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Review Article

Modern diagnostic aids: Exploring advanced tools

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ABSTRACT

Orthodontic diagnosis and treatment planning have evolved in recent years making it more reliable and easy clinical tool. Recent diagnostic tools are issue oriented. Orthodontic treatment is carried out in all three dimensions, but we were having diagnostic aids to examine patient in two dimensions. But, now the concept of orthodontic treatment have changed w.r.t aesthetics and function. The recent advancement of digital technologies is 3D imaging making it more dynamic. The 3 dimensional diagnostic tools include digital scanning, 3D models, digital radiographic records and analysis, CBCT, CAD/CAM technology and 3D printers. The accuracy has been increased. Diagnostic capabilities of the imaging tools have been improved with digital processes, making orthodontic treatment more efficient, accurate and comfortable as compared to past. This article aims to give an insight into recent technology in diagnostic tools.

1. Introduction

Varied diagnostic methods are the clinical tools which help in diagnosis and treatment planning of abnormal cases which is important for better results. It is important to maintain all the records of treatment progress for more efficient treatment results.[1] The process of diagnosis involves clinical examination and evaluation of the problem followed by interpretation of diagnostic records and the information gathered from them.[2] A problem list is then formulated and a specific goal oriented treatment plan is formulated. Thus, the accuracy of information gathered is the most important factor in formulation of a good treatment plan. Inadequate records lead to poor standards of treatment.[3,4]

Orthodontic diagnostic aids comprise of case history, clinical examination, study models, radiographs and photographs. This is the basic set of information required in all the cases. Pretreatment records of malocclusion, are irreversibly altered by the treatment. They are the evidence to patient-doctor or medicolegal disputes. These records must be permanent, durable, clear and easily stored and retrievable.[5] Records are needed for follow up of the case and evaluating treatment outcome.

2. Radiation techniques

2.1. Cone beam computed tomography (CBCT or CBVI)

Cone-beam volumetric imaging (CBVI), also called cone-beam computed tomography (CBCT), has been used in dentistry since 1998. The images it produces are true 3D images, without the distortion seen in either 2D pictures or digital images and radiographs.[6]

2.1.1. Applications

1. Implant site evaluation.

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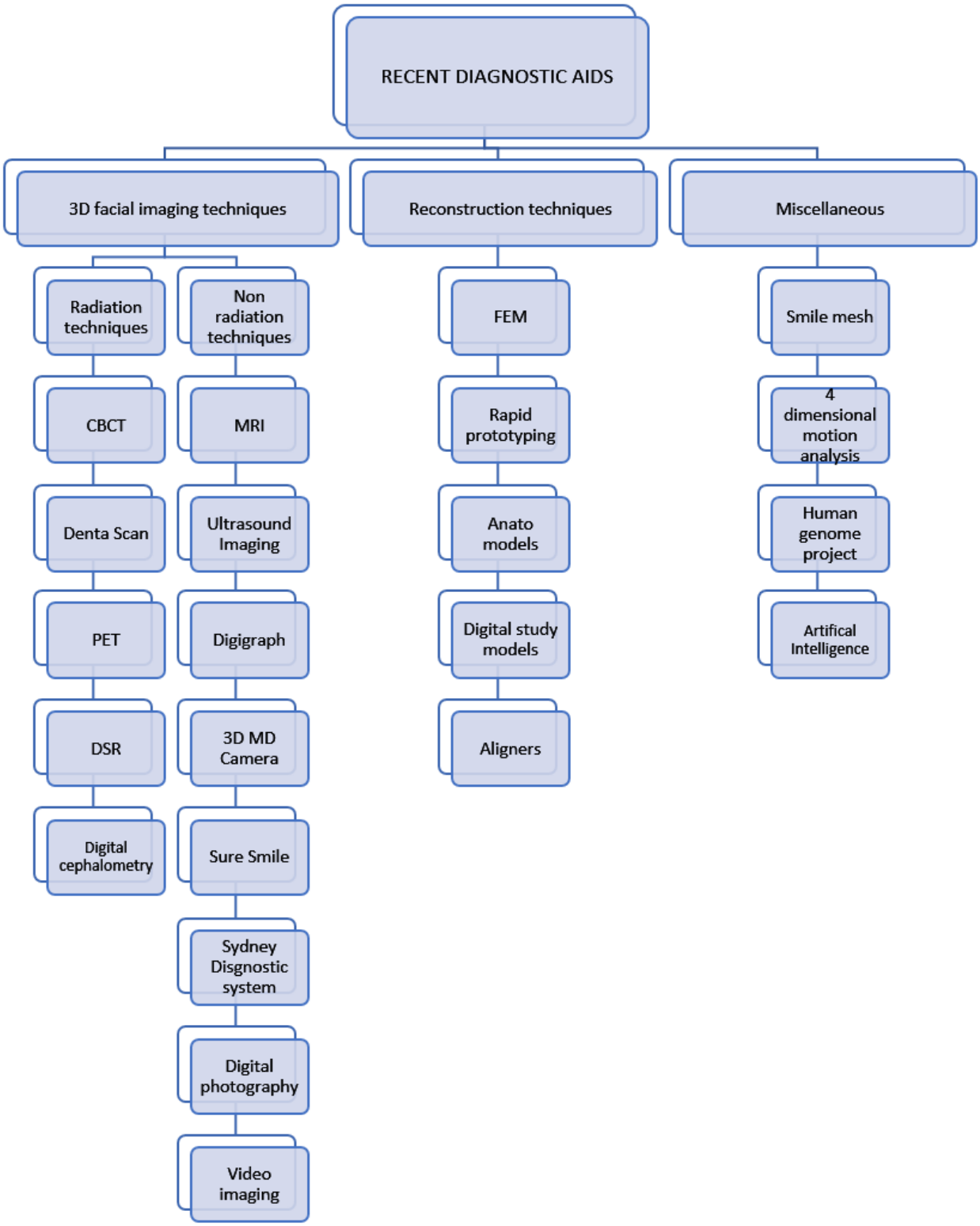

Figure 1: Classification of recent diagnostic aids

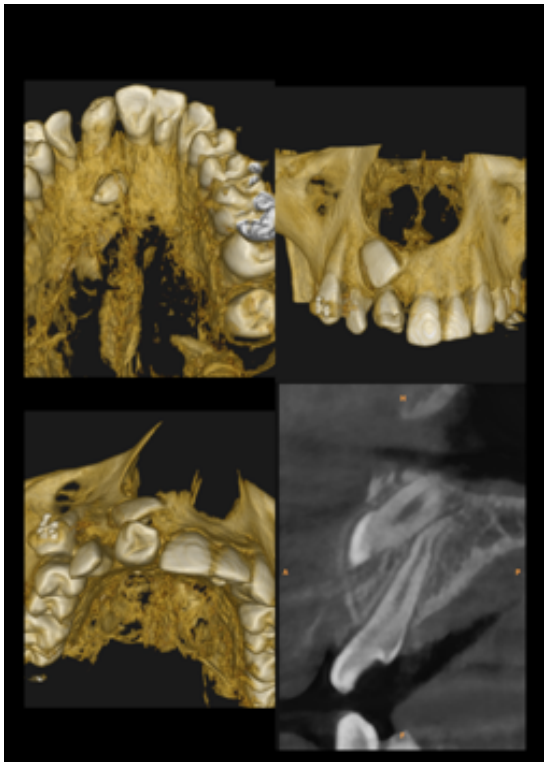

Figure 2: CBCT Scan & Image.

2. Assessment of impacted teeth.
3. 3D & 2D Orthognathic/ Orthodontic evaluation.
4. Maxillofacial trauma, fractures and lesions.
5. TMJ assessment
6. Maxillofacial deformities & alveolar clefts.
7. Examination of paranasal sinuses.
8. Assessment of facial asymmetries
9. Airway examination.
10. Detect and examine cysts, tumours or other abnormalities in the exposed volume.[6]

2.1.2. *Advantages*

1. Rapid scan time.
2. Beam limitation.
3. Image accuracy.
4. Reduced patient radiation dose.
5. Ray sum or ray casting any multiplanar image can be thickened.
6. Decreased radiation dosage.[7–9]

2.1.3. *Disadvantages*

1. Supine positioning of the patient during scanning may alter the position of the facial soft tissues.
2. There may be difficulty in identifying anatomic landmarks as sella, porion and articulare due to lack of fine detail in the definition of landmarks.
3. Metal artefacts from dental restorations and implants compromise image quality in the occlusal plane.[7–9]

2.2. *Dentascan*

Dentascan was developed by Schwarz et al (1987). It is a specialized type of computed tomography study (CT or "CAT" scan), performed on a conventional CT scanner specially for obtaining true cross-sections of the mandible and maxilla. Thin slice images are obtained, reconstructed then run through a software program to produce paraxial and panoramic images.[10]

Figure 3: Dentascan[11]

2.2.1. *Applications*

1. Visualization of internal bone morphology in 3 dimensions; assists in precise treatment planning.
2. Bone quality and density can be made in cross-sectional view.
3. Pre-operative planning and pre-operative modeling of endosseous dental implants and subperiosteal implants.
4. Evaluation of cysts, tumors, and fractures in the jaw.
5. The precise location of the mandibular canal.
6. The location of the floor of the maxillary sinuses.[10]

2.2.2. *Advantages*

1. Bone height and width can be measured.
2. Identification of soft and hard tissue pathology.
3. Localization of anatomical structures.
4. Measuring the vital qualitative dimensions necessary for implant placement.[10]

2.2.3. *Disadvantages*

1. Greater radiation exposure.
2. Expensive.[10]

2.3. Pet scan

PET imaging was developed in the 1970s for brain research purposes. It is an imaging technique that helps in revealing metabolism or biochemical function in body tissues and organs. It uses a safe injectable radioactive drug called a tracer to show both typical and atypical metabolic activity. This is normally radioactive glucose that is injectable into the vein. PET scan unlike other imaging technique, focus on processor and molecular activity in the body, giving the potential to find disease in its earliest stage. Diseased cells in your body absorb more of the radiotracer than healthy cells. These are called 'Hot spot'. The scanner detects diseased cells that absorb large amounts of the radiotracer, which indicate a potential health problem. If PET scan and CT scan are performed at the same time (PET-CT) it produces 3D images providing more accurate diagnosis. [12]

2.3.1. Applications

1. Assessment of condylar growth activity in cases of condylar hyperplasia.
2. Abnormal bone activity in occult disease of the jaws.
3. Detection of osteoblastic metastatic tumors involving bone.
4. Diagnosing osteonecrosis of the jaw.
5. Metastasis of cancer cells.
6. Access the effectiveness of treatment.
7. Evaluate prognosis of cancer. [13]

2.3.2. Advantages

1. Provides a mean of assessing physiologic changes in the absence of anatomic change.
2. High sensitivity and specificity.
3. Early detection of disease. [13]

2.3.3. Disadvantages

1. Cost of the tests and the equipments used is high.
2. Radiation builds up in a patient's body over a lifetime, a higher risk of the negative health effects associated with radiation exposure, such as cancer.
3. Nuclear medicine produces radioactive waste products, creating a disposal problem. [13]

2.4. Subtraction radiography digital (DSR)

Digital subtraction radiography was introduced by B.G Zeides des Plantes in 1920. It is a method that resolve deficiencies and increase diagnostic accuracy emphasize differences between pairs of radiographs by reducing 'structural noise' i.e., eliminating the structures that remain the same between the radiograph pairs and displaying them as a neutral background in the subtracted 'resultant image'. Image or pixel subtraction is an image processing technique in which the digital numeric value of one pixel or whole image is subtracted from another image and a new image is generated. [14,15]

2.4.1. Applications

1. Detect small osseous changes.
2. Useful in diagnosis of dental, periodontal and carious lesions.
3. Quantitative estimation of mass or volume of a lesion.
4. Absolute bone mass or volume changes can be measured using a reference wedge.
5. Measure up to 5% bone changes with greater than 90% accuracy.
6. Contrast enhancement of image with color has been suggested to aid in detection of small defects (periodontal).
7. Detection of small changes in mandibular condyle position and integrity of articular surface or osseous remodeling around granular hydroxyapatite implants.
8. Assessing progress of periodontal therapy and failure of implants therapy. [16]

2.4.2. Advantages

1. Efficient method for comparing and analyzing images of the same source.
2. Technique is very sensitive and detect changes which are very small. [16]

2.4.3. Disadvantages

1. Subtracted image must be of identical anatomy region.
2. Density and contrast of original radiograph affect that of resulting image.
3. Standardization of geometry is the biggest challenge to DSR. [16]

2.5. Digital cephalometry

Cephalometry is a radiographic technique. Since its advent in 1931, has remained unchanged. Cephalometry is a vital tool in orthodontics for evaluation of craniofacial complex, determination of morphology and growth, diagnosis of anomalies forecasting future relationship, planning treatment and evaluating the results of growth and effects of treatment. [17]

Digital cephalometry involves recording of cephalometric images digitally i.e., a non-film medium (not on films) as a digital image. [17]

These are 2 methods of recording digital cephalometrics :-

1. Indirect digital radiography (computed radiography)- It uses plates that are radiated and then digitally scanned. It uses similar equipment as used in conventional radiography except it uses photostimulable phosphor plate which replace silver halide crystals of conventional film.

2. Direct digital radiography- It is connected directly to the computer with the use of USB and provide immediate images. [17]

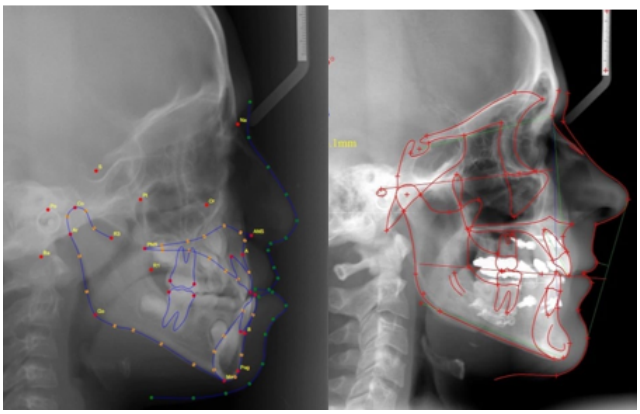

Figure 4: Cephalometric image [18]

2.6. Advantages

1. Reduced x-ray exposure 40-50%.
2. Need for x-ray film developing and processing eliminated.
3. Provide more sensitive and higher definition images.
4. Multiple original images can be made.
5. Superimposition of cephalogram possible.
6. Digital image can be manipulated and enhanced through image processing system.
7. Easy storage and retrieval of tracing. [17]

3. Non-Radiation Techniques

3.1. Magnetc resonance imaging (MRI)

The original name for the medical technology is nuclear magnetic resonance imaging (NMRI). It is a non-invasive technique. It allows 3D imaging of dental structures in any age group without any harmful radiation exposure. MRI uses strong magnetic fields and non-ionizing radiation in the radiofrequency range to provide contrast for distinguishing pathological soft tissue from normal soft tissue. [19,20]

Principle- MRI works by obtaining a resonance signal from the hydrogen nucleus i.e. its imaging of water in the tissue. There is enhancement of signal-noise ratio, contrast resolution and imaging time. [19]

3.1.1. Types of MRI

1. Diffusion MRI
2. Magnetic resonance spectroscopy
3. Functional MRI
4. Interventional MRI
5. Radiation therapy simulation
6. Current density imaging
7. Magnetic resonance guided focused ultrasound
8. Multinuclear imaging

3.1.2. Applications

1. Examine bones, joints and connective tissue e.g., cartilage, muscles and tendons for injuries or structural abnormalities
2. Examination of salivary glands, maxillary sinuses
3. Application in implant dentistry
4. Diagnosis of head and neck lesion.
5. Congenital disorders.
6. Infections.
7. Malignant tumours.
8. Evaluation of tongue posture and deglutitive movements.
9. Evaluation of masticatory muscles.
10. Evaluation of TMJ disc: perforations and disc displacements.
11. Estimation of tongue volume. [19]

3.1.3. Advantages

1. MRI does not have radiation hazards hence safer.
2. Anatomical details are as good as in CT scan.
3. Greater tissue characterization is possible.
4. Imaging of blood vessels, blood flow, visualization of thrombus is possible.
5. High contrast images achievable [19]

3.1.4. Disadvantages

1. Long imaging time.
2. Some patients may complain of mild pain or tingling sensation.
3. Noise produced may cause discomfort.
4. Not used in patients with cardiac pacemaker.
5. Not used in patients with ferromagnetic substances implanted in body.
6. Image distortion occurs in patients wearing stainless steel appliances like brackets, wires.
7. Expensive.
8. Room used should be free of ferromagnetic materials. [19]

3.2. Ultrasound imaging

Ian Donald introduced the ultrasound in diagnostic medicine in 1956, used to measure the parietal diameter of the fetal head. Sound waves with vibrating frequency in the range of 1 to 20 MHz are used in diagnostic ultrasonography. It is a non-invasive radiation free procedure. It has a great diagnostic value. [21]

Principle- Scanners used in sonography generate electrical impulses that converted into ultra-high frequency sound waves by a transducer (convert one form of energy into another). Sound waves that are reflected back toward

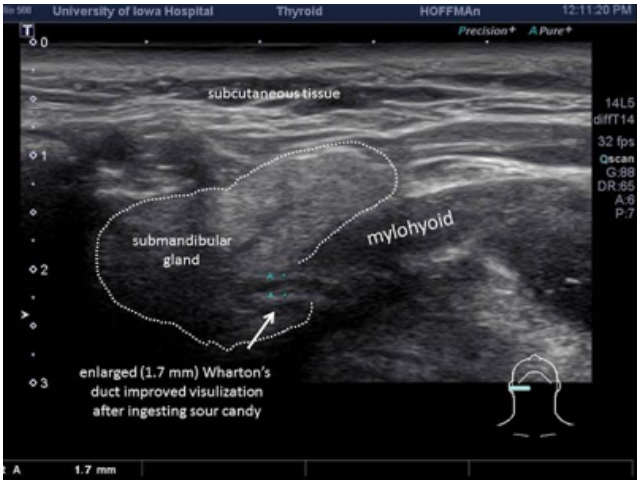

Figure 5: Ultrasound Examination (Submandibular salivary gland).[22]

the transducer cause a change in the thickness of the piezoelectric crystal, which produces an electrical signal that is amplified, processed and ultimately displayed as an image on a monitor.[21]

3.2.1. Applications

1. Assessment of lymph nodes- benign/ malignant.
2. Periapical lesions.
3. Fractures in maxillofacial region.
4. Studying tongue morphology and tongue function.
5. Post-surgery, oedema and hematoma.
6. Detection of thyroid gland and parotid gland lesions.
7. Temporomandibular disorders.
8. Detection of sialoliths.
9. Demonstrate thickness of soft tissue for placement of orthodontic miniscrew.[21]

3.2.2. Advantages

1. Sound waves are not ionizing radiation.
2. Useful for delineating the interfaces between solid and fluid-filled spaces.
3. It renders "live" images.
4. Inexpensive and readily available technique.
5. Instant, noninvasive method for the observation of relatively deep areas.
6. This can differentiate normal tissues and pathological lesions.
7. Spatial resolution is better in high frequency ultrasound transducers.
8. In TMJ ultrasound therapy reduces pain, swelling and improve circulation.[23,24]

3.2.3. Disadvantages

1. Sonography performs very poorly when there is a gas between the transducer and the organ of interest.
2. Difficulties imaging structures deep in the body, especially in obese patients.
3. Operator-dependent.
4. A high level of skill and experience is needed to acquire good-quality images and make accurate diagnoses.
5. Once an image has been acquired there is no exact way to tell which part of the body was imaged.[23,24]

3.3. Digigraph

The DigiGraph is a synthesis of video imaging, computer technology and 3D sonic digitizing. The DigiGraph Work Station equipment measures about 5 feet x 3 feet x 7 feet (152 cm x 91 cm x 213 cm). It is a non-invasive and non-radiographic cephalometric analysis. This device records cephalometric landmarks by lightly touching the sonic digitizing probe to the patient's skin. Two blank discs are loaded into the digigraph, to store all the first-time records of the patient.[25]

3.3.1. Advantages

1. Reduces radiation exposure.
2. Measures linear distances.
3. Measures mesiodistal width of teeth after digitization of plaster cast.
4. Perform many record taking functions.
5. Able to analyze diagnostic records at the first appointment.[25]

3.4. 3D MD camera

Visualization of teeth, roots, gums, bones, nerves, airway and relation of these to each other is done with 3D imaging. This system works on multiple cameras to generate the resulting surface mesh for a given scan. Each modular camera unit (MCU) contains three cameras: one color camera generates the texture images and two black & white cameras form the surface information. It does not use radiations.[26]

Figure 6: Simulation of 3D MD camera

3.4.1. Applications

1. Surface imaging in the fields of orthodontics, orthognathic surgeries, anthropometry and forensic science.
2. Assessment of treatment outcome.
3. Craniofacial growth study.[27]

3.4.2. Advantages

1. Highly precise digital 3D imaging is possible.
2. Non-invasive.
3. Short capture speed (1.5 milliseconds).
4. Images are of high quality and can be easily exported.
5. Images allow simulation and superimposition with radiological images.[27]

3.4.3. Disadvantages

1. Slowness of method leads to distortion of scanned image.
2. Safety issues of exposing eyes to laser beam.
3. Inability to capture soft tissue texture.
4. To obtain high density image, the face needs to be illuminated several times with light.
5. The camera does not provide 180º ear to ear facial model.
6. Procedure needs a dedicated special apparatus with precise calibration.
7. Needs complex patient positioning arrangements to avoid errors.
8. Without calibration the reliability degrades rapidly.[27]

3.5. Sure smile

The SureSmile technology was developed by Dr Rohit C. L. Sachdeva and is owned by OraMetrix. This technique uses a unique 3-D camera called an OraScanner to scan the teeth. Teeth don't reflect light as enamel is translucent. So just before scanning, teeth are coated with a liquid called SureWhite that contains some of the same ingredients as toothpaste.[28]

3.5.1. Applications

1. 3D viewing of models like frontal, lateral, posterior or occlusal views is possible.
2. Teeth can also be viewed in individual arches.
3. Operator can diagnose and plan the treatment with tools to measure tooth and arch dimensions and symmetric and asymmetric arch forms**.**
4. A coronal cross section like a 3D CAT scan is also available.[28]

3.5.2. Advantages

1. Reduce errors in treatment resulting from appliance management.
2. Provides image capturing, 3D visualization of tools for diagnosis, monitoring and patient communication.
3. Undesirable tooth movement may be reduced.
4. Arch wire selection errors may be reduced.
5. Bracket positioning errors may be reduced.
6. Bonding adhesive thickness errors can be reduced[28]

3.5.3. Disadvantages

1. Not all orthodontists offer Sure Smile.
2. The cost of Sure Smile is often higher than traditional braces.[28]

3.6. Sydney diagnostic system

This is a new non radiographic craniofacial imaging technique in which images are formed from standardized digital photograph of the lateral head and the study models. This permits orthodontic diagnosis and treatment planning without a lateral cephalogram. It is reliable in comparison to lateral cephalogram if the degree of error between images is tolerable.[29]

Figure 7: SDS image is created by incorporating dental models into digital photograph of face.[29]

3.6.1. Applications

1. Quantitative information on soft and hard tissues for diagnosis and treatment planning.
2. Provide valuable data on soft-tissue changes during orthodontic treatment.
3. Useful for repeated recordings during treatment without the risks of inherent radiation exposure.[29]

3.6.2. Advantages

1. Simple and non-invasive craniofacial imaging system.
2. Reliable and valid for orthodontic treatment planning.
3. No risk of inherent radiation exposure.[29]

3.6.3. Disadvantages

1. Exact quantitative correlation between hard and soft tissues is questionable.

2. Technique is very sensitive.[29]

3.7. Digital photography

Sir John Herschel first used the term photography in 1839. Photographs are essential aid in clinical documentation of the case. A full set of intraoral and extraoral photographs at the start, in between and at the completion of the treatment are essential. Photography turned digital since 1981 and the advantages were immediate viewing, no film processing, less need for retakes, efficient retrieval and low cost.[30]

1. Taking extraoral photographs
   (a) Frontal view with lips at rest
   (b) Frontal view with smile
   (c) Right profile view
   (d) Three-quarter view with smile

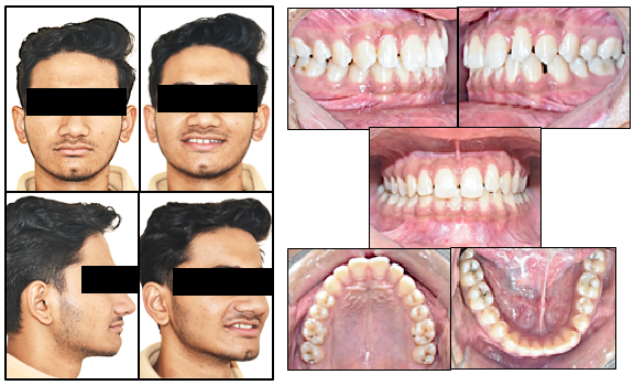

Figure 8: Digital photographs

1. Taking intraoral photoraphs
   (a) Frontal view
   (b) Right lateral view
   (c) Left lateral view
   (d) Maxillary occlusal view
   (e) Mandibular occlusal view

3.7.1. Applications

1. Diagnosis and treatment planning
2. Legal documentation
3. Forensic documentation
4. Patient education and communication[30]

3.8. Video imaging

Video is a technology of electrically capturing, recording, processing, storing, transmitting and reconstructing a sequence of still images representing scenes in motion. Imaging is the formation of an image.[31]

3.8.1. Advantages

1. Improved Communication
2. Data manipulation
   (a) Ease of archiving
   (b) Decreased storage space
   (c) Rapid comparison of treatment plans
3. Improved treatment planning
4. Interface with collaborating specialists

Comparing soft tissue with hard tissue data, reflects soft tissue changes quickly with osseous changes during the treatment planning i.e immediate visualization with the bony movement. Thereby helping in assimilation of various treatment possibilities. Coordinated collateral soft tissue esthetic surgery i.e., rhinoplasties and submental suction lipectomies can be planned.[31]

Various software programmes available are: -

1. JOE (1960s)
2. PorDios (1980s)
3. Nemoceph (2004)
4. Digigraph
5. Dentofacial planner
6. Winceph 8.0
7. OrisCeph
8. Quick Ceph (1988)
9. Lightning Ceph
10. Cephbasic (FYITEL software)

4. Reconstruction Techniques

4.1. Finite element modelling (FEM)

R. Courant first developed this technique in 1943. It is a highly precise technique used to analyze structural stress. FEM can simulate various components like teeth, alveolar bone, periodontal ligament and craniofacial bones by dividing them into smaller elements. The quantification of stress in periodontal ligament is important, as PDL plays a crucial role in tooth movement and stress in this tissue is transferred to the alveolus resulting in bone remodelling.[32]

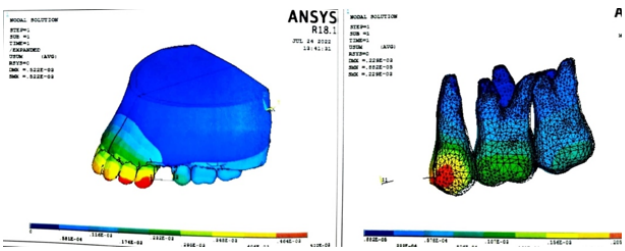

Figure 9: 3D Finite element models

4.1.1. Advantages

1. Useful in study of stresses and strains from various external forces.
2. Evaluation of craniofacial growth observed during growth changes.
3. Simulate each model for the exact pre, intra and post operative behavior.[32]

4.1.2. Disadvantages

1. Inaccurate data, information and interpretation will yield misguiding results.
2. Modeling human structures is difficult because of their complex anatomy and lack of knowledge about their mechanical behaviors.[32]

4.2. Rapid prototyping

It is a manufacturing process that converts the 3D computer data provided by a STL file format directly to a physical model, built layer by layer with a high degree of accuracy. 3D images are seen as 2D on film and the computer screen. This limitation can be overcome with the use of CT to make a model by means of rapid prototyping to produce physical models and devices by a process of material addition.[33]

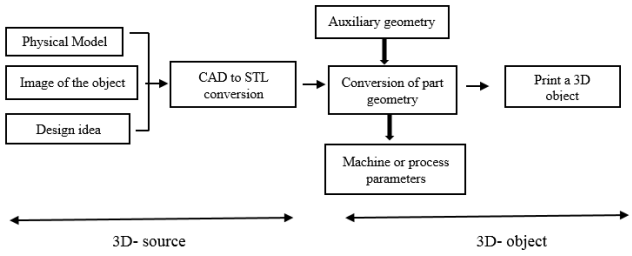

Figure 10: Process of rapid prototyping

4.2.1. Application

1. Diagnosis of an impacted tooth and fabrication of bonded attachments.
2. Preparation of customized trays for indirect bonding procedures.
3. Fabrication of high-end customized brackets and arch wires used in lingual orthodontics.
4. For fabrication of dental replica models.
5. For makings study models for surgical positioning of orthodontic mini-implants.
6. Used in cleft lip and palate patients for nasoalveolar moulding and prosthetic replacements when required.[33]

4.2.2. Advantages

1. Surgical access is made easier because models provide an accurate understanding of the anatomic relationships between the impacted tooth and the other teeth.
2. Probability of orthodontic complications is decreased because the orthodontist obtains the information necessary for optimal orthodontic mechanics.[33]

4.2.3. Disadvantages

1. Exposure of the patient to CT radiation.
2. Higher costs.[33]

4.3. The anatomodel

AnatoModel provides a tool which allows a doctor to set up both the dentition and the jaws to simulate pre-surgical orthodontics and the actual surgery. It is a 3D digital study model created directly from the CBCT scan data. Eliminating the need for impressions avoids patient discomfort and saves the orthodontist valuable chair time, staff time and materials.[34,35]

4.3.1. Applications

1. Provides cross-sectional views of the hard and soft tissues, without superimpositions.
2. Assessing treatment outcomes and different patterns of bone remodeling.
3. Allow superimposition of 3D models
4. Determine the thickness and morphology of bone at sites
5. Provide the opportunity to examine facial asymmetries, soft tissues and the airway in three dimensions.
6. Detect and examine cysts, tumours or other abnormalities in the exposed volume.
7. Cone beam imaging of impacted canines can show the size of its follicle, inclination of the long axis of the tooth, labial to palatal position, amount of the bone covering the tooth, and proximity to and resorption of roots of adjacent teeth.[34]

4.3.2. Advantages

1. Rapid scan time.
2. Beam limitation.
3. Reduced patient radiation dose.
4. Ray sum or ray casting any multiplanar image can be "thickened".[34,35]

4.3.3. Disadvantages

1. Supine positioning may alter the position of the facial soft tissues.
2. There may be difficulty in identifying anatomic landmarks.
3. Metal artefacts from dental restorations and implants compromise image quality in the occlusal plane.
4. Effective dose from conventional panoramic and cephalometric views is much less than from cone beam examinations.[34,35]

4.4. Digital study models

Study models are accurate three-dimensional replicas of patient's oral cavity. Study models have long been an essential part of diagnostic process.

They have traditionally been cast out of either plaster or stone and have served two main purposes:

1. Provide information for diagnosis and treatment planning.
2. Provide a 3-D record of the original malocclusion, mid stages, during correction and outcome of the treatment.[36,37]

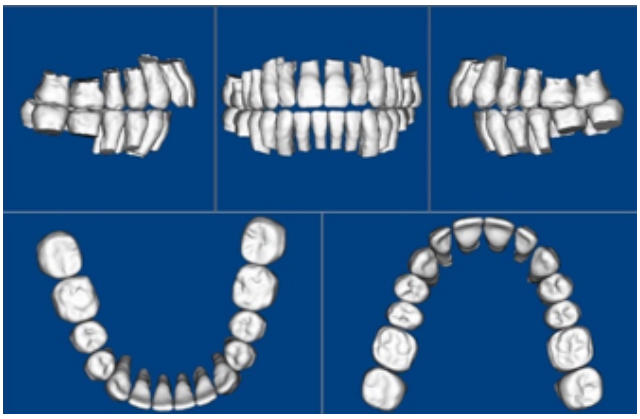

Figure 11: Digital study models

4.4.1. Applications

1. Bottom of Form
2. Storage of study model images.
3. Measurement of incisor intrusions.
4. To see effect of headgear.
5. Determine the center of rotation produced by orthodontic forces.
6. For lower incisor space analysis.
7. Assess the facial and dental arch symmetry.[36,37]

4.4.2. Advantages

1. Holograms are very resistant to damage.
2. Better suited to transport by post.
3. Can be stored with patient's clinical records.
4. Accurate measurements such as intercanine width can be measured.[36,37]

4.4.3. Disadvantages

Once made, a hologram cannot be adjusted as a set of study casts.[36]

4.5. Aligners

Harold D. Kesling in 1945, first advised the use of rubber-based tooth positioners and demonstrated that these not only helped in detailing orthodontically treated cases but could also sequentially reposition misaligned teeth. Fabricating appliances by making impressions, pouring casts, sectioning individual teeth, re-arranging them into proper alignment and repeating this process at every appointment was time-consuming process. The solution to which arrived in the form of a clear aligner system named Invisalign, which involved a series of removable polyurethane aligners created digitally by two graduates – Zia Chishti and Kelsey Wirth, launched in 1998 by Align Technology (Santa Clara, CA).[38]

4.5.1. Generations

1. Clear aligners have undergone multiple transformations over the years to treat various malocclusions more aesthetically, comfortably, and effectively.
2. These transformations of clear aligners in general and Invisalign in particular, are highly representative and have eight generations of clear aligners.[38]

5. Miscellaneous

5.1. Smile mesh

It is a multimedia computer program for smile measurement (developed by Ackermann et al) used to analyse photographs of posed smiles with lines that can be adjusted to appropriate. A posed smile is reproducible. The lip tooth relationship changes are more likely a part of ageing rather than part of growth and development. To quantify smile characteristics from photographs in a clinical orthodontic setting to capture posed social smile. This morphometric tool was created to measure the lip-tooth characteristics of anterior tooth display.[39,40]

Quantify aspects of the smile are-

1. Maxillary incisor display
2. Upper lip drape
3. Buccal corridor ratio
4. Midline offset
5. Interlabial gap
6. Intercommisure width in its frontal plane

5.2. The fourth dimension motion analysis

Smile analysis in orthodontics is important for dynamic measures to assess facial soft-tissue movements. This technology will have a successful diagnosis, treatment planning and outcome for patients with severe facial disabilities (eg, cleft lip and palate).[41,42]

5.2.1. Applications

Measurement of upper and lower lip movements in repaired cleft lip patients.[42]

5.2.2. Advantages

1. Dynamic measures to assess facial soft-tissue movements.
2. The mean animation comparisons can be viewed.[42]

5.2.3. Disadvantages

Data acquisition is limited to facial landmarks and do not include the entire 3-dimensional facial surfaces.[42]

5.3. Human genome project

The human genome project launched in 1990 and completed in 2003. It refers to international scientific research that aimed to map and sequence the complete set of genetic material (DNA). It had significant implications for orthodontics, in understanding the genetic basis for various dental and craniofacial conditions. This would change the way clinicians choose therapeutic modalities in the future.[43,44]

5.3.1. Applications

1. More accurately discern the environmental and genetic factors.
2. Measuring changes in the expression of genes and proteins within the tissue.
3. Mandibular prognathism has recently been mapped to regions on chromosomes 1, 6, and 19.[44]

5.3.2. Advantages

1. Used as diagnostic tools.
2. Screening tools in pre-symptomatic individuals who are at risk because of family history.[43,44]

5.3.3. Disadvantages

1. Genetic testing may open up ethical or psychological problems.
2. People may feel angry, depressed, anxious, or guilty about their results.
3. Genetic testing can provide only limited information about an inherited condition.[43,44]

5.4. Artificial intelligence

Artificial intelligence, term first introduced in 1955 by John McCarthy, describes the ability of machines to perform tasks that are classified as intelligent. AI refers to the ability to mimic cognitive functions of human intelligence. AI has two important branches:- expert system and machine learning. AI applications in various fields, including everyday life and medicine. AI applications in orthodontics, contributing to diagnosis, treatment planning and clinical practice.[45]

5.4.1. In the field of diagnostic imaging,

AI can be categorized into three main domains:

1. Operational AI- enhances healthcare delivery.
2. Diagnostic AI- aids in the interpretation of clinical images.
3. Predictive AI- forecasts future outcomes.[45]

5.4.2. Applications

1. Diagnosis- relies on a series of analysis to evaluate patients' facial profile, dental and skeletal relationship, skeletal maturation stages and upper-airway patency.
   (a) Cephalometric analysis- posteroanterior cephalograms assess mandibular deviation which helps in evaluating facial symmetry.
   (b) Dental analysis- provide information including molar relationship, tooth crowding, dental arch width, overjet and overbite. Manual analysis is time-consuming.
   (c) Facial analysis- evaluate facial asymmetry and proportions.
   (d) Skeletal maturation determination- determine the patients' growth spurt which is important in orthodontic treatment especially in cases of functional and orthopaedics treatments.
   (e) Upper airway obstruction assessment- upper airway obstruction can afftect breathing which can result in abnormal development of craniofacial structures leads to malocclusion and other abnormalities.
2. Treatment planning
   (a) Decision making for extractions- there is no absolute standard formula for extraction diagnosis and patterns. The decision depends on the orthodontist experience.
   (b) Decision making for orthognathic surgery- for patients with severe dentofacial deformities, combined orthodontic and orthognathic surgical treatment is required.
   (c) Treatment outcome prediction- can help orthodontist to analyze and treat malocclusions more scientifically, reduce risks and complications during and after treatment.
3. Clinical practice
   (a) Practice guidance- deep overbite is the most common malocclusion to correct. This model can provide a treatment protocol on deep overbite correction from different aspects.
   (b) Follow up- allows orthodontist to track treatment progress and provide timely feedback based on oral scans of the dentition which avoids unnecessary visits.
   (c) Clinical documentation- clinical photos and radiographs are taken for diagnosis and treatment planning. AI can help in storing these images that enhance the efficiency of clinical practice.[46]

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None.

7. Conflict of Interest

None.

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