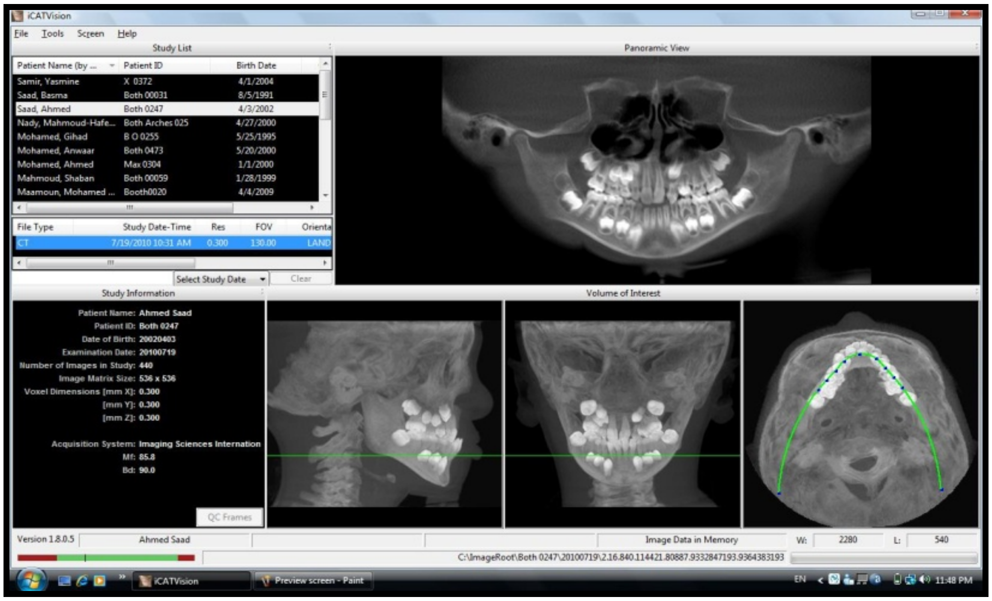

Figure (1): Preview screen of CBCT scan

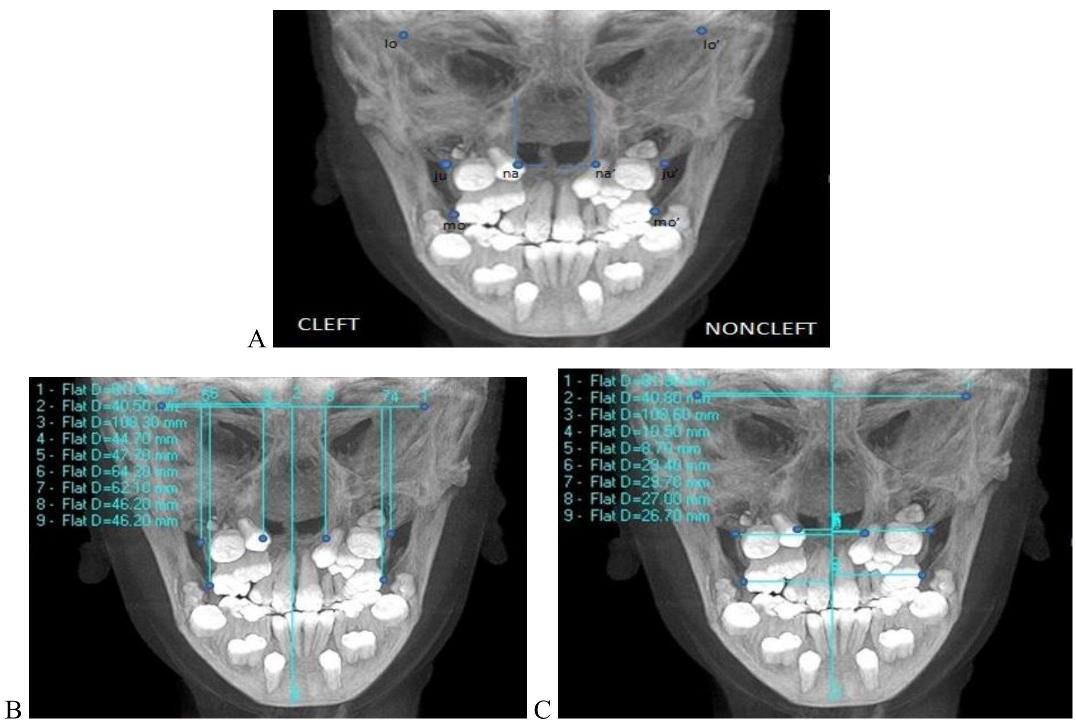

Figure (2): A: Digitization of landmarks in synthesized PA view in MIP screen, B,C: Landmarks, Reference lines and measurements used in PA analysis for assessment of B: vertical and C: horizontal asymmetry

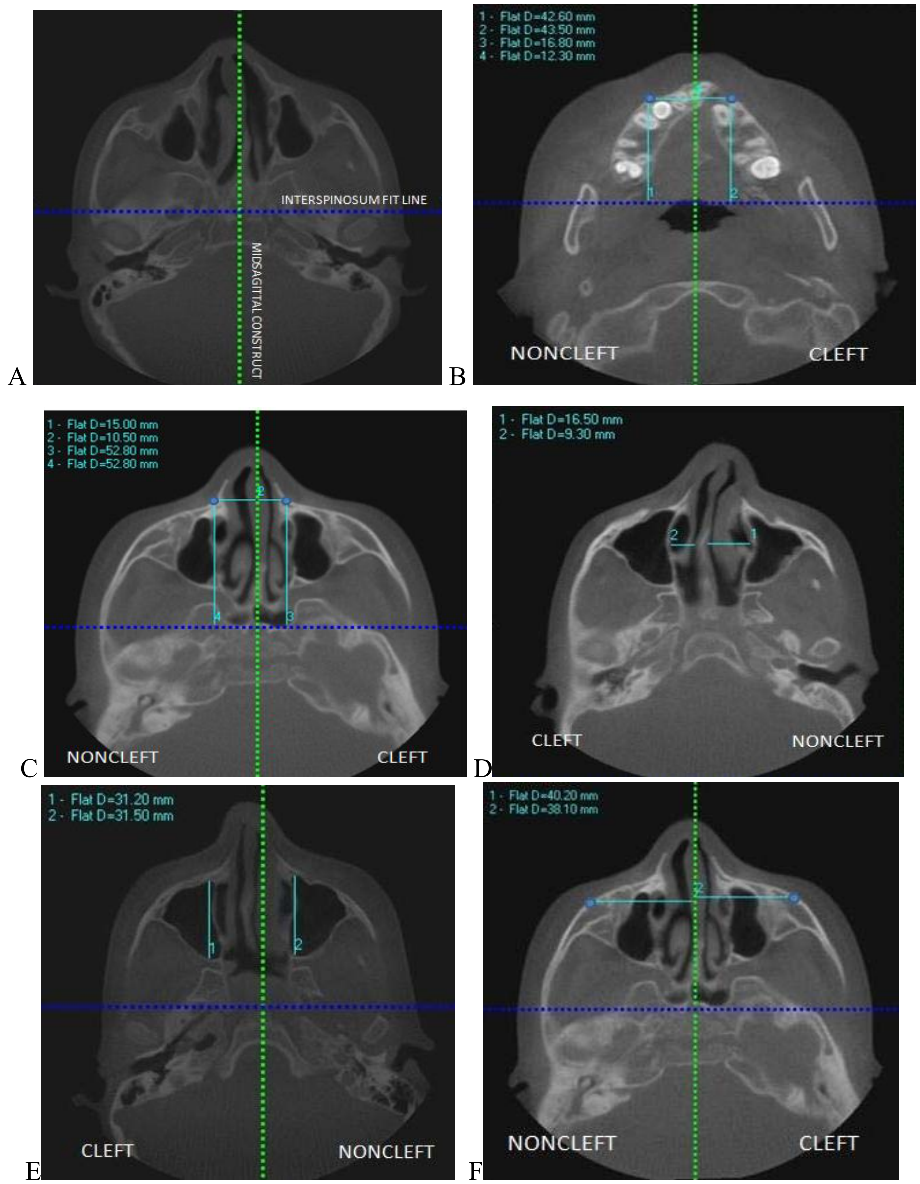

Figure (3): Synthesized axial views in different levels showing A: interspinosum fit line and midsagittal construct reference lines used in assessment of sagittal and transverse asymmetry, B-F; assessment of a sample of paired measurements in different levels, B: assessment of sagittal and transverse asymmetry of maxilloalveolare, C: sagittal and transverse asymmetry of pyriforme, D: transverse nasal chamber width E: sagittal asymmetry of total maxillary sinus length, and F: transverse asymmetry of malare

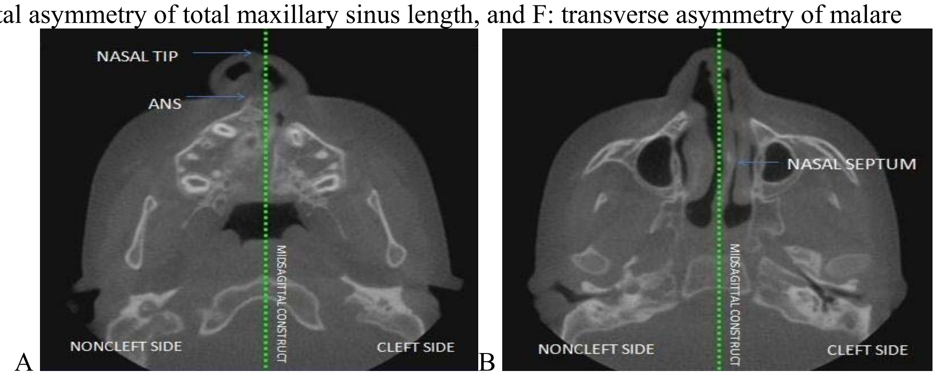

Figure (4): Synthesized axial views showing unpaired measurements with respect to midsagittal construct A: ANS and nasal tip shift, B: nasal septum shift

Table (1): Results of measurement error for PA and axial measurements by Dahlberg's method (n=5)

View	Measurement		Cleft side	Non-Cleft side
PA	Horizontal asymmetry	Nasal cavity	0.19	0.22
		Maxillary dento-alveolar	0.22	0.10
		Molar point	0.01	0.11
	Vertical asymmetry	Nasal cavity	0.46	0.34
		Maxillary dento-alveolar	0.12	0.18
		Molar point	0.11	0.07
Axial	Sagittal asymmetry	Supraorbital margin	1.59	1.67
		Malare	4.06	3.98
		Pyriforme	0.49	0.82
		Maxilloalveolare	2.37	3.76
		Maxillary sinus total length	1.06	0.71
	Transverse asymmetry	Malare	6.27	6.33
		Pyriforme	0.59	0.49
		Maxilloalveolare	0.35	0.24
		Maxillary sinus total width	2.12	2.08
		Nasal chamber width	0.04	0.04
		ANS	0.06	

Table (2): Results of reliability coefficient for PA and axial measurements

View	Measurements		Cronbach's alpha value	
			Cleft side	Non-Cleft side
PA	Horizontal asymmetry	Nasal cavity	0.950*	0.948*
		Maxillary dento-alveolar	0.931*	0.991*
		Molar point	0.999*	0.990*
	Vertical asymmetry	Nasal cavity	0.901*	0.928*
		Maxillary dento-alveolar	0.988*	0.989*
		Molar point	0.991*	0.992*
Axial	Sagittal asymmetry	Supraorbital margin	0.951*	0.967*
		Malare	0.880*	0.904*
		Pyriforme	0.973*	0.980*
		Maxilloalveolare	0.913*	0.946*
		Maxillary sinus total. length	0.978*	0.963*
	Transverse asymmetry	Malare	0.843*	0.857*
		Pyriforme	0.990*	0.974*
		Maxilloalveolare	0.994*	0.985*
		Maxillary sinus total width	0.961*	0.945*
		Nasal chamber width	0.998*	0.997*
		ANS	0.997*	

*: Significant at P ≤ 0.05

Table (3): Mean, standard deviation values and results of paired t-test for the comparison between different asymmetry measurements of cleft and non-cleft sides in PA and axial views

View	Measurement	Side	Cleft side		Non-cleft side		*P*-value
			Mean	SD	Mean	SD	
PA	Horizontal asymmetry	Nasal cavity	11.2	1.6	13.2	1.7	<0.001*
		Maxillary dento-alveolar	30.3	1.7	31.2	1.4	0.030*
		Molar point	27.1	2.5	27.9	1.4	0.292
	Vertical asymmetry	Nasal cavity	47	3.5	45.5	3.6	0.029*
		Maxillary dento-alveolar	47.9	2.7	48.8	3.5	0.033*
		Molar point	60.4	4.7	61.7	5.1	0.001*
Axial	Sagittal asymmetry	Supraorbital margin	60.7	2.2	60.8	2.5	0.712
		Malare	47.3	2.2	47.5	2.1	0.622
		Pyriforme	55.4	2	56.9	1.6	<0.001*
		Maxilloalveolare	54.6	2.9	56.5	3.1	<0.001*
		Maxillary sinus total length	30.2	2.6	30.8	2.9	0.005*
	Transverse asymmetry	Supraorbital margin	39.9	2.2	40.6	2.8	0.067
		Malare	55	2.3	55.9	2.7	0.017*
		Pyriforme	12.6	1.7	14.3	2.2	0.006*
		Maxilloalveolare	14.2	1.8	16	1.4	<0.001*
		Maxillary sinus total width	21.6	2.4	22.2	2.6	0.067
		Nasal chamber width	8.9	1.7	10.8	2.1	<0.001*

*: Significant at P ≤ 0.05

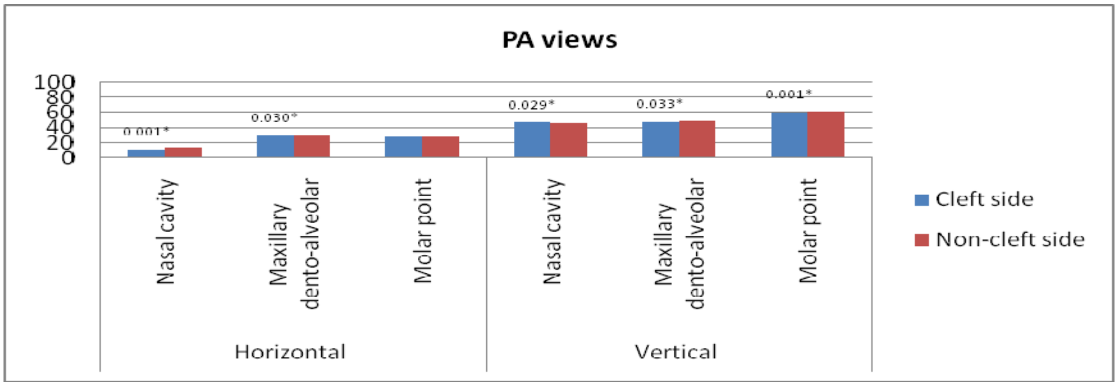

Figure (5): Comparison between horizontal and vertical asymmetry measurements of cleft and non-cleft sides in PA views

Table (4): Results of Spearman's correlation coefficient for the correlation between degree of asymmetry of different structures

Plane	Variables	Correlation coefficient	P-value
Horizontal	Nasal cavity and maxillary dento-alveolar	0.478	0.072
	Nasal cavity and molar point	0.572	0.026*
	maxillary dento-alveolar and molar point	0.677	0.006*
Vertical	Nasal cavity and maxillary dento-alveolar	0.217	0.437
	Nasal cavity and molar point	0.404	0.135
	maxillary dento-alveolar and molar point	0.225	0.421

*: Significant at $P \leq 0.05$

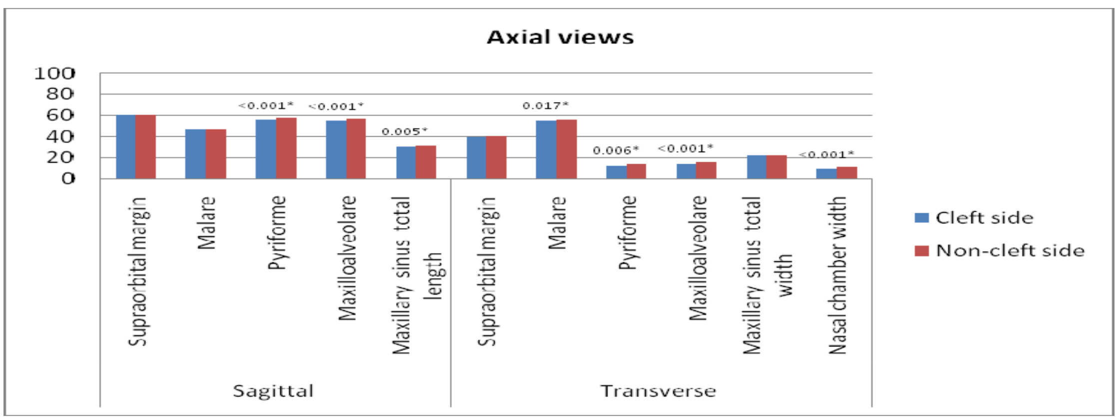

Figure (6): Comparison between sagittal and transverse paired asymmetry measurements of cleft and non-cleft sides in axial views

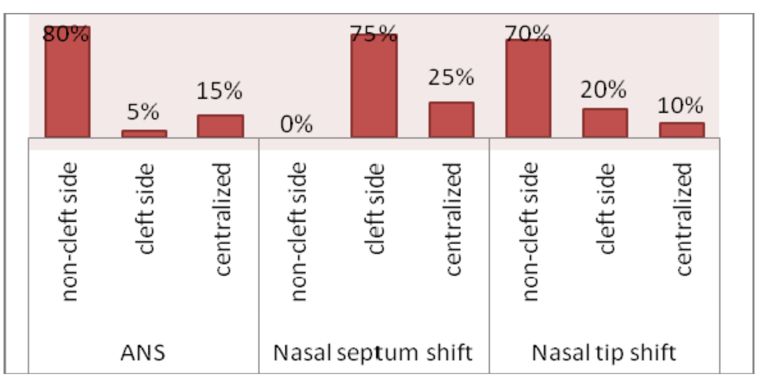

Figure (7): Comparison between unpaired measurements in axial views

4. Discussion:

Morphologic and positional abnormalities in patients with CLP are present in 3D space. Moreover, it is known that asymmetries have clinical implications during orthodontic and surgical diagnosis and treatment planning of UCLP patients, therefore; accurate radiographic imaging is essential.. CBCT technology provides an excellent radiographic resource that improves understanding, and hence improves orthodontic and surgical treatment of CLP patients. Recently the use of CBCT precludes the use of other imaging modalities due to its usefulness and accurate reproduction of anatomic structures, , Sukovic, (2003); Schniderman et al, (2009); Miyamoto and Nakajima (2011).

The fact that individuals with UCLP display a unilateral malformation allowed us to utilize the measurements of the contralateral noncleft side of each patient as an internal control in both PA and axial views. There is a known possibility that development of the cleft side influenced the control noncleft side within the same individual and vice versa as suggested by Suri et al, (2008).

Patients in mixed dentition stage were included in the current study where this stage is considered one of the advanced stages of growth and development, Smahel et al, (1993). Moreover, patients were included prior to performing alveolar cleft grafting due to the controversies related to timing of the alveolar bone graft, the sites and types of bone for the graft and the impact of surgical interference on maxillary growth and the whole facial development, Vig, (1999); Eppley et al, (2000).

CBCT scans were ordered for every patient in the study as a part of routine orthodontic preparation prior to alveolar cleft grafting. CBCT offers isotropic volumetric data, the entire volume can be reoriented to create views in different planes allowing optimally visualization of anatomic features, Mozzo et al, (1998). The i-CAT software could be used on a personal computer that allows image manipulation in axial, coronal and sagittal planes generating images replicating those commonly used in clinical practice. For both PA and axial views analyses, linear measurements were acquired directly on the synthesized images.

In the PA analysis, the landmarks used were suggested in the previous studies Grayson et al, (1983); Forsberg et al, (1984); Grummons et al, (1987). For assessment of vertical asymmetry, the horizontal base line (LOL') was constructed by connecting the two latero-orbitale (lo,lo') landmarks on the frontal views. LOL' has been extensively employed and validated by other investigators for the assessment of vertical asymmetries on frontal cephalometric radiographs. It is possible, that severe temporal asymmetries seen in patients with craniofacial syndromes may influence the position of lo and lo', hence adversely affecting vertical measurements taken from the LOL' base line. Despite the fact such cases were not included in our study sample, yet it could be a source of potential error as suggested by Suri et al, (2008).

In analysis of the maxillary and deeper midfacial structures in the axial views, the cranial base reference system was chosen, Suri et al, (2008). The cranial base is remote from the cleft region and has many positionally stable, homogenous neurovascular foramina and landmarks on which the anatomic midlines can be constructed. It has been recommended that anatomic landmarks to study asymmetry in the facial skeleton should be based on such remote stable points, Marsh et al, (1986); Corbo et al, (2005). Even within the cranial base, rather than selecting one or two points to establish the reference planes, the midsagittal construct was drawn by joining the mid points of lines connecting several landmarks in the midline, therefore, potential errors due to asymmetry of any cranial base landmarks were avoided, Suri et al, (2008).

Previous studies revealed that inconsistency in landmark identification was the most important source of random error Houston, (1983); Sandham and Cheng, (1988); Liu and Gravely, (1991). From the results it could be suggested that, reproducibility of landmarks did not seem to be affected by the interval of one week between the two registrations done by the same investigator and were found to be comparable to those suggested by Schniderman et al, (2009).

In the current study there was a significant asymmetry of the nasal cavity in vertical, transverse and sagittal planes in PA and axial views. In the transverse plane, there was a significant reduction in nasal chamber width as well as increased vertical height on the cleft side. This reduction in the size of the nasal cavity on the cleft side was in accordance with several studies describing the nasal stigmata of UCLP on the bony and soft tissue levels, Smahel and Brejcha, (1983); Mølsted and Dahl, (1990); Pruzansky and Aduss, (1990); Kyrkanides, (1995); Suri et al, (2008). It is suggested that those findings could be due to absence of the nasal floor on the cleft side due to presence of the alveolar cleft into this region allowing continuation defect as compared to the noncleft side. Nostril floor width asymmetry was thought to be the most frequent residual deformity in repaired UCLP, Farkas et al (1993). Moreover; the lower half of the nasal septum was consistently deviated toward the cleft side in 75% of our study sample which contributed to the reduced nasal chamber width on the cleft side. These findings were in agreement with Latham, (1969), Mølsted and Dahl, (1990); Suzuki et al, (1999).

Furthermore, a significant sagittal depression of the bony alar base represented by pyriforme was found in axial views. A deviation of the ANS toward the noncleft side was noted in 80% of the cases, similar to the findings of Mølsted and Dahl, (1990); Kolbenstvedt et al, (2002); Suri et al, (2008). Besides, there was a reduction in the transverse position of the pyriforme in axial views on the cleft side which was in contrast to the findings of Suri et al, (2008) who did not find asymmetry of the pyriforme in the transverse plane in his studied sample of Indian children with UCLP.

Furthermore, it was found that the nasal tip was deviated toward the side opposite to the cleft in axial views in 70% of the subjects. This finding is in accordance to that reported by Berkowitz and Pruzansky, (1968). The deflection of the nose tip toward the noncleft side is probably due to combined influence the cleft-related asymmetric muscle insertion and tension, asymmetric growth restraint on the nasal septum and effects of surgery, Latham, (1969).

In the current study, there was a significant reduction in maxillary dentoalveolar height and width on the cleft side in PA view and axial views analysis. These findings were in accordance with that of Smahel and Brejcha, (1983); Mølsted and Dahl, (1990). The decreased dentoalveolar arch width localized to the cleft side is a common feature in patients with UCLP and reflects the phenomenon of “arch collapse” , Subtelny, (1990); Long et al, (2000). It is suggested that this could be due to mechanical displacement of the unsupported segment due to superadded tension after primary lip and palatal repair surgeries due to pressure from the buccal musculature. In addition, adaptive growth of the nasal septum should be considered where the cleft segment grows without the control effect of a midpalatal suture due to lack of continuity of the alveolar arch, Latham, (1969).

The aforementioned asymmetries of the bony alar base and the basal dentoalveolar complex evident from the reduced measurements of pyriforme and maxilloalveolare on the cleft side should be considered while planning cleft rehabilitation through; alveolar bone grafts, surgically assisted maxillary expansion, orthognathic surgery with maxillary advancement or distraction osteogenesis, as well as chelio-rhinoplasty procedures, Vig, (1999); Long et al, (2000); Kuroe et al, (2003); Sander et al, (2011). In this respect, evaluation and quantification of existing defects by CBCT scans should be commenced if external facial asymmetry is noted in the pretreatment clinical examination. This is crucial to achieve successful surgical outcomes during different stages of treatment.

It is worthy to mention that, the molar point measurements were reduced on the cleft side in the vertical plane as compared to the noncleft side. This finding has not been otherwise reported in literature. This is in contrast to the findings of Atherton , (1967) who found that the vertical height of the maxilla in the molar region was almost identical on the cleft and noncleft sides in a group of skulls with unoperated clefts. Therefore, we suggest that vertical asymmetry of the molar point might be a direct result of surgical intervention.

Nevertheless, the difference in the molar point measurements was not significant in the horizontal plane. The fact that most maxillary molars erupt in good buccolingual relationship can be interpreted in several ways:, it might be that early surgery does not inhibit the lateral growth in this area of active bone proliferation prior to eruption of the first molars; second, lip surgery causes rotation of the maxillae so that the distal ends flare outward resulting in greater arch width across the first molars; third, since the nasopharynx is relatively wider than normal prior to repair sufficient width is maintained despite surgery, Subtelny , (1955). In accordance to the findings of Laspos et al, (1997) the reduced height of the maxillary dentoalveolus and the molar point on the cleft side indicates canting of the occlusal plane in UCLP patients. In addition, there was a statistically significant positive correlation in horizontal asymmetry between nasal cavity and molar point as well between maxillary dentoalveolus and molar point. This might be attributed to horizontal collapse of the cleft side as a direct result of adaptive growth.

It is worthy to mention that in the current study, a significant reduction in the transverse position of the malare on the cleft side was found indicating collapse of the malar prominence on the cleft side. Even though this finding was an obvious clinical observation in the studied sample of UCLP patients, presented as collapse of the malar prominence on the cleft side, still upto our knowledge, it was not reported elsewhere in literature. Even though, reliability coefficient of this measurement showed significant but lower values than other measurements, we suggest that this finding could be a result of adaptive growth of the midface on the cleft side following lip and palatal repair surgery. Further studies are required to approve or disprove this explanation in newborns prior to lip repair.

As regards the maxillary sinuses; it was found that both sides were of similar transverse dimension but the total antero-posterior length was smaller on the cleft side. This could be attributed to deficient antero-posterior dimension of the maxilla as a whole on the cleft side. This finding has not been addressed by Suzuki et al, (1999) and Suri et al, (2008) who reported absence of major transverse and sagittal craniofacial asymmetries of the deeper midfacial structures far from the cleft in their study sample.

Conclusions:

Within the limitations of the current study it can be concluded that CBCT is an excellent technology for quantifying and analyzing surface as well as deep defects in patients with CLP in 3D planes. Most midfacial asymmetries and deformities in the eight to

12-year-old patients with repaired complete UCLP; prior to orthodontic preparation for alveolar cleft grafting were in the nasal chamber, maxillary dento-alveolar complex, maxillary sinus and malar prominence regions.

Recommendations:

Results of the current study are of great clinical value for both the maxillofacial surgeon as well as the orthodontist which can influence treatment decisions based on critical CBCT analysis. Hence it is recommended that; during preparation for alveolar cleft grafting correction of arch collapse should be obtained by anterior arch expansion. Moreover, alveolar grafting should be performed with the aim to achieve nasal floor symmetry. Additionally, chelio-rhinoplasty procedures should aim to address the nasal tip shift as well as shifted nasal septum.

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