Review Article

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Clinical utility of cone-beam computed tomography in patients with cleft lip palate: Current perspectives and guidelines

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ABSTRACT

The aim of this article is to provide a comprehensive review of the application of cone-beam computed tomography (CBCT) in individuals with cleft lip and palate (CLP). A literature search was conducted from September 2016 to December 2017 in Medline, Scopus, ScienceDirect, Google Scholar, and Ebscohost databases using keywords "CBCT, cleft lip and palate." The inclusion criterion was any published original article where CBCT was used to assess the craniofacial structures in patients with CLP. An additional Google and manual search was carried out by examining the references of the included articles. All retrieved relevant articles (69 original articles) were tabulated under different sections and analyzed. Data were tabulated as follows – CBCT in the assessment of craniofacial structures in CLP, first author, year of publication, study design, characteristics of the study population and number of participants, age/gender distribution, and conclusions of the studies which are also described in the narrated review. Apart from this, the search also included guidelines for the application of CBCT in patients with CLP. This article gives the cleft team a compilation of all recent literature regarding the use of CBCT in patients with CLP, which helps in providing better care for patients with CLP, keeping in mind the various guidelines issued by different professional bodies regulating the welfare of patients.

Keywords: Cone-beam computed tomography, cone-beam computed tomographic guidelines, diagnosis and treatment planning, patients with cleft lip palate

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INTRODUCTION

Cone-beam computed tomography (CBCT) was developed as an evolutionary process of computed tomography (CT) for obtaining three-dimensional (3D) information of the craniofacial structures [Figure 1].[1] Even though the technique used in CBCT has been applied in medical imaging since 1982, the technological transfer of CBCT to dentistry first occurred in 1998.[2-4] The NewTom QR-DVT 9000 became the first commercial CBCT unit to be introduced in the market in Europe in 1999.[5] Since its inception, constant use of CBCT in different fields of dentistry has led to the introduction of various CBCT devices.[3] CBCT technology provides excellent imaging at reduced radiation doses and lower cost than CT.[6] In orthodontics, the application of CBCT extends from locating impacted teeth to planning of orthognathic surgeries.[3,7-14]

Cleft lip and palate (CLP) is a true 3D facial deformity, and it could be assumed that 3D imaging would provide a better insight into the anatomical condition.[15] This information is important in treatment planning.

The objective of this article is to assess the awareness of CBCT use in the management of patients with CLP. The assessment of criteria, limitations, and guidelines assumes importance with the increased use of CBCT in patients with CLP. As CBCT has been recently introduced, it is imperative that the cleft team should be aware of all the aspects of the use of CBCT in patients

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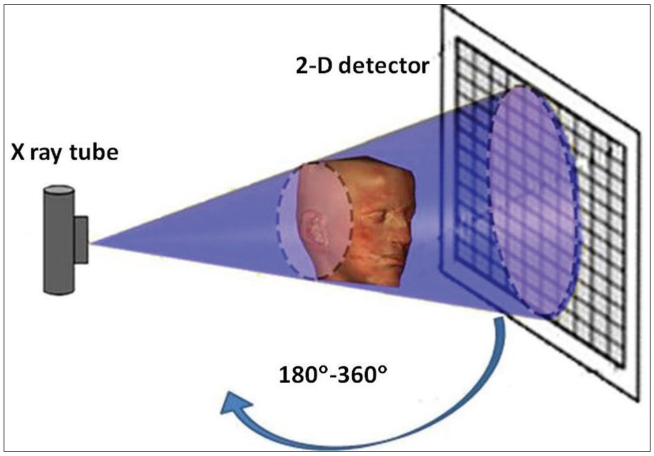

Figure 1: Basic principle of CBCT. CBCT: Cone-beam computed tomography

with CLP to safeguard the patients against unwarranted radiation and its consequences.

METHODS

Data selection and extraction

The electronic databases and citation indexes used were Medline, Scopus, ScienceDirect, Google Scholar, and Ebscohost. All potential articles were checked if they fulfilled the inclusion criterion. The general search term used was "CBCT and CLP." The search included articles published in English language of any peer-reviewed journal from September 2016 to December 2017. A Google and manual search of reference lists from journals was carried out to improve the sensitivity of the literature search. Journals searched were American Journal of Orthodontics and Dentofacial Orthopedics, European Journal of Orthodontics, Angle Orthodontist, The Cleft Palate Craniofacial Journal, and Journal of CLP and Craniofacial Anomalies. Apart from this, the search also included guidelines for the application of CBCT in patients with CLP. All the relevant literature was extracted and analyzed.

Data extraction and data synthesis

The articles were first selected based on the abstract, and then, the full text was retrieved when the authors agreed upon the subjective selection. Then, these two authors performed the final selection of articles based on the inclusion criteria. A total of 69 articles were selected for CBCT in patients with CLP. After selection of articles, data was categorized under different headings such as (1) CBCT in the assessment of alveolar bone defects (3), (2) alveolar bone grafting (13), (3) alveolar bone morphology/thickness (4), (4) sella turcica (2), (5) facial symmetry (3), (6) maxillary morphology (1), (7) mandibular morphology (6), (8) soft-tissue thickness (2), (9) pharyngeal airway (16), (10) maxillary sinus volume (2), (11) orthognathic surgical planning (2), (12) nasal morphology (5), (13) tooth morphology (3), and (14) incidental findings (2). Data were tabulated as follows – CBCT in the assessment of craniofacial structures in CLP, first author, year of publication, study design, characteristics of the study population and number of participants, age/gender distribution, and conclusions of the studies [Table 1], which are described in the narrated review.

Guidelines for the use of cone-beam computed tomography in patients with cleft lip and palate

Although CBCT appears to hold promise for advances in research and clinical application, there is some uncertainty and controversy related to its radiation dose. Some guidelines have been suggested such as the Ionizing Radiation Medical Exposure Regulations 2000 which states that all medical exposures, including CBCT, have to be justified.[15] For any diagnostic radiographs in dentistry, As Low As Reasonably Achievable (ALARA) principle applies.[82] As per the ALARA principle, CBCT scans should be reserved for selected cases when we need some additional information. With time, ALARA has been modified to As Low As Diagnostically Acceptable which assists the clinicians in selecting appropriate size of field of view (FOV) based on region of interest (ROI).[83]

In 2010, the American Association of Orthodontists[84] adopted a resolution (26-10H, 2010) which states that "there may be clinical situations where CBCT may be of value, however the use of such technology is not routinely required for orthodontic radiography."

The panel consisting of members from the American Academy of Oral and Maxillofacial Radiology and Board certified orthodontists concluded that the use of CBCT in orthodontics should be based on clinical presentation.[85] Guidelines stated by various professional bodies recommend the use of CBCT in selected cases where conventional radiography cannot supply satisfactory diagnostic information.[86-91] Such cases include CLP, impacted teeth, and orthognathic surgical planning.

3D imaging with less radiation dose also has good applicability in CLP patients. Published literature on the treatment outcomes in patients with CLP suggests that important information may be obtained through CBCT imaging. Scientific evidence also proved that the use of CBCT alters diagnosis and improves treatment plans in CLP. Available evidence implies that CBCT imaging in CLP patients provides a good diagnostic

Table 1: Compilation of studies using CBCT in patients with CLP

Topic	Author	Year	Sample size and type	Study design	Conclusion
Alveolar bone defect	Quereshy *et al.*[16]	2012	14 UCLP	Retrospective study	CBCT is a useful tool to assess the volume defect of alveolar bone
	Wangsrimongkol *et al.*[17]	2013	20 CLP	Retrospective study	CBCT is reliable to evaluate the success of ABG
	Deçolli *et al.*[18]	2014	2 BCLP	Retrospective study	CBCT scan is effective in estimating the volume of alveolar bone defect in CLP patients
ABG	Hamada *et al.*[19]	2005	13 ABG-treated CLP 9 UCLP 4 BCLP	Prospective study	CBCT is useful for the clinical assessment of ABG
	Oberoi *et al.*[20]	2009	21 CLP 17 UCLP 4 BCLP	Prospective study	CBCT and Amira are a reproducible and practical method to assess outcome of SABG
	Shirota *et al.*[21]	2010	13 CLP 10 UCLP 2 CLP 1 UCLA	Retrospective study	Assessment of the alveolar cleft volume using CBCT scan data and image analysis software assists in extracting the correct volume of bone
	Zhang *et al.*[22]	2012	19 UCLP	Retrospective cross-sectional study	Limited CBCT scan and 3D reconstruction are a promising method for the evaluation of the outcome of ABG
	Trindade-Suedam *et al.*[23]	2012	31 UCLP Divided into SABG TABG	Prospective study	SABG produces better outcome than TABG
	Liu *et al.*[17]	2013	7 UCLP 4 females + 3 males	Retrospective study	CBCT imaging and analysis are a reproducible method of 3 D evaluation of estimate the volume of the defect of the UCLP
	Amirlak *et al.*[24]	2013	Five simulated alveolar clefts	In vitro study	CBCT is a reliable and accurate tool to measure alveolar cleft defects and grafts
	Suomalainen *et al.*[25]	2014	35 UCLP - 6 months after SABG	Retrospective study	CBCT provides a reproducible and practical clinical method to evaluate the presence and position of grafted bone
	Linderup *et al.*[26]	2015	10 UCLP	Retrospective study	CBCT is a reproducible and practical method for assessing the volume of ABG when compared with third-party software
	Liu *et al.*[27]	2016	52 CLP 39 UCLP 4 BCLP 8 UCLA 1-BCLA	Retrospective study	CBCT can provide a reference and assistance for patients with bone grafted alveolar clefts in determining the labiolingual thickness
	de Moura *et al.*[28]	2016	1 UCLP	*In vitro* study/simulated alveolar bone defect	There is potential to improve CBCT image quality while reducing the radiation dose significantly during postoperative examinations for ABG
	Garib *et al.*[29]	2017	UCLP (case report)	Prospective study - A case report	RME performed after SABG will result in complete opening of the midline suture without compromising the integrity of the grafted alveolar cleft
	Oberoi *et al.*[30]	2010	21 CLP 17 UCLP + 4 BCLP	Prospective study	CBCT is reliable to assess the eruption of the canine after SABG
Alveolar bone morphology/ thickness	Garib *et al.*[31]	2012	10 BCLP	Retrospective	CBCT showed good accuracy and reproducibility for quantitative analyses of buccal and lingual alveolar bone thickness

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Topic	Author	Year	Sample size and type	Study design	Conclusion
	Ercan *et al.*[32]	2015	31 UCLP (7 unrepaired CLP)	Retrospective	CBCT is a reliable tool to assess the bone support of teeth adjacent to the cleft region in patients affected by UCLP using CBCT
	Ghoneima *et al.*[33]	2017	39 UCLP 11 males + 18 females	Retrospective	CBCT images allow to visualize the alveolar bone around a specific tooth to measure the amount of bone labial, lingual, mesial, and distal to that tooth
	Yatabe *et al.*[34]	2015	30 UCL 22 CLP + 8 UCLA 14 females + 16 males Postorthodontic techniques	Retrospective case-control study	CBCT is effective to measure the buccal crest bone
Sella turcica	Yasa *et al.*[35]	2017	54 CLP (29 males + 25 females) 85 control	Retrospective case-control study	CBCT can be used to assess the sella turcica. The cleft subjects had a flattened short sella turcica compared to the control group
	Paknahad *et al.*[36]	2017	20 UCLP 20 BCLP 20 control	Retrospective case-control study	The size of the sella turcica was smaller in patients with cleft than noncleft group. No difference was found in the size of the sella turcica among cleft types
Midfacial asymmetry	Choi *et al.*[37]	2013	26 UCLP 18 males + 8 females (postorthodontic treatment)	Retrospective study	The nasolabial and dentoalveolar regions show significant differences in linear measurements and soft-tissue thickness
Hard-tissue and soft-tissue facial symmetry	Starbuck *et al.*[38]	2014	55 UCLP	Retrospective study	CBCT is useful for assessing the relationship between hard and soft tissue of the face to increase the likelihood of successful surgical outcomes
Lower facial asymmetry	Lin *et al.*[39]	2015	30 UCLP 23 right + 7 left 20 male + 10 female 40 control Class III	Retrospective case-control study	CBCT is effective to measure facial asymmetry in three dimensions
Maxillary morphology	Schneiderman *et al.*[40]	2009	6 NSUCLP patients 7 control	Retrospective case-control study	Analysis of maxillary dimension can be carried out from CBCT scan using linear measurements. CBCT can be used as a tool for the precise quantification of skeletal areas where growth may have been problematic
Mandibular morphology	Veli *et al.*[41]	2011	15 UCLP 8 males + 7 females 8 right + 7 left 17 control	Retrospective study	CBCT is effective to measure asymmetry in three dimensions
Temporomandibular fossa and mandibular condyle	Uçar *et al.*[42]	2016	17 BCLP 7 females + 10 males 17 control	Retrospective case-control study	The position of the mandibular condyle and temporomandibular fossa were similar in patients affected by BCLP and controls
Mandibular morphology	Kim *et al.*[43]	2013	28 UCLP 17 males + 11 females	Retrospective study	The correlation between structural asymmetries and chin deviation was analyzed using 3D CBCT images
Condylar and ramal vertical asymmetry	Celikoglu *et al.*[44]	2013	20 UCLP 21 BCLP 21 control	Retrospective study	The ramal height and ramal plus condylar height measurements were lower in the cleft side in the UCLP patients Ramal asymmetry index differ between the patients affected by UCLP and BCLP

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Topic	Author	Year	Sample size and type	Study design	Conclusion
Mandibular transverse widths	Celikoglu *et al.*[45]	2015	29 UCLP 8 females + 21 males 18 BCLP 17 females + 11 males 28 control 8 females + 20 males	Retrospective case-control study	CBCT is a technology used for the assessment of mandibular transversal widths of those patients affected by UCLP and BCLP
Mandibular volume	Celikoglu *et al.*[46]	2016		Retrospective case-control study	UCLP and BCLP groups had insignificantly decreased mandibular volume values compared to control group
Facial soft-tissue thickness	Celikoglu *et al.*[47]	2014	20 BCLP 20 control	Retrospective cross-sectional	The BCLP group had a decreased facial thickness around subnasale and labrale superius compared with the controls
	Celikoglu *et al.*[48]	2015	34 UCLP 9 right + 25 left 11 females + 23 males 32 control	Retrospective case-control	Thickness of the subnasale and the labrale superius were significantly thinner in the UCLP group compared to the controls
Pharyngeal airway	Cheung and Oberoi[49]	2012	16 UCLP 3 BCLP	Retrospective cross-sectional	Airway volume in the CLP group is more when you compare to non-CLP group
	Yoshihara *et al.*[50]	2012	Juvenile group 10 UCLP 5 BCLP 19 control Adolescent 14 UCLP 4 BCLP 18 control	Retrospective case-control	Oropharyngeal airway is larger in the adolescent controls than in the juvenile controls; there were no significant differences in airway between the adolescent and juvenile patients with CLP
	Xu *et al.*[51]	2013	32 isolated CP 10 males + 20 females	Retrospective cross-sectional	There is an enlarged nasopharynx in the sagittal plane and increased nasopharyngeal airway volume at the palatal plane in patients with ICP
	Celikoglu *et al.*[52]	2014	16 BCLP (11 females + 5 males) 16 control (10 females + 6 males)	Retrospective cross-sectional	Oropharyngeal and total airway volumes were found to be less in the BCLP group
	Celikoglu *et al.*[53]	2014	30 UCLP (20 males + 10 females) 30 control (14 males + 16 females)	Retrospective cross-sectional	Oropharyngeal airway volume was statistically significant less in the UCLP group than in the control group
	Nemțoi *et al.*[54]	2015	15 UCLP 12 control	Retrospective cross-sectional	CBCT can be regarded as equivalent to CT with regard to the diagnostic information. Pharyngeal airway volume is less in CLP than normal
	Pimenta *et al.*[55]	2015	30 UCLP 19 male + 13 15 control	Retrospective case-control study	NV and PV airways showed no difference between the cleft and noncleft subjects
	Rana *et al.*[56]	2016	20 UCLP 40 control	Retrospective case-control study	There was no significant difference in the pharyngeal area and volume between surgically treated UCLP and noncleft groups
	Al-Fahdawi *et al.*[57]	2018	14 BCLP (7 females + 7 males) 20 UCLP (10 females + 10 males) 24 control (12 females + 12 males)	Retrospective case-control study	UCLP patients significantly less superior oropharyngeal airway volume than both controls and BCLP patients
	Shahidi *et al.*[58]	2016	30 CUCLP (19 males + 11 females) 30 control	Retrospective case-control study	Total airway and nasopharyngeal airway is reduced. Inferior airway is not compromised
	Agarwal and Marwah[59]	2016	14 UCLP 6 BCLP 20 control (10 males + 10 females)	Cross-sectional study	Oropharyngeal, nasopharyngeal, and total pharyngeal airway significantly less in cleft patient than control group

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Topic	Author	Year	Sample size and type	Study design	Conclusion
	Joy *et al*.[60]	2017	55 CBCT control 55 NSUCLP	Retrospective case-control study	CLP patients have smaller volumetric airway dimensions compared to control and shown to be associated with OSA
	Al-Fahdawi *et al*.[61]	2017	14 BCLP (7 females + 7 males) 20 UCLP (10 females + 10 males) 24 control (12 females + 12 males)	Retrospective case-control study	There is no significant volume, cross-sectional area, or depth of nasopharyngeal airway. UCLP and BCLP did not show significantly less than controls
	Rana *et al*.[62]	2016	20 UCLP 11 early palatal surgery 9 late palatal surgery 40 control	Retrospective cross-sectional study	There was no significant difference in the pharyngeal airway between different groups
	Mordente *et al*.[63]	2016	40 UCLP (23 males + 17 females) 10 Hyrax 10 i Mini-M 10 i Mini-B 10 fan shaped	Prospective nonrandomized clinical trial	Hyrax and iMini-M do not increase the volume. RME did not increase the volume of the oropharyngeal airway
	Yatabe *et al*.[64]	2017	24 CLP 25 control	Retrospective case-control study	The BAMP therapy produced a symmetric and similar protraction of the maxillary region in patients with and without oral clefts
Orthognathic surgical planning	Lonic *et al*.[65]	2016	20 UCLP 6 BCLP 4 CP	Prospective study	3D simulation using CBCT renders important information for accurate planning in complex CL/P cases involving facial asymmetry
Maxillary expansion	Figueiredo *et al*.[66]	2014	10 hyrax expander 10 fan-shaped expander 10 inverted mini-hyrax	Prospective study	CBCT to evaluate different appliances in patients with clefts might have great value, enhancing the knowledge concerning their treatment. The hyrax appliance caused both anterior and posterior maxillary expansion and might be better indicated for patients with clefts
	Garib *et al*.[67]	2016	50 BCLP 25 EDO 25 hyrax	Prospective nonrandomized controlled clinical trial	The EDO produced skeletal changes similar to the conventional hyrax expander
	Mordente *et al*.[63]	2016	40 UCLP 23 males + 17 females 10 hyrax 10 fan-type 10 inverted mini-hyrax supported on the 16, 26 (i-Mini-M) 10-inverted mini-hyrax supported on 14, 24 (i-Mini-B)	Nonrandomized controlled clinical trial	The hyrax and i-Mini-M significantly increase nasal cavity volume RME did not increase the volume of the oropharyngeal airway
	de Almeida *et al*.[68]	2017	46 BCLP	Two-arm parallel trial prospective study	No difference was found between the orthopedic, dental, and alveolar bone plate changes of SME and RME in children with BCLP
Volumetric analysis of maxillary sinus	Lopes de Rezende Barbosa *et al*.[69]	2014	30 UCLP 15 BCLP 15 control	Retrospective case-control study	Patients with UCLP and BCLP present maxillary sinuses with smaller volumes when compared to age-matched control subjects
	Erdur *et al*.[70]	2015	44 UCLP 45 control	Retrospective case-control study	Maxillary sinus volumes is reduced in UCLP compared with the control group

Table 1: Contd...

Topic	Author	Year	Sample size and type	Study design	Conclusion
	Kula *et al*.[71]	2016	15 UCLP 15 control	Retrospective case-control study	Children with UCLP have significantly more maxillary sinus mucosal thickening and smaller sinuses than controls
Nasal morphology	Jiang *et al*.[72]	2014	66 cleft patients 42 controls	Retrospective case-control study	Patients with CP and/or alveolus presented greater deviation of nasal septum than noncleft controls
Nasal cavity volume	Farzal *et al*.[73]	2016	10 UCLP 10 BCLP 10 control	Retrospective case-control study	Nasal cavity volume is decreased in children with UCLP and BCLP when compared to nasal cavity volume of control
Nasal septal deviation	Dedeoglu *et al*.[74]	2016	24 UCLP	Retrospective case-control study	Higher frequencies of anterior nasal septal deviation associated with UCLP compared to the control In UCLP patients, the incidence of neurovascular structures in the sphenoid sinus was lower than that in nonsyndromic control patients
Nasolacrimal duct	Altun *et al*.[75]	2017	28 UCLP 28 control	Retrospective study	The diameter of the nasolacrimal duct at the affected side of unilateral CLP was narrower than the unaffected side According to this result, the CLP deformity can have an effect on the nasolacrimal duct diameter
Tooth morphology	Zhou *et al*.[76]	2013	40 UCLP 20 BCLP 53 control	Retrospective case-control study	The permanent upper incisors in nonsyndromic CLP patients are underdeveloped. Incisor developmental deficiency was greater in teeth adjacent to the cleft
	Celebi *et al*.[77]	2015	40-UCLP 20 males + 20 females 40 control 20 males + 20 females	Retrospective case-control study	Root volumes of central incisors on the cleft side were smaller than noncleft side. Root development of the central incisor is more influenced by the cleft in females than in males
	Celikoglu *et al*.[78]	2015	50 cleft patients 28 UCLP 22 BCLP (22 patients)	Retrospective case-control study	All patients affected by UCLP and BCLP were found to have at least one maxillary dental anomaly
	Buyuk *et al*.[79]	2016	44 UCLP 26 males + 18 females 51 control 21 males + 30 females	Retrospective case-control study	UCLP patients had a significantly higher prevalence of dehiscence than the controls Fenestrations at maxillary central incisors were significantly more common on the cleft side in UCLP patients compared with controls
Incidental findings	Kuijpers *et al*.[80]	2014			On 95.1% of the CBCTs, incidental findings were found. CBCT imaging is not only helpful tool in the treatment of CLP patients, but it also provides diagnostic information for almost all specialties involved in CLP treatment
	Nemtoi *et al*.[81]	2015	21 UCLP 4 BCLP	Retrospective case-control study	In CLP patients, an extended FOV may have added value as the diagnostic information may be useful for other craniofacial team. The incidental findings are related to problems, such as middle ear and mastoid problems, agenesis of teeth, and supernumerary and impacted teeth

UCL: Unilateral cleft lip, UCLP: Unilateral cleft lip and palate, BCLP: Bilateral cleft lip and palate, CLP: Cleft lip and palate, ABG: Alveolar bone grafting, SABG: Secondary alveolar bone grafting, TABG: Tertiary alveolar bone grafting. NSUCLP: Nonsyndromic unilateral cleft lip and palate, CUCLP: Complete unilateral cleft lip and palate, CBCT: Cone-beam computed tomography, CP: Cleft palate, EDO: Expander with differential opening, ICP: Isolated cleft palate, CT: Computed tomography, OSA: Obstructive sleep apnea, FOV: Field of view, RME: Rapid maxillary expansion, SME: Slow maxillary expansion, 3D: Three-dimensional, UCLA: Unilateral Cleft Lip Alveolus, NV: Nasal Airway Volume, PV: Pharyngeal Airway Volume, i Mini-M: Inverted mini-hyrax supported on the first permanent molars, i Mini-B: Inverted minihyrax supported on the first premolars tool for quantifying and analyzing surface and deep craniofacial structures. Recent improvements in CBCT features such as spatial resolution, soft-tissue contrast, and specialized reconstruction algorithms, along with a significantly reduced radiation exposure, make it a preferred imaging modality of choice for CLP patients. All available guidelines justify the use of CBCT in CLP patients.[86-90] CBCT is preferred over the use of CT images for lesser radiation and lower cost. All 3D imaging tools for the assessment of soft and skeletal tissue in patients with orofacial clefts were quantitatively analyzed and CBCT was given highest quality score by Kuijpers *et al*.[92]

Cone-beam computed tomography for the assessment of alveolar defect

The volume of the cleft defect was calculated by measuring facial width, facial height, and facial length using CBCT [Figure 2a]. Several studies have proved that CBCT is a reliable tool to assess the volume defect of alveolar bone.[16-18] These data can be used to quantify the amount of graft material needed.

Cone-beam computed tomography for the assessment of secondary alveolar bone grafting

Secondary alveolar bone grafting (SABG) is the gold standard for the treatment of alveolar defects in individuals with CLP. A successful alveolar bone graft bridges the cleft defect with bone, facilitates eruption of the permanent canine through the cleft, preserves the periodontal health of the adjacent teeth, and allows closure of the communication between oral and nasal cavities. CBCT is successfully used to quantify the volumetric outcome of SABG in alveolar defects in patients with CLP [Figure 2b].[17,19-29] Oberoi *et al*. assessed the treatment outcome of SABG using CBCT by assessing the eruption of the canine through the graft.[30]

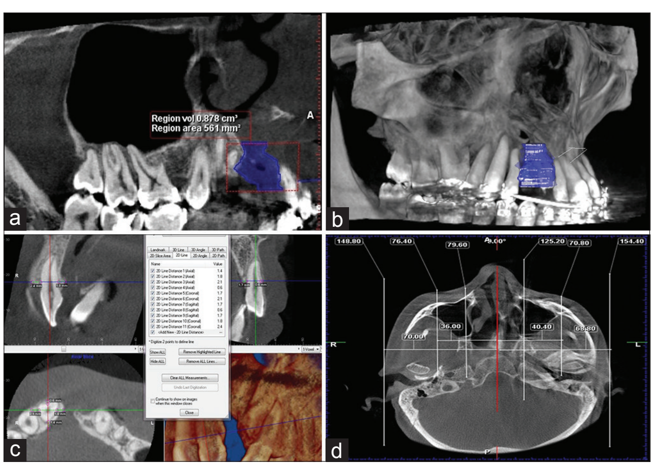

Figure 2: CBCT in the assessment of craniofacial structures in patients with CLP. (a) CBCT in the assessment of volume of cleft defect, (b) CBCT in the assessment of ABG, (c) CBCT in the assessment of ABT, (d) CBCT in the assessment of facial asymmetry in axial slice. CBCT: Cone-beam computed tomography, CLP: Cleft lip and palate, ABG: Alveolar bone grafting, ABT: Alveolar bone thickness

Cone-beam computed tomography in the assessment of alveolar bone thickness teeth adjacent to the defect

The extent of desired tooth movement is estimated by assessing the thickness and level of alveolar bone around the teeth adjacent to the cleft. The poor availability of bone on the teeth adjacent to the cleft indicates that tooth movement should be avoided or minimized in the cleft region before the placement of alveolar bone graft. CBCT images allow visualization of the alveolar bone around a specific tooth to measure the bone at labial, lingual, mesial, and distal to that tooth [Figure 2c]. Several studies have measured and compared alveolar bone thickness on the coronal, sagittal, and axial sections passing at different levels in the tooth adjacent to the defects with unilateral CLP (UCLP) and bilateral CLP (BCLP), using CBCT imaging.[31-34]

Cone-beam computed tomography in the morphometric analysis of sella turcica

The effect of deviations in the morphology of the sella turcica in individuals with clefts has been reported in several 2D cephalometric studies. There are two studies where CBCT is used to measure size and shape of sella.[35,36] The size of the sella turcica was smaller in patients with cleft as compared to the noncleft group. No difference was found in the size of the sella turcica among UCLP and BCLP.[36]

Cone-beam computed tomography in the assessment of facial asymmetry

Quantitative assessment and localization of asymmetry in particular facial regions are often challenging to maxillofacial surgeons and orthodontists. CBCT images and the specialized software packages allow precise tissue depth measurements to be collected to quantify craniofacial asymmetry and develop a treatment plan for the patient. Several studies have quantitatively analyzed the asymmetry of the cranial base, nasolabial region, and mandible in UCLP patients.[37] Midfacial hard- and soft-tissue asymmetries between the cleft and noncleft sides were compared and correlated using CBCT.[38,39] Symmetry was assessed using the predefined landmarks in sagittal, coronal, and axial planes [Figure 2d].

Cone-beam computed tomography in the assessment of maxillary morphology

CBCT can be used to assess the dimension of maxillary complex in patients with CLP. Schneiderman *et al*.

used a set of 18 new measurements to describe the maxillary morphology in six patients with UCLP and seven normal individuals.[40] These measurements were found to be reliable and repeatable with a conclusion that CBCT is a useful tool for the precise quantification of skeletal areas.

Cone-beam computed tomography in the assessment of mandibular morphology

The positional and morphological features of the mandible with a UCLP were studied using CBCT.[41,42] The correlation between structural asymmetries and chin deviation was analyzed by Kim *et al*. using 3D CBCT images.[43] Celikoglu *et al*. analyzed condylar, ramal, condylar plus ramal heights using CBCT images to assess the vertical asymmetry on cleft and noncleft side.[44] Celikoglu *et al*. also assessed the mandibular dental, alveolar, and skeletal transversal widths in both UCLP and BCLP groups.[45] Celikoglu *et al*. in another study demonstrated that mandibular volume significantly reduced in CLP as compared to control group.[46]

Cone-beam computed tomography in the assessment of facial soft-tissue thickness

Celikoglu *et al*. measured facial soft-tissue thickness in individuals with UCLP and BCLP.[47,48] The thickness of the subnasale and the labrale superius was found to be thinner in the UCLP and BCLP groups when compared with the controls.

Cone-beam computed tomography in the assessment of pharyngeal airway

Patients affected by CLP usually complain of snoring and respiratory difficulties during sleep. Patients affected by CLP have increased incidence of mouth breathing and hyperpnoea during sleep. An advantage of CBCT imaging over conventional 2D imaging is the ability to measure volumes, which provides an added dimension for the volumetric assessment of airway [Figure 3a]. Several studies have concluded that CBCT is a simple and effective method for the evaluation of the airway volumes in patients with cleft.[49-63] Yatabe *et al*. assessed the changes in pharyngeal airway after protraction therapy in individuals with CLP using CBCT.[64]

Cone-beam computed tomography in the orthognathic surgical planning

CBCT can be used for surgical simulation in left patients [Figure 3b] in patients with CLP. Lonic *et al*. compared 3D surgical simulation with conventional 2D planning and reported that 3D simulation using CBCT renders important information for accurate planning in complex CLP cases involving facial asymmetry.[65]

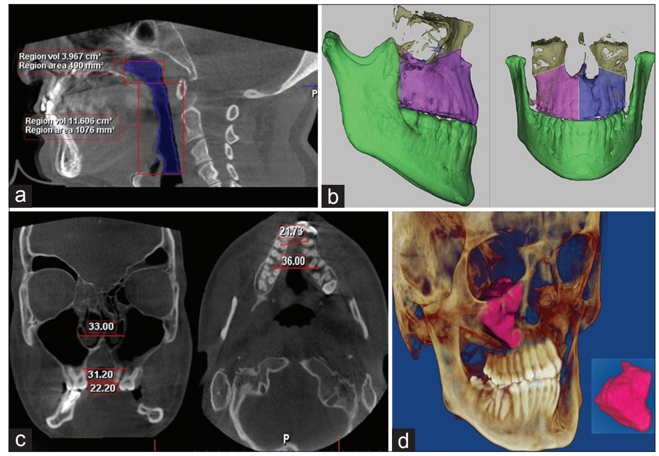

Figure 3: CBCT in the assessment of craniofacial structures in patients with CLP. (a) CBCT in the assessment of pharyngeal volume, (b) CBCT in surgical simulation, (c) CBCT in assessment of expansion, (d) CBCT in volumetric assessment of maxillary sinus. CBCT: Cone-beam computed tomography, CLP: Cleft lip and palate

Cone-beam computed tomography in the maxillary expansion

One of the side effects of early intervention with surgery in CLP is hypoplastic maxilla with a constricted arch. Such patients can be treated with maxillary expansion to promote maxillary growth. CBCT scans will provide detailed information about craniofacial, maxillary, and mandibular changes resulting from rapid maxillary expansion (RME) [Figure 3c]. The effect of RME appliance on skeletal, dental, and soft tissue in CLP was studied by several investigators using CBCT, and the measurements made pre- and post-treatment in all three planes of space were compared.[63,66-68]

Cone-beam computed tomography in the assessment of maxillary sinus

CBCT has been used to assess the volume of the sinus [Figure 3d].[69-71] Several researchers reported that patients with UCLP and BCLP present maxillary sinuses with smaller volumes when compared to age-matched controls. It was also concluded that children with UCLP have significantly more maxillary sinus mucosal thickening.

Cone-beam computed tomography in the assessment of nasal morphology

Patients with CLP frequently present with anatomical and physiological impairments of the nose, and among them, deviation of nasal septum is considered one of the most commonly occurring concurrent deformities of patients with CLP. CBCT had been used to visualize maxillary and nasal structures [Figure 4a]. Patients with CLP often suffer from nasal obstruction that may be related to the effects on nasal volume. Nasal airway assessment requires understanding of nasal volume which can be measured using CBCT. Jiang *et al*. reported that patients with cleft palate and alveolus presented greater deviation of nasal septum than noncleft controls.[72] Farzal *et al*. observed that overall nasal cavity volume is decreased in children with UCLP and BCLP when compared to nasal cavity volumes of noncleft children.[73] Dedeoglu *et al*. observed that anterior nasal septal deviation was found to be more in patients with UCLP compared to the patients in the control group.[74] Altun *et al*. analyzed the morphometric changes in the nasolacrimal duct in patients with UCLP using CBCT and reported that the nasolacrimal duct diameter was narrower on the affected side when compared to the unaffected side.[75]

Cone-beam computed tomography in the assessment of tooth morphology

Patients with CLP usually present dental anomalies such as hypodontia, supernumerary teeth, ectopic eruption, impacted teeth, microdontia, fused teeth, and posterior crossbite. CBCT can provide more accurate and highly detailed linear, angular, and volumetric measurements [Figure 4b]. Zhou *et al*. qualitatively evaluated the shape and length of the incisor in patients with CLP.[76] The permanent upper incisors in Nonsyndromic cleft lip palate patients patients are underdeveloped. Incisor developmental deficiency was greater in teeth adjacent to the cleft. Celebi *et al*. compared the root development and anomalies of permanent upper incisors in patients with UCLP with a well-matched control group.[77] Root volumes of central incisors on the cleft side were smaller than noncleft side. Root development of the central incisor is more influenced by the cleft in females than in males. Celikoglu *et al*. compared the frequency of maxillary dental anomalies in patients with UCLP and BCLP.[78] It was concluded that patients with UCLP and BCLP were found to have at least one maxillary dental anomaly. The most frequently observed dental anomaly was tooth agenesis. Canine impactions were observed more commonly in the cleft side than in the normal side. All dental anomalies were found to be higher in both cleft groups than noncleft group. Buyuk *et al*. reported that patients with UCLP had a significantly higher prevalence of dehiscence than the controls. Fenestrations at maxillary central incisors were significantly more common on the cleft side in UCLP.[79]

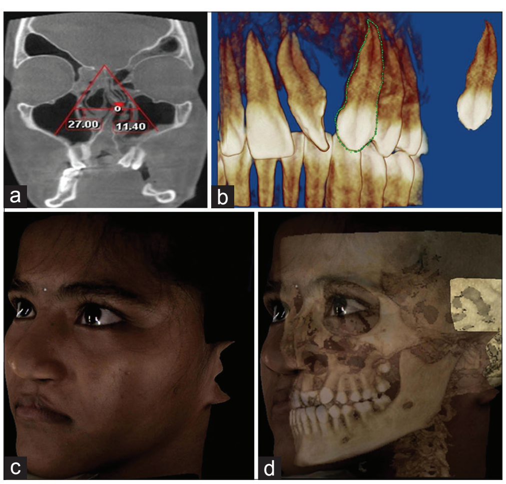

Figure 4: CBCT in the assessment of craniofacial structures in patients with CLP, (a) CBCT in assessment of nasal symmetry, (b) CBCT in assessment of tooth morphology, (c) 3D photos using CBCT, (d) integration of 3D photograph with 3D CBCT. CBCT: Cone-beam computed tomography, 3D: Three-dimensional

Cone-beam computed tomography in incidental findings

CBCT is frequently used in treatment planning of CLP. Thorough examination of CBCT images of cleft patient reported high number of incidental findings, indicating that CBCT imaging may provide diagnostic information of areas other than ROI.[80,81]

Limitations of cone-beam computed tomography in current prospective

Capturing of the whole volume in CBCT is an advantage as compared to CT because lesions in between the slices can be missed out in CT. However, the capturing time and acquisition time are more in CBCT as compared to CT and any movement in the patient can affect the whole-image quality unlike the CT where only those captured slices at the time of motion are affected.[93] Newer CBCT machines are programmed to overcome errors due to movement by factoring in the amount of movement with algorithms.

Spatial resolution may not be accurate and may be incorrectly assumed to be equal to scan resolution and voxel size.[34] Different machines and image setting may result in different voxel sizes. A 0.2-mm voxel size has an average spatial resolution of 0.4 mm between the objects. Therefore, voxel size should be determined depending on the structures/anatomy that needs to be studied. Although radiation dose increases with decrease in the voxel size, some of manufacturers claimed that the voxel size does not affect radiation dose. Some manufacturers even implement preset "resolution" protocols (e.g., visualization of high-contrast details or low-contrast soft tissues) with smaller voxel sizes to keep the noise relatively constant.

Scatter level or noise is often higher in CBCT than in CT due to relative high amount of electronic noise in the detector giving rise to artifacts.[93] Noise and spatial resolution are interdependent as any factor that improves one diminishes the other. Although antiscatter grids can be used to decrease the artifacts, it may increase the radiation dosage.[93] Although Hounsfield units, is displayed in CBCT images for all structures is may not be reliable due to increased scattered radiation and error in data truncation.(i.e. mass outside the FOV influencing grey values inside it). The resulting uncertainty related to HU accuracy and consistency is often too large for routine clinical application. Even for CBCT images in which grey values are distributed along a pseudo-HU scale (i.e. with a minimum value of 21000), the quantitative use of grey values should be avoided in current dental CBCT systems. It should also be kept in mind that partial volume averaging which is one of the limitations of CBCT displays average density when reporting objects with different densities.[34]

Another important aspect of CBCT is the FOV which should be carefully restricted to cover the ROI so as to minimize the radiation exposure following the ALARA principle.[82] CBCT scans with large FOV cannot be reconstructed at small voxel sizes owing to the excessive increase in file size and reconstruction time. Large FOV will also cause artifacts or noise in the image because of increased amount of scattered radiation. FOV should be selected preferably in consultation with a radiologist; as smaller the FOV, sharper the image, and lesser the dosage.[93]

Areas requiring further studies of cone-beam computed tomography in patients with cleft lip and palate

The idea of generating diagnostic records such as lateral cephalograms and panoramic radiographic study model from a single CBCT scan is most captivating to an orthodontist. Another interesting and useful function of CBCT with 3D software is the ability to superimpose the craniofacial structures at different intervals. The current research has focused on generating a simplified superimposition technique which will help the clinician to identify the positional changes in the craniofacial structures after different surgical procedures and to assess the best treatment choice in CLP patients. CBCT imaging with integrated 3D photographs [Figure 4c] visualizes the soft tissue in relation to dentition and skeletal tissues.[94] Since a CBCT image and a 3D photograph are generated in one imaging session, the patient position, facial expression, and muscle position remain unchanged, resulting in images that are perfectly compatible [Figure 4d]. This technology provides valuable information for surgical simulation and also to document superimposition following surgery.

Further research using CBCT images can be directed to study the alveolar bone boundary limit for orthopedic and orthodontic therapy.[3] Understanding the limits of the alveolar boundary for expansion or tooth movement will aid in treatment planning. Using this information, the orthodontist may be able to visualize the impact of cleft on the ability to move teeth in the sagittal or transverse planes.

Qualitative and quantitative information gained through research using CBCT should be incorporated into the cleft team to enhance the diagnosis and to refine the treatment plan. Over the period, not much CBCT data have been gathered to understand the exact 3D craniofacial morphology in cleft patients. Further studies are required to evaluate the effect of cleft on various skeletal and soft tissues.

Recommendation

Dosage of CBCT imaging is in the range of 40–130 μSv, which is equivalent to 4–17 days of natural background radiation.[95] While we cannot ignore the risk of radiation, benefits of 3D imaging modality on treatment planning, treatment outcome, and treatment evaluation must also be weighed. Before prescribing CBCT, the risk–benefit analysis has to be carried out. Whenever CBCT scan is recommended, appropriate FOV to cover the ROI, voxel size, and recommended resolution protocol should be selected to minimize radiation dose.

CONCLUSION

There are many published articles listing the various indications, considerations, limitations, and guidelines for the use of CBCT in orthodontics. The welfare of the patient is the prime objective for all involved in providing care to patient with CLP. This article not only gives the cleft team a compilation of all recent literature regarding use of CBCT in patients with CLP, but it will also help in providing better care for patients with CLP, keeping in mind the various guidelines issued by different professional bodies regulating the welfare of patients. To steer clear of trouble, risk–benefit analysis should be carried out before prescribing CBCT, keeping in mind the advantages, indications, and limitations.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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