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Ministry of Higher Education
And Scientific Research
University of Baghdad
College of Dentistry

Imaging in Orthodontic: 2D vs 3D

A Project
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University of Baghdad, Department of Orthodontics
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Bachelor of Dental Surgery

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Certification of the Supervisor

I certify that this project entitled "**Imaging in orthodontic**" was prepared by **Reem Ayser Mohammed** under my Supervision at the College of Dentistry/University of Baghdad in partial fulfillment of the graduation requirements for the Bachelor Degree in Dentistry.

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Date:

Dedication

First of all, I thank "**Allah”** almighty for granting me the will and strength to accomplish this study, and I wish that his blessings upon me may continue throughout my life…

My world **(Father & Mother)** who support me and they are being the reason of what I am be now with their prays of day and night make me able to get success and honor.

My support in life, my wonderful brothers **(Karar & Mustafa)**.

My treasures that college gave me, who are the real mean of friendship **(Dudy & Leno).**

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All friends for their unlimited encouragement and help.

Finally, to all who encouraged me even through a word.

REEM AYSER

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Table of Content

	Subjects	Page No.
	Certification of the Supervisor	I
	Dedication	II
	Acknowledgment	III
	Table of contents	IV
	List of Figures	VI
	List of Tables	IX
	List of abbreviations	X
	Introduction	1
	Aims of study	2
	Chapter one: Review of Literature	3
1.1	What Does the Clinician Need in Terms of Imaging	3
1.2	Comparison between X-ray and light	3
1.3	Technique of radiographic	4
1.3.1	Intraoral radiographs	4
1.3.1.1	Periapical radiographs	5
1.3.1.1.1	Diagnostic objectives of periapical radiography	5
1.3.1.1.1.1	Paralleling technique	6
1.3.1.1.1.2	Bisecting line angle technique	7
1.3.1.2	Bitewing radiographs	8
1.3.1.2.1	Diagnostic Objectives of Bitewing Radiography	8
1.3.1.3	Occlusal radiograghs	9
1.3.1.3.1	Diagnostic Objectives of Occlusal Radiography	10

1.3.2	Extraoral radiographs	11
1.3.2.1	Indication of extraoral radiographs	11
1.3.2.2	Panoramic radiographs	11
1.3.2.2.1	Indication of panoramic radiographs	12
1.3.2.3	Cephalometric radiographs	13
1.3.2.3.1	Indication of cephalometric radiographs	14
1.3.2.3.2	Commonly used cephalometric points and reference lines	14
1.3.2.3.3	Assessment of Anteroposterior skeletal pattern	14
1.3.2.3.4	Assessment of vertical skeletal pattern	16
1.3.2.3.5	3D Cephalometry	18
1.3.2.4	Cone beam computed tomography	20
1.3.2.4.1	Advantages of CBCT	20
1.3.2.4.2	Limitation of CBCT	21
1.3.2.4.3	Application of CBCT in orthodontics	21
	Chapter two: Discussion	26
	Chapter three: Conclusions and Suggestions	27
	References	28

List of Figures

No.	Title	Page
1	Film and long axis of tooth are parallel to each other, and central rays are perpendicular to both.	4
2	Periapical survey of the early mixed dentition	6
3	Periapical radiograph showing the impaction of the lower left second premolar and the tipped permanent first molar.	6
4	A, Preorthodontic periapical radiograph of lower anterior teeth before intrusion. B, Periapical radiograph of lower anterior area after intrusion	6
5	Position of film, tooth and the central beam in paralleling technique	7
6	A tooth and its radiographic image will be equal in length when central ray is perpendicular to bisecting line.	7
7	Proximal enamel caries	8
8	Recurrent caries: intraoral bitewing radiograph	8
9	Anterior maxillary occlusal projection. (A) The shaded area outlines the image field. (B) Anterior maxillary occlusal radiograph. (C) Position of the patient with the receptor in place and the aiming ring aligned for exposure	9
10	Upper occlusal radiograph taken to investigate the impacted canine.	10
11	The triangular split of the mid-palatine suture is evident on the occlusal view radiograph.	11
12	OPT radiograph of patient with a displaced upper left canine and absent lower second premolars	12

13	picture in the left show Panoramic radiograph before treatment visualizes the residual roots of the first molar (black arrow). And picture in the right show Panoramic radiograph after treatment	13
14	A, Panoramic radiograph before treatment. B, Panoramic radiograph after hemisection and extraction of the distal portion of the first molar. C, Panoramic radiograph after extraction of the mesial portion of the first molar. D, Panoramic radiograph after space closure	13
15	The mandibular symphysis, body, ramus, condyles, and coronoid processes are traced.	14
16	Commonly used points and reference lines	14
17	classification of ANB angle	15
18	Wits analysis. For MH (female, age 13 years), the distance from AO to BO for MH is 0.3 mm, suggesting a Class I skeletal pattern.	16
19	Ballard conversion tracing	16
20	Vertical facial relationships. FMPA, Frankfort–mandibular plane angle; MMPA, maxillary– mandibular plane angle	17
21	Face heights. LAFH, lower anterior face height; LPFH, lower posterior face height; TAFH, total anterior face height; TPFH, total posterior face height; UAFH, upper anterior face height; UPFH, upper posterior face height	18
22	Volume-rendered CBCT images for the	19
23	Image Noise	21
24	Typical CBCT vs. CT image in which appear the poor tissue contrastof CBCT	21
25	Depiction of impacted maxillary canines using a conventional 2D panorex (A) and3D volumetric renderings (B-F).	22
26	CBCT images offer important information and finer details in treatment planning of supernumerary teeth.	22

27	Volume rendering of CBCT scans of an individual with a unilateral cleft lip and palate (a) before and (b) after alveolar bone grafting	24
28	Right (A) and left (B) temporomandibular joint (TMJ) images acquired with a 6X6 FOV. The high- resolution images provide proper assessment of the TMJ bone anatomy.	24
29	Hard tissue representation of the augmented bony patient model with detailed occlusion Virtual diagnosis, treatment planning and evaluation of treatment outcomes for patients treated by orthognathic surgery.	25

List of Tables

No.	Title	Page
1	Comparison between x-ray and light	3

List of Abbreviations

2D	Two dimentional
3D	Three dimenional
ALARA	as low as reasonably Attainable
CBCT	Cone beam computed tomography.
OPG	Orthopantomogram
TMJ	Tempromandibular joint
MMPA	Maxillary-mandibular plane angle
FMPA	Frankfort-mandibular plane angle
TAFH	Total anterior face height
UAFH	Upper anterior face height
LAFH	Lower anterior face height
TPFH	Total posterior face height
CT	Computed tomograghy
MRI	Magnetic Resonance Imaging

Introduction

Imaging in orthodontics has evolved from cephalometric and extraoral films, manual cephalometric tracings, to digital imaging and intraoral scanners. Software-assisted cephalometric tracings and three-dimensional image analysis have become routine in orthodontic diagnosis and treatment planning. Determination of biologic boundaries of orthodontic treatment and evaluation of temporomandibular joints and airway became part of orthodontic assessment. Use of advanced imaging and software to digitally plan the orthognathic surgery and accurately predict a successful outcome is now integral to orthodontic practice **(Tanna *et al*., 2021)**. The history of imaging and orthodontics is a story of technology informing biology. Advances in imaging changed our thinking as our understanding of craniofacial growth and the impact of orthodontic treatment deepened **(Hans *et al*., 2015)**.

New diagnostic methods have made orthodontic diagnosis and treatment planning more important in our litigious society. It is crucial to maintain precise records of treatment progress since a poor record might suggest a low degree of orthodontic therapy. For orthodontic records, a diagnostic report accompanied by study models, radiographs, and photographs is necessary to establish the case's state before treatment and to chronicle the course of treatment. Making an accurate diagnosis is made much easier with the use of dental records that are issue oriented. So, the aims of orthodontic therapy (function and aesthetics) are changing. Because of the advancement of digital technologies in private practice, an enhanced three-dimensional (3D) diagnostic and treatment planning technique has been established. 3D imaging in orthodontics makes it feasible to diagnose and arrange therapy in advance, as well as evaluate dentoskeletal relationships and facial aesthetics thereafter **(Taneva *et al*., 2014)**.

Aims of the study

- To summarize the different types of X-rays in dental use.
- To identify the imaging techniques used in orthodontic treatment.
- To differentiated between 2D &3D imaging.

Chapter one:

Review of Literature

1.1 What Does the Clinician Need in Terms of Imaging?

In today's dental practice, one should only use a well-designed X-ray machine where the time exposure controls are electronic and thus accurately deliver the proper exposure to patients. To obtain proper images of the oral cavity and dental tissues, one must at all times be aware of the basic rule of radiology: ALARA. This means dentists are taking images using As-Low- As-Reasonably-Achievable doses of radiation. In order to be protected from the biological effects of radiation, some precautions must be taken, and also proper use of radiographs should be known by the professions. Maximum patient benefit should be targeted, with minimum patient and operator dose. Considering the presence of risk, although it is minimal in all individuals, efforts should be made to use as low as possible doses, and all unnecessary exposures should be avoided **(Delantoni *et al*., 2022)**.

1.2 Comparison between X-ray and light

Table 1: Comparison between x-ray and light **(Brant *et al*., 2012)**.

Similarity	**Difference**
Both belong to the same electro – magnetic radiation family.	X-ray and light cast the shadows of the objects in the same manner.
Both travel in straight lines at the same speed which is 186,000 miles per seconds.	X-ray has the ability to penetrate objects that the light cannot pass through.
Both affected the photographic films and made them black.	X-ray has the ability to ionize atoms. And is invisible.
Both not affected by magnetic fields.	X-ray has the ability to produce light (blue light) called (fluorescence).

1.3 Technique of radiographic

1.3.1 Intraoral radiographs

The word intraoral radiography means making the radiograph of an oral structure by placing the X-ray film in the oral cavity while X-ray source is outside of the oral cavity **(Rawlani and shobha, 2014)** (Fig.1). It is of high significance to select the technique appropriate for the correct diagnosis thus the application of selection criteria for intraoral radiography. Which are used where needed intraoral radiographs are the initial diagnostic tool for dentists prior to more advanced imaging which are used where needed **(Delantoni *et al*., 2022)**. The radiographic image will have five basic characteristics that includes density, contrast, sharpness, distortion and magnification which affects the quality of film and can be controlled by six principles of shadow casting **(Delantoni *et al*., 2022)**.

1. Radiation source should be as small as possible.

2. The target to object distance should be as long as practically possible.

3. The object to film distance should be as small as possible.

4. The X-ray tube, patient and film should not move during exposure.

5. The film and teeth should be parallel to each other.

6. The central beam should be at right angle to film and object both.

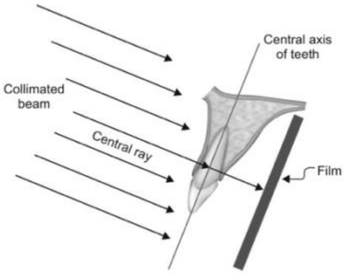

Fig 1: Film and long axis of tooth are parallel to each other, and central rays are perpendicular to both **(Rawlani and shobha, 2014)**.

1.3.1.1 Periapical radiographs

2D imaging is commonly prescribed and belongs to the most frequently taken X-ray images in humans. Allow one-time demonstration of both teeth and their periapical tissues (hence the name periapicals), Correctly taken periapical radiograph using digital sensor or film size 2 should demonstrate the whole tooth and about 5 mm of periapical tissues **(Rozylo-kalinowska, 2020)**. So, these can be used in any part of the mouth and are useful for assessing root form and local pathology, and locating unerupted teeth (like the upper occlusal, they can be used with other radiographic views to identify the position of these teeth using parallax) **(Littlewood and Mitchell, 2019)**.

1.3.1.1.1 Diagnostic objectives of periapical radiography (White and pharaoh, 2018).

- Assess extent of dental caries.
- Detect presence and assess extent of periapical inflammation.
- Assess periodontal bone loss.
- Evaluate root morphology (Fig.2).
- Assess implant osseointegration and peri-implant bone loss.
- Evaluate unerupted and impacted teeth (Fig.3).
- Evaluate consequences of traumatic injuries to the teeth and alveolar bone (Fig.4).
- Evaluate external and internal root resorption.
- Assess pulp morphology.
- Determine length of endodontic instrumentation during treatment.

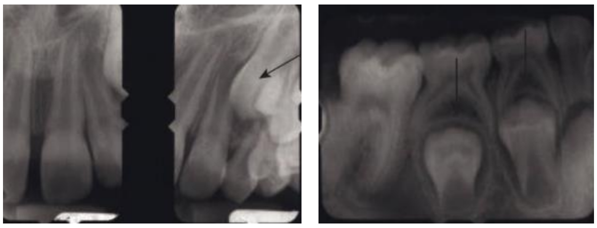

Fig 2: Periapical survey of the early mixed dentition **(Staley, 2011)**.

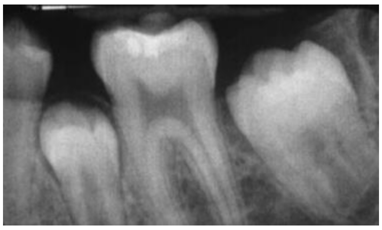

Fig 3: Periapical radiograph showing the impaction of the lower left second premolar and the tipped permanent first molar **(Staley, 2011)**.

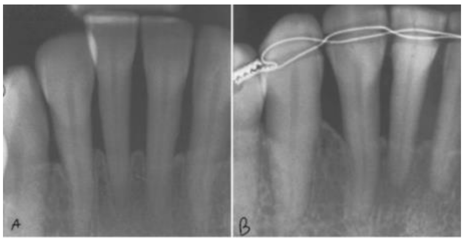

Fig 4: A, Preorthodontic periapical radiograph of lower anterior teeth before intrusion. Note the level alveolar crest between the canine and the lateral incisors. B, Periapical radiograph of lower anterior area after intrusion **(Graber *et al*., 2005)**.

1.3.1.1.1.1 Paralleling technique

The paralleling technique was developed in 1920 by McCormick. This technique is also known as the Fitzgerald technique, right angle technique, long cone or extended cone technique. The essence of this technique is that the X-ray film is placed parallel to the long axis of the teeth and the central beam of X-ray is directed at right angles to the teeth and film both (Fig.5). To achieve parallelism between the film and the tooth, the film must be placed away from the tooth and toward the middle of the oral cavity **(Rawlani and shobha, 2014)**.

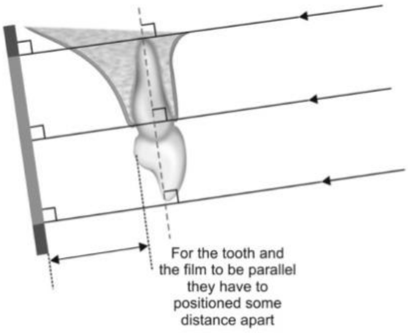

Fig 5: Position of film, tooth and the central beam in paralleling technique **(Rawlani and shobha, 2014)**.

1.3.1.1.1.2 Bisecting line angle technique

In this method, the image receptor is placed as close to the teeth as possible without deforming it. However, when the image receptor is in this position, it is not parallel to the long axes of the teeth. This arrangement inherently causes distortion. Nevertheless, by directing the central ray perpendicular to an imaginary plane that bisects the angle between the teeth and the image receptor, the practitioner can make the length of the tooth's image on the image receptor correspond to the actual length of the tooth (Fig.6). This angle between a tooth and the image receptor is especially apparent when teeth are radiographed in the maxilla or anterior mandible. Although the projected length of a tooth is correct, these images display a distorted image of the position of alveolar crest with respect to the cementoenamel junction of a tooth. In recent years, the bisecting-angle technique is used less frequently for general periapical radiography as use of the paralleling technique has increased **(White and pharaoh, 2018)**.

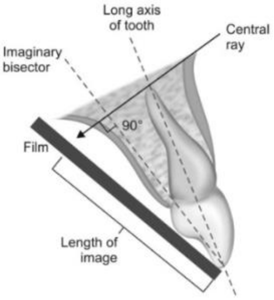

Fig 6: A tooth and its radiographic image will be equal in length when central ray is perpendicular to bisecting line **(Rawlani and shobha, 2014)**.

1.3.1.2 Bitewing radiographs

2D imaging Bitewing (also called interproximal) radiographs include the crowns of the maxillary and mandibular teeth and the alveolar crest on the same receptor. The long axis of bitewing receptors usually is oriented horizontally but may be oriented vertically. The beam is directed through the interproximal spaces and parallel with the occlusal plane **(White and pharaoh, 2018)**. The receptor is placed parallel to the buccal and lingual surfaces of the teeth being examined and is perpendicular to the x- ray beam. They may be useful in assessing caries and the condition of existing restorations **(Littlewood and Mitchell, 2019)**.

1.3.1.2.1 Diagnostic Objectives of Bitewing Radiography (White and pharaoh, 2018).

- Detect early interproximal caries before it becomes clinically apparent (Fig.7).

- Detect secondary caries below restorations (Fig.8).

- Assess loss of the interdental and furcation bone.

Fig 7: Proximal enamel caries **(koong,2017)**.

Fig 8: Recurrent caries: intraoral bitewing radiograph **(Koong, 2017)**.

1.3.1.3 Occlusal radiograghs

2D imaging an occlusal radiograph displays a relatively large segment of a dental arch. Their size is bigger compared to the periapical film. They are 5.5 × 7.5 cm in size (Fig.9). They are used in palatine and alveolar process fractures, in embedded teeth, in the detection of foreign bodies in the jaws, especially in locations of salivary gland stones (sialolithiasis) in the lower jaw, in the detection of supernumerary or partial anodontia, in the surgical or orthodontic examination of the hard and soft palate defects, and the examination of the torus **(Delantoni *et al*., 2022)**. Occlusal radiographs also are useful when patients are unable to open wide enough for periapical images or for other reasons cannot accept periapical receptors. Because occlusal radiographs are exposed at a steep angulation, they may be used with conventional periapical images to determine the location of objects in all three dimensions. With the growth of cone beam computed tomography (CBCT) in dentistry, many of these diagnostic objectives are now accomplished with CBCT imaging rather than occlusal radiography Nevertheless, occlusal radiographs continue to be used where access to CBCT imaging may be limited **(Singh, 2015)**.

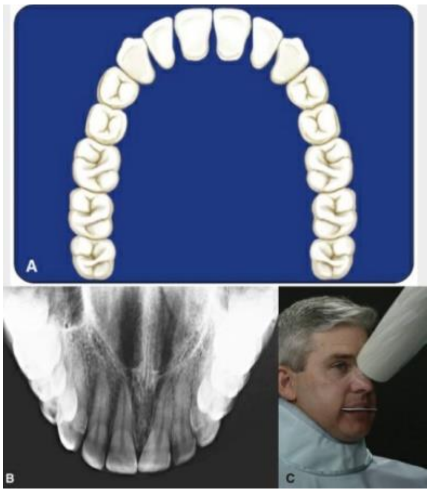

Fig 9: Anterior maxillary occlusal projection. (A) The shaded area outlines the image field. (B) Anterior maxillary occlusal radiograph. (C) Position of the patient with the receptor in place and the aiming ring aligned for exposure **(White and pharaoh, 2018)**.

1.3.1.3.1 Diagnostic Objectives of Occlusal Radiography (White and pharaoh, 2018).

- To locate supernumerary, unerupted, and impacted teeth (Fig.10).

- To localize foreign bodies in the jaws and floor of the mouth.

- To identify and determine the full extent of disease (e.g., cysts, osteomyelitis, malignancies) in the jaws, palate, and floor of the mouth.

- To evaluate and monitor changes in the midpalatal suture during orthodontic palatal expansion (Fig.11). To detect and locate sialoliths in the ducts of sublingual and submandibular glands.

- To evaluate the integrity of the anterior, medial, and lateral outlines of the maxillary sinus.

- To aid in the examination of patients with trismus, who can open their mouths only a few millimeters; this condition precludes intraoral radiography, which may be impossible or at least extremely painful for the patient.

- To obtain information about the location, nature, extent, and displacement of fractures of the mandible and maxilla.

Fig 10: Upper occlusal radiograph taken to investigate the impacted canine **(Littlewood and Mitchell, 2019)**.

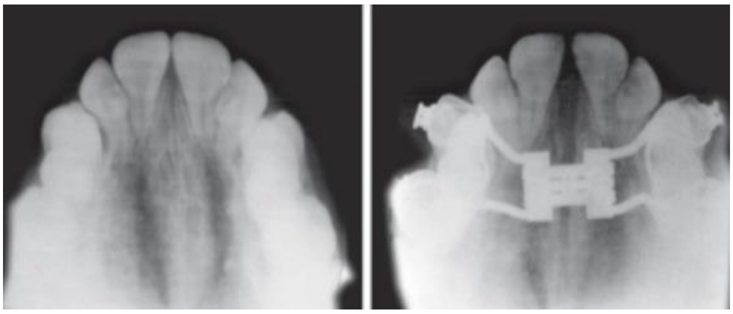

Fig 11: The triangular split of the mid-palatine suture is evident on the occlusal view radiograph (**Littlewood and Mitchell, 2019**).

1.3.2 Extraoral radiographs

Extraoral radiography utilizes the screen film in cassettes equipped with screens. Screen-film combination is faster than the film alone and therefore, one can make the radiograph with reasonably short exposure time and thus reduces the radiation to the patient. An important aspect of the extraoral radiography technique is the immobilization of patients. These radiographs are useful in cases of trauma, trismus or any other reason due to which the patient is unable to open the mouth **(Rawlani and shobha, 2014)**.

1.3.2.1 Indication of extraoral radiographs (Rawlani and shobha, 2014).

- To examine the extent of lesions.
- Examination of large area of jawbone.
- To evaluate trauma.
- To evaluate impacted teeth.
- To evaluate temporomandibular joint.

1.3.2.2 Panoramic radiographs

A panoramic radiograph is 2D radioghraphs is Widely used in orthodontics, Panoramic radiographs are also required by the American Board of Orthodontics for examination of treatment success of cases (Fig.12). In particular the panoramic radiograph is used in the assessment of tooth root parallelism. it enables clinicians to visualize all teeth present, temporomandibular joints, the alveolus, and other orofacial structures in a single radiograph. For a routine diagnostic process, a panoramic radiograph offers several advantages including low costs and easy access. It dispenses low amount of radiation. It is considered more like a screening radiograph and does not allow for consistent and reliable measurements. Despite its benefits, the radiograph provides an incomplete rendering of the anatomy or pathology presented by a patient. Both false positive and negative interpretations occur frequently **(Faman, 2007)**.

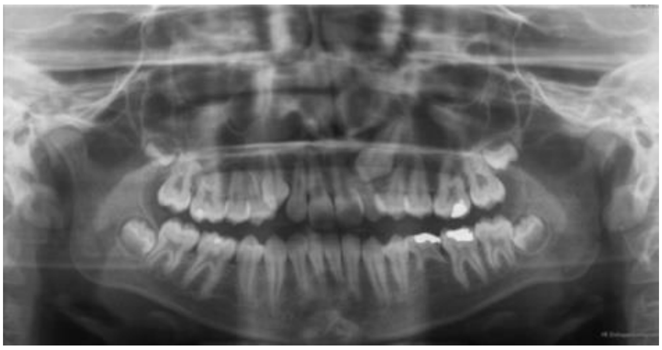

Fig 12: OPG radiograph of patient with a displaced upper left canine and absent lower second premolars **(Littlewood and Mitchell, 2019)**.

1.3.2.2.1 Indication of panoramic radiographs (Delantoni *et al*., 2022).

1) For initial diagnostic purposes and before and after treatment (Fig.13&14).
2) Comprehensive evaluation of maxilla and mandible.
3) Trauma.
4) Wisdom teeth localizations.
5) Known or suspected large lesions.
6) Dental development examinations in the mixed dentition period.
7) TMJ pains.
8) In people who cannot tolerate intra-oral radiographs.

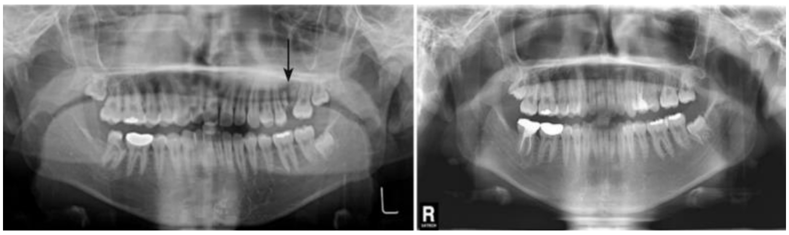

Fig 13: picture in the left show Panoramic radiograph before treatment visualizes the residual roots of the first molar (black arrow). And picture in the right show Panoramic radiograph after treatment **(Graber *et al*., 2005)**.

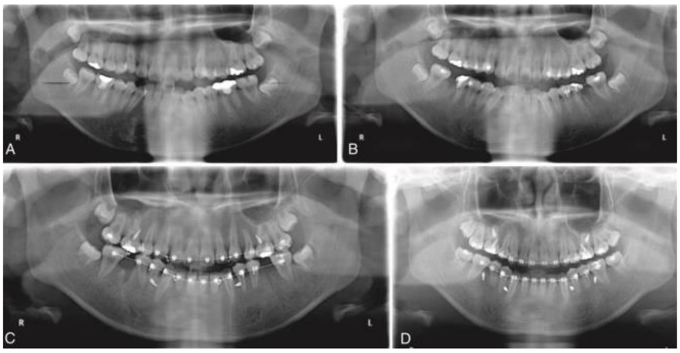

Fig 14: A, Panoramic radiograph before treatment. B, Panoramic radiograph after hemisection and extraction of the distal portion of the first molar. C, Panoramic radiograph after extraction of the mesial portion of the first molar. D, Panoramic radiograph after space closure **(Graber *et al*., 2005)**.

1.3.2.3 Cephalometric radiographs

The lateral cephalogram depicts a projection of the entire craniofacial structures onto a sagittal 2D plane. It is mainly used to perform cephalometric analyses to compare a patient's measurements to standard norms. Cephalometric radiographs are very valuable in orthodontics as they provide a measurable assessment of maxilla, mandible, dentition, and their spatial relationships in the anteroposterior and vertical dimensions. Anatomical structures such as the condyles, temporal fossa, and auditory meatus are sometimes more challenging to identify as they are not located on the mid-sagittal plane (Fig.15). The 2D posteroanterior cephalogram is not commonly employed as a part of routine orthodontic records despite its usefulness in transverse analyses **(Retrouvey *et al*., 2021)**.

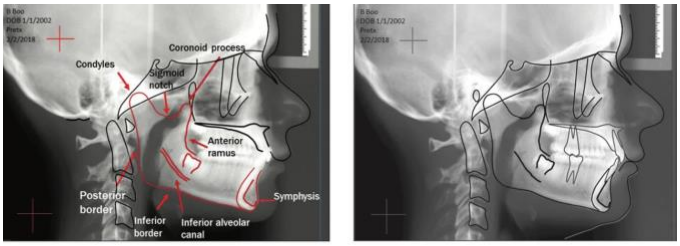

Fig 15: The mandibular symphysis, body, ramus, condyles, and coronoid processes are traced **(Kula *et al*., 2020)**.

1.3.2.3.1 Indication of cephalometric radiographs (Littlewood and Mitchell, 2019).

1) Aid to diagnosis and treatment planning.
2) Pre-treatment record.
3) Monitoring treatment progress.
4) End of orthodontic treatment.
5) Research purposes.

1.3.2.3.2 Commonly used cephalometric points and reference lines.

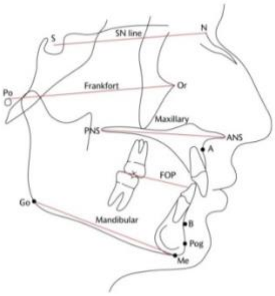

Fig 16: Commonly used points and reference lines **(Littlewood and Mitchell, 2019)**.

1.3.2.3.3 Assessment of Anteroposterior skeletal pattern

1) Angle ANB

In order to be able to compare the position of the maxilla and mandible, it is necessary to have a fixed point or plane. The skeletal pattern is often determined cephalometrically by comparing the relationship of the maxilla and mandible with the cranial base by means of angles SNA and SNB. The difference between these two measurements, angle ANB(Fig.17) **(Singh, 2007)**. So is classified broadly as follows:

ANB < 2°= Class III, 2°- 4°= Class I, ANB > 4°= Class II

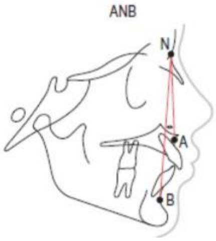

Fig 17: classification of ANB angle **(Littlewood and Mitchell, 2019)**.

2) Wit's analysis

This analysis compares the relationship of the maxilla and mandible with the occlusal plane. There are several definitions of the occlusal plane, but for the purposes of the Wits analysis it is taken to be a line drawn between the cusp tips of the molars and premolars (or deciduous molars), which is known as the functional occlusal plane. Perpendicular lines from both point A and point B are dropped to the functional occlusal plane to give points AO and BO. The distance between AO and BO is then measured. The mean values are 1 mm (SD ±1.9 mm) for males and 0 mm (SD ±1.77 mm) for females (fig.18). The main drawback to the Wits analysis is that the functional occlusal plane is not easy to locate, which obviously affects the accuracy and reproducibility of the Wits analysis. A slight difference in the angulation of the functional occlusal plane can have a marked effect on the relative positions of AO and BO **(Naragond *et al*., 2012)**.

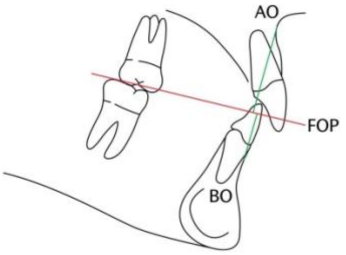

Fig 18: Wit's analysis. For MH (female, age 13 years), the distance from AO to BO for MH is 0.3 mm, suggesting a Class I skeletal pattern **(Littlewood and Mitchell, 2019)**.

3) Ballard conversion

This analysis uses the incisors as indicators of the relative position of the maxilla and mandible. It is easy to confuse a Ballard conversion and a prognosis tracing, but in the former the aim is to tilt the teeth to their normal angles (thus eliminating any dentoalveolar compensation) with the result that the residual overjet will indicate the relationship of the maxilla to the mandible (Fig.19) **(Singh, 2007)**.

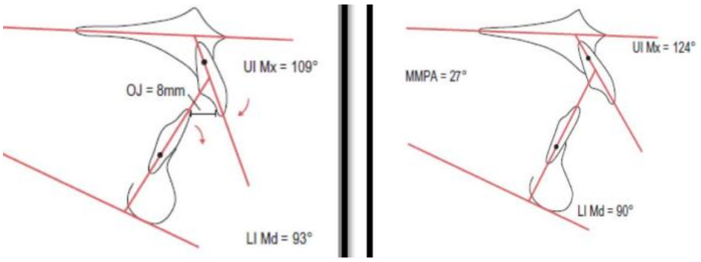

Fig 19: Ballard conversion tracing **(Littlewood and Mitchell, 2019)**.

1.3.2.3.4 Assessment of vertical skeletal pattern

1) Maxillary-mandibular plane angle (MMPA)

The MMPA is a common method for evaluating the vertical jaw relationship, with horizontal reference planes that are easily located. The mean value is 27° ± 5° (Fig.20) **(Kumar and sundareswaran, 2014)**.

2) Frankfort-mandibular plane angle (FMPA)

The FMPA uses the Frankfort plane as a horizontal reference to the mandibular plane. This method ignores the maxillary plane, which if affected by a significant cant can give a misleading value to the vertical jaw relationship. It is useful to use this measurement in conjunction with the MMPA plane angle. The mean value is 27° ± 5° (Fig.20) **(Kumar and sundareswaran, 2014)**.

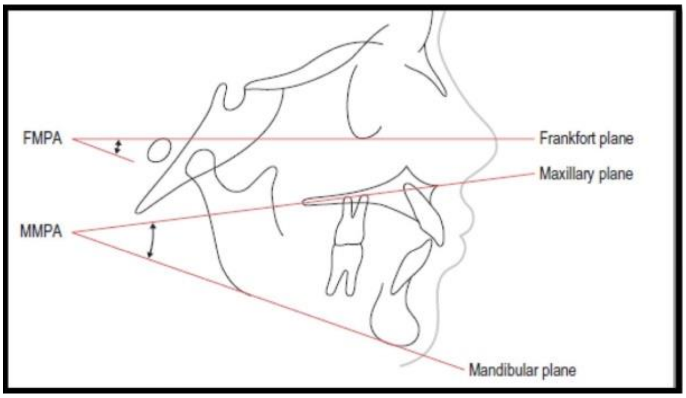

Fig 20: Vertical facial relationships. FMPA, Frankfort–mandibular plane angle; MMPA, maxillary–mandibular plane angle **(Littlewood and Mitchell, 2019)**.

3) Anterior and posterior face heights

Total anterior face height (TAFH) extends from nasion to menton, with both lines constructed perpendicular to the maxillary plane (mean 119 mm in an adult male).

TAFH is further subdivided into:

- Upper anterior face height (UAFH); nasion to maxillary plane (mean 54 mm). Lower anterior face height (LAFH); maxillary plane to menton (mean 65 mm) and Total posterior face height (TPFH) extends from sella to gonion, with both lines constructed perpendicular to the maxillary plane (mean 79 mm in an adult male) (Fig.21).

TPFH is therefore subdivided into:

- Upper posterior face height (UPFH); sella to maxillary plane (mean 46 mm). Lower posterior face height (LPFH); maxillary plane to gonion (mean 33 mm) and The TPFH should be approximately 65% of the TAFH.

It should be noted that the TPFH (unlike the TAFH) is influenced by a particularly superior or inferior position of sella and this will affect the TPFH/TAFH ratio. Referring to the SN–maxillary plane angle can cheque the relative position of sella within the cranium. The LAFH should be approximately 55% of the TAFH (Fig.21) (**Littlewood and Mitchell, 2019)**.

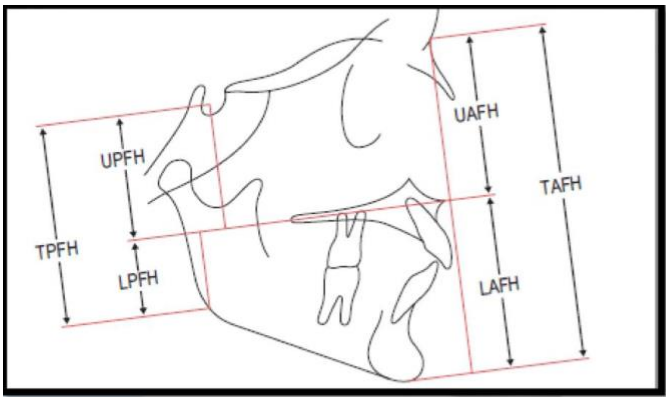

Fig 21: Face heights. LAFH, lower anterior face height; LPFH, lower posterior face height; TAFH, total anterior face height; TPFH, total posterior face height; UAFH, upper anterior face height; UPFH, upper posterior face height **(Littlewood and Mitchell, 2019)**.

1.3.2.3.5 3D Cephalometry

- Cephalometric analysis in orthodontics is an important diagnostic tool for the assessment of craniofacial morphology. The lateral cephalograms enable orthodontists to determine the size and shape of the jaws, their position in sagittal and vertical relation to the anterior base of the skull, and their position in relation to each other. It involves determining hard tissue and soft tissue landmarks and making angular and linear measurements. The information provided by the lateral cephalogram about the vertical and sagittal structure of the facial skull cannot be obtained by any other diagnostic measure. However, cephalometric measurements on the 2D images suffer from several limitations such as the difficulty in locating some reference points and landmarks, image distortion, differences in magnifications, superimposition of the bilateral craniofacial structures, and measurement errors. Another important drawback of lateral and frontal cephalograms is the lack of information about cross-sectional area and volume **(Bourzgui, 2012)**.

- CBCT provide a 3D method for cephalometric analysis. Compared with the traditional cephalometric radiographs, the CBCT produces images that are anatomically true (real-size 1:1 scale) with accurate volumetric 3D depiction of hard and soft tissues of the skull and lack of superimposition of the anatomical structures (Fig.22). Other advantages of this method over the 2D cephalometric analysis include the reduced radiation exposure (as the 3D visualization software generates a 2D lateral image from the 3D data set) and the high precision of the linear and angular measurements obtained. Reliability studies demonstrated that cephalograms reconstructed from CBCT data have no statistically significant differences in linear and angular measurements relative to traditional cephalograms, whereas measurement error from CBCT images are lower than those from cephalograms **(Shahakbari *et al*., 2018)**.

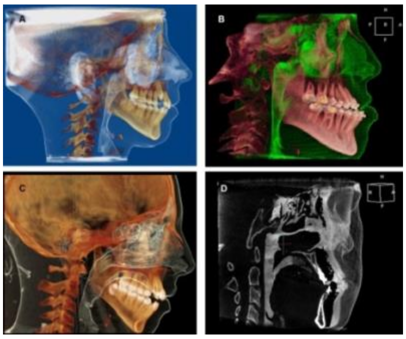

Fig 22: Volume-rendered CBCT images for the airway in either color enhanced form (A, B, and C) or shaded form (D) where the colors or the shadow are used to aid better visualization and assessment of the airway, as well as correlations with the surrounding head and neck structures **(Bourzgui, 2012)**.

1.3.2.4 Cone beam computed tomography.

Historically, 2D imaging, including traditional radiographs and photographs, combined with 3D data obtained from models and clinical examination has been a mainstay of orthodontic diagnosis and treatment planning. In contrast, in cases where indicated, the acquisition of the clinical information entirely from 3D imaging, including CBCT, would allow for the evaluation and analysis of the true anatomy providing clinically accurate 3D representations of craniofacial structures, teeth and roots with no superimposition of structures. Unlike several other 3D imaging methods (e.g., structured light or surface laser scanning), CBCT imaging, in addition providing acceptable representation of soft tissue surface anatomy has the advantage, over most 3D imaging modalities of incorporating details of skeletal and dental structures, albeit with the caveat that the patient is exposed to radiation **(Kapila, 2014)**. Role of cone beams computed tomography (CBCT), for dental and maxillofacial diagnostic osseous tasks has been rapidly developed as an alternative to conventional CT for assessment of the TMJ, CBCT results in images of CT-like quality, yet is made with less expensive equipment and components, shorter patient examination time, and much lower radiation dose than required for conventional CT **(Macleod and Heath, 2008)**.

1.3.2.4.1 Advantages of CBCT: (Macleod and Heath, 2008).

1) X-ray beam limitation.
2) High-speed scanning,
3) Size and cost.
4) Low patient radion dose.
5) Reduse image artifact.

1.3.2.4.2 Limitation of CBCT: (Kailash, 2014).

1) Image noise (Fig.23).
2) Poor soft tissue contrast (Fig. 24).
3) Artifacts.

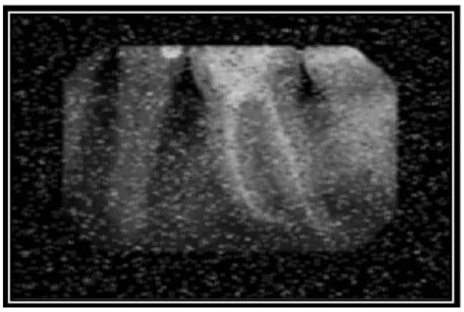

Fig 23: Image Noise **(Kailash, 2014).**

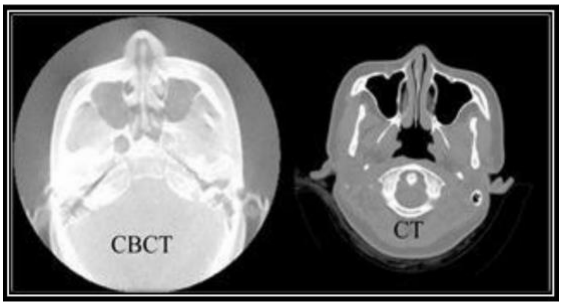

Fig 24: Typical CBCT vs. CT image in which appear the poor tissue contrast of CBCT **(Kapila et al., 2011).**

1.3.2.4.3 Application of CBCT in orthodontics:

- **Impacted and transposed teeth:** possibly are the most common indications for CBCT imaging in orthodontics. Of the many clinical situations presented to the orthodontist, impacted teeth are one in which CBCT has been shown to improve diagnosis and contribute to modifications in treatment planning in a significant number of subjects, CBCT enhances the ability to localize impacted canines accurately, evaluate their proximity to other teeth, determine the follicle size and presence of pathology and assess resorption of adjacent teeth (Fig.25) **(Kapila, 2014)**.

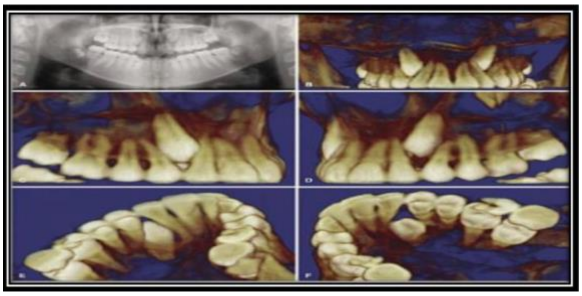

Fig 25: Depiction of impacted maxillary canines using a conventional 2D panorex (A) and3D volumetric renderings (B-F) **(Kapila, 2014)**.

- **Supernumerary teeth:** the presence of supernumerary teeth can pose a challenge in the ability to distinguish which tooth is actually the "supernumerary" and which is the "normal tooth" (Fig.26) **(Katheria *et al*., 2010)**. Accurate measurements and the determination of the precise location of the tooth from CBCT images may allow the clinician to make an informed decision on which tooth or teeth to extract on the basis of size, shape and retrievability of the teeth, The information obtained from CBCT images also facilitates the determination of the optimal surgical access to these teeth in order to minimize harm to adjacent teeth and to surrounding tissue. These points are illustrated well in a case showing the advantages of CBCT over routine radiography in deriving optimal diagnostic information and refined treatment approaches **(Kapila *et al*., 2011).**

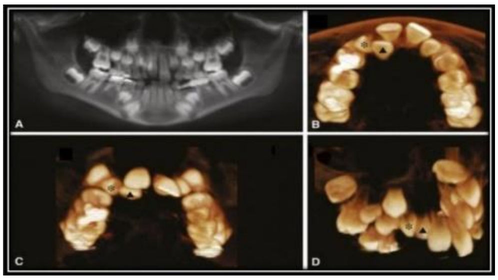

Fig 26: CBCT images offer important information and finer details in treatment planning of supernumerary teeth **(Kapila *et al*., 2011)**.

- **Root resorption, morphology:** Since root parallelism is an important goal of orthodontic treatment, its accurate determination may provide valuable information in assessing the quality of treatment outcomes and post-treatment stability. Root parallelism and relationships customarily are determined with panoramic radiographs that often demonstrate inaccuracies in root angulation, especially that of maxillary and mandibular anterior teeth **(Garcia *et al*., 2008)**. By contrast, CBCT provides more accurate root angular measurements relative to those derived from 2D radiographs **(Bouwens *et al*., 2011)**.

- **Tooth- bone relationship:** in bimaxillary protrusion cases, Class 3 patients with an initial symphysis bone width, cases with preexisting periodontal disease, after maxillary expansion treatment, CBC provides valuable information about tooth-bone relationships, and it might reduce the risk factor for dehiscence. While assessing deficiencies of buccolingual thickness in the alveolar ridge of patients subjected to critical tooth movement, high resolution and a limited FOV is recommended **(Garib, 2014).**
- **Cleft lip and palate (CLP):** CL/P are the most common craniofacial anomaly in humans, and it has significant impacts on affected individuals (Fig.27). Typically, orthodontists first perform rapid palatal expansion on CL/P patients at about 9 years of age prior to the placement of a bone graft at the defect site. This timing of graft placement allows the alveolar graft to heal in time for the canine to erupt into the arch **(Leslie and Marazita, 2013)**. Orthodontists then align the teeth, open the space for implants and/or prepare the patients for orthognathic surgery, as needed. Missing or dysmorphic incisors are common at the cleft site. Therefore, radiographs of the dentition at an early age are needed to examine the number and morphology of the patient's teeth, which provides craniofacial team time to treatment plan for extractions, restorative dentistry, orthodontics to open or close space and implants. While 2D radiographs have been used for this purpose, CBCT may provide more precise information on the numbers, quality and location of teeth in proximity of the cleft site **(Zhou *et al*., 2013).**

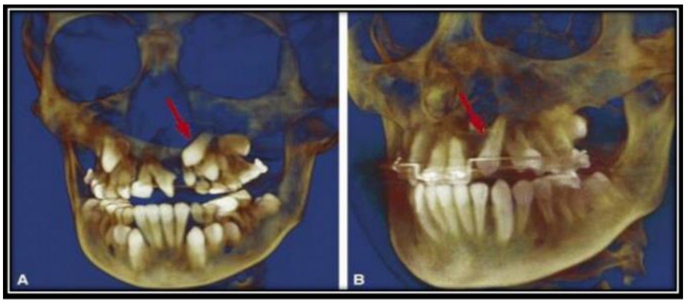

Fig 27: Volume rendering of CBCT scans of an individual with a unilateral cleft lip and palate (a) before and (b) after alveolar bone grafting **(Oberoi *et al*., 2009)**.

- **Temporomandibular joint health and disease:** The spectrum of the clinical and pathologic presentation of TMJ osteoarthritis ranges from structural and functional failure of the joint with disc displacement and degeneration (best diagnosed with magnetic resonance imaging [MRI] to Subchondral bone alteration and sclerosis(best diagnosed with cross-sectional images from CBCT or CT scans), bone erosions or overgrowth (osteophytes, best diagnosed with complementing multiplanar cross-sectional images with assessment of the respective solid 3D surface models constructed from CBCT or CT scans) and loss of articular fibrocartilage and synovitis (best diagnosed with MRI) (Fig.28) **(Ahmad *et al*., 2009)**.

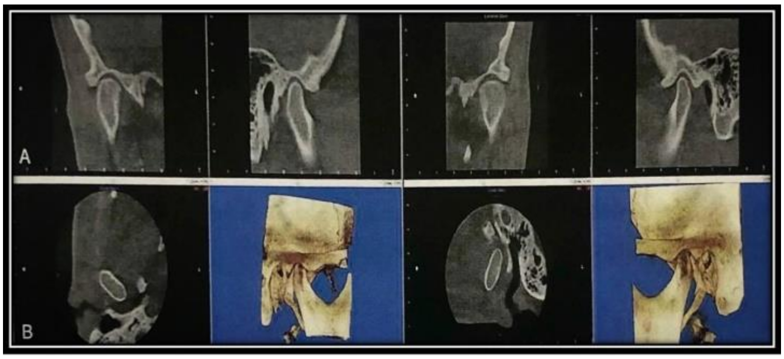

Fig 28: Right (A) and left (B) temporomandibular joint (TMJ) images acquired with a 6X6 FOV. The high- resolution images provide proper assessment of the TMJ bone anatomy **(Kapila, 2014)**.

- **Treatment outcome:** taking CBCT at the end of orthodontic treatment is a controversial issue. However, it must be taken into consideration that studies on response to treatment can help elucidate clinical questions on variability of outcomes of treatment. There are studies assessing treatment outcomes of orthognathic surgery, maxillary expansion, bone grafting and several orthopedic appliances **(Kapila, 2014)**.
- **Orthognathic treatment planning:** CBCT imaging in tandem with appropriate software and visual patent-specific models enables the examination of hard and soft craniofacial tissues and their spatial relationships. Virtual anatomical models can be fabricated from CT volumes and co-registered with other available 3D image data. The virtual models can then be used to simulate or test treatment options, construct anatomically correct replacement grafts and ultimately be an important tool during the surgical procedure (Fig.30). Databases also can be linked to anatomical models to provide the modelled tissues with attributes that simulate tissue responses to growth, treatment and function **(Schendel *et al*., 2009)**.

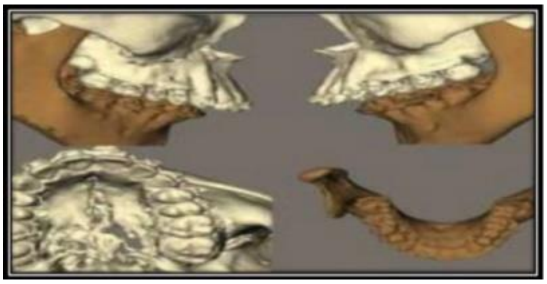

Fig 29: Hard tissue representation of the augmented bony patient model Virtual diagnosis treatment planning and evaluation of treatment outcomes for patients treated by orthognathic surgery **(Shetty et al., 2017).**

Chapter two:

Discussion

Before the onset of panoramic radiography, various X-ray projections have been in use in dentomaxillofacial radiology to demonstrate teeth and maxillofacial skeleton. Many of them have been replaced by panoramic radiography, but several types are still requested. The next change in dentomaxillofacial radiology was introduction of cone-beam computed tomography, and its popularity can be judged by number of brands offering such equipment as well as growing numbers of installations in dental offices, apart from hospitals and diagnostic imaging centres. In more recent years, there has been a move towards 3D digital records for orthodontic patients.

Intraoral scanning can now be used, instead of traditional impressions, to produce virtual study models. Software can be used to efficiently measure arch lengths, tooth size discrepancies, as well as provide ‘virtual treatment set-ups’ offering predictions of the likely occlusion at the end of treatment. When combined with the information gained from CBCT, this may allow a better 3D understanding of the relation- ships of the crowns to the roots and surrounding alveolar bone, helping to define the biological bony limits of any orthodontic treatment. In recent years, the use of CBCT in orthodontics has gained popularity and preferred as an imaging method by many clinicians for diagnosis and treatment planning Clinicians should have comprehensive knowledge about advantages, disadvantages, limitations and the risks due to increased radiation dose before deciding to use CBCT. The possibilities of CBCT application for orthodontic reasons range from impacted teeth to TMJ morphology, according to some studies, CBCT should not be considered as a routine and standard method of diagnosis and treatment planning, based on its high radiation dose compared with conventional radiographs and availability of limited supporting evidence provided.

Chapter three:

Conclusions and Suggestions

3.1 Conclusions

1-Any radiograph carries a low but identifiable risk, so each radiograph must be clinically justified. A radiograph is only prescribed after a full clinical examination to ensure that information cannot be gained by a less invasive method. In contemporary dental practice it is utterly impossible to imagine diagnostic work- flow without the benefits of radiology.

2-Radiographs are the foundation of imaging diagnostics in dentistry as the main areas of interest in this field are hard tissues of teeth and tooth-bearing bone. Visualisation methods using ionising radiation are still the most suitable for imaging of dental and alveolar tissues as they are based on attenuation of X-rays by dense objects.

3-Radiographic machines and cone-beam computed tomography (CBCT) are more and more frequently being installed and used in dental offices. The goals of gathering and computing digital orthodontic data are to obtain the most accurate depiction of the patient’s unique occlusal and craniofacial structures and store the data efficiently and simulate different treatment options, so to formulate a final treatment plan and compare the findings to other types of malocclusions and facilitate an analysis of treatment progress and plan for orthognathic surgery.

3.2 Suggestions

CBCT Recently used to do such analysis instead of the conventional 2D lateral cephalometric radiograph. Another aid to the clinician is the repeatability and reproducibility of this method, which reduces human error in cephalometric analysis. Further studies can be done to provide more information about how to measure anteroposterior jaw relationship using CBCT.

References

(A)

- Ahmed, F. (2006) *The efficacy of identifying incidental maxillofacial pathologies and anomalies using cone beam computed tomography by orthodontists and orthodontic residents* [Ann Arbor]: University of Michigan, 2009,844-860.

(B)

- Bourzgui, F. (Ed.). (2012). *Orthodontics: Basic aspects and clinical considerations*. BoD–Books on Demand, 185.
- Bouwens, DG., Cevidanes, L., Ludlow, JB. and Phillips, C. (2011) *Comparison of mesiodistal root angulation with posttreatment panoramic radiographs and cone-beam computed tomography.* Am J Orthod Dentofacial Orthop, 139(1), 126-132.

(D)

- Delantoni, A., & Orhan, K. (2022). *Atlas of Dentomaxillofacial Anatomical Imaging.* Springer, 1-7.

(F)

- Farman, A. G. (2007) *Panoramic Radiology, Seminars on Maxillofacial Imaging and Interpretation*, 7.

(G)

- Garcia-Figueroa, M.A., Raboud, D.W., Lam, E.W., Heo, G. and Major, P.W. (2008) *Effect of buccolingual root angulation on the mesiodistal angulation shown on panoramic radiographs.* Am J Orthod Dentofacial Orthon 134(1) 93-99.
- Garib, DG., Calil, LR., Leal, CR. And Janson, G. (2014) *Is there a consensus for CBCT use in Orthodontics? Dental Press Journal of Orthodontics*, 19(5), 136-149.

- Grabber, T. M., Vanarsdall, R. L., & Vig, K. W. (2005) *Orthodontics: Current Principals and Techniques* 4th edSt. Louis, MO: Elsevier Mosby, 1097-121.

(H)

- Hans MG, Palomo JM, Valiathan M. *History of imaging in orthodontics from Broadbent to cone-beam computed tomography.* Am J Orthod Dentofacial Orthop. 2015 Dec;148(6):914-21. doi: 10.1016/j.ajodo.2015.09.007. PMID: 26672697.

(K)

- Kailash, S. (2014) *CBCT Cone Beam Computed Tomography*. Journal of Academy of Dental Education, 1(1). 9-15.
- Katheria, BC., Kau, CH. And Tate, R. (2010) *Effectiveness of impacted and supernumerary tooth diagnosis from traditional radiography versus cone beam computed tomography.* Pediatric Dentistry, 32 (4), 304 - 309.
- Kapila, SD. (2014) *Cone beam computed tomography in orthodontics: Indications, insights, and innovation* Willev Blackwell. 71-4.
- Kapila, SD., Conley, R.S. and Harrell, W.E.Jr. (2011) *The current status of cone beams computed tomography imaging in orthodontics.* Dentomaxillofacial Radiology, 40(1), 24-34.
- Koong, B. (2017). *Atlas of oral and maxillofacial radiology.* John Wiley & Sons,58-5.
- Kula, K., & Ghoneima, A. (2020). *Cephalometry in Orthodontics: 2D and 3D.* Quintessence Publishing Company,23.
- Kumar,V.and Sundareswaran,S. (2014) *Cephalometric Assessment of Sagittal Dysplasia* - A Review of Twenty-One Methods. The Journal of Indian Orthodontic Society, 48(1):33-41.

(L)

- Leslie, EJ., Marazita, ML. (2013) *Genetics of cleft lip and cleft palate*. Am J Med Genet C Semin Med Genet, 163(4), 246-258.
- Littlewood, S. J., & Mitchell, L. (2019). *An introduction to orthodontics.* Oxford university press,63-74.

(M)

- Macleod, I. and Heath, N. (2008) *Cone-beam computed tomography (CBCT) in dental practice.* Dent Update, 35(9), 590-2, 594-8.

(N)

- Naragond, A., Kenganal, S., Sagarkar, R., Kumar and N.S., Sugaradday. (2012) *Diagnostic Limitations of Cephalometrics in Orthodontics*-A Review. *IOSR Journal of Dental and Medical Sciences.* 3(1):30-35.

(O)

- Oberoi, S., Chigurupati, R., Gill, P., Hoffman, W.Y. and Vargervik K. (2009) *Volumetric assessment ofsecondary alveolar bone grafting using cone beam computed tomography. Cleft Palate Craniofac* J, 46(5), 503-511.

(R)

- Retrouvey, J. M., & Abdallah, M. N. (Eds.). (2021). *3D Diagnosis and treatment planning in orthodontics: an atlas for the clinician* (p. 11). Springer International Publishing,7.
- Rozylo-Kalinowska, I. (2020). *Imaging techniques in dental radiology: acquisition, anatomic analysis and interpretation of radiographic images.* Springer Nature, 13-20.

(S)

- Schendel, S., Lane, C. and Harrell, Jr. (2009) *3D orthognathic surgery simulation using image fusion.* Semin. Orthod. 15. 48-56.
- Shivlal m Rawlani and Shobha S Rawlani (2014). *Oral and MaxillOfacial iMaging Techniques*,22-24.

- Shahakbari, R., Pahlevankash, M., Eshghpour, M. and Atali, A. (2018) *Comparison of digital cephalometric tracing by onyx cephalometric software versus manual method. International Journal of Contemporary Dental and Medical Reviews*. 3(1):1-5.
- Singh, G. (Ed.). (2015). *Textbook of orthodontics. JP Medical Ltd,* 73-90.
- Singh, G. (2007) *Textbook of Orthodontics. Jaypee Brothers Medical Publishers (P)* LId. 94-121.
- Staley, R. N., & Reske, N. T. (2011). *Essentials of orthodontics: diagnosis and treatment. John Wiley & Sons.*, 261-301.
  - Shetty SK, Neeraja, Dr. Kumar M and Dr. Vivek. (2017) *CBCT in Orthognathic Surgery. Scholars Journal of Dental Sciences (SJDS)* ; 4(12):547-555. **(T)**
- Taneva E, Kusnoto B, Evans CA(2014) *3D scanning, imaging, and printing in orthodontics. Issues in Contemporary Orthodontics.* Bourzgui F (ed): IntechOpen, London, UK;. 10.5772/60010.
- Tanna NK, AlMuzaini AAAY, Mupparapu M. (2021) *Imaging in Orthodontics.* Dent Clin North Am. Jul;65(3):623-641. doi: 10.1016/j.cden.2021.02.008. Epub 2021 May 3. PMID: 34051933.

(W)

- White, S. C., & Pharoah, M. J. (2018). *White and Pharoah's Oral Radiology: Principles and Interpretation.* Elsevier Health Sciences,291-299

(Z)

- Zhou, W., Li W., Lin J., Liu, D., Xie X, and Zhang Z. (2013) *Tooth lengths of the permanent upper incisors in patients with cleft lip and palate determined with cone beam computed tomography.* Cleft Palate Craniofac Journal, 50(1), 88-95.