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# Digital Evaluation Techniques In Periodontics: A Review Paper

[1]Dr. Neelam Gavali, Assistant Professor, Department of Periodontology, Bharati Vidyapeeth Deemed University Dental College and Hospital - Pune, Maharashtra, India.

[2]Dr. Yogesh Khadtare, Assistant Professor, Department of Periodontology, Bharati Vidyapeeth Deemed University Dental College and Hospital - Pune, Maharashtra, India.

[3]Dr. Pramod Waghmare, Professor, Department of Periodontology, Bharati Vidyapeeth Deemed University Dental College and Hospital - Pune, Maharashtra, India.

[4]Dr. Nishita Bhosale, Assistant Professor, Department of Periodontology, Bharati Vidyapeeth Deemed University Dental College and Hospital - Pune, Maharashtra, India.

[5]Dr. Shweta Bhole, Post-Graduate Student, Department of Periodontology, Bharati Vidyapeeth Deemed University Dental College and Hospital - Pune, Maharashtra, India.

[6]Dr Pooja Shendge, Post-Graduate Student, Department of Periodontology, Bharati Vidyapeeth Deemed University Dental College and Hospital - Pune, Maharashtra, India.

[7]Dr Shashwat Thombre, Post-Graduate Student, Department of Periodontology, Bharati Vidyapeeth Deemed University Dental College and Hospital - Pune, Maharashtra, India.

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**Corresponding Author:** Dr. Neelam Gavali, Assistant Professor, Department of Periodontology, Bharati Vidyapeeth Deemed University Dental College and Hospital - Pune, Maharashtra, India.

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## Abstract

### Aim

The aim of this review is to discuss the different digital techniques for evaluation of various periodontal parameters.

The present world is focusing on the advances which increase the accuracy of diagnosis of the disease and improves the treatment success. The current diagnostic approaches including clinical probing and intraoral radiography have shown several limitations in their reliability and accuracy. Thus the use of artificial intelligence decreases the bias and errors which are common in conventional methods. Advances in

digitization in periodontics will further help in periodontal diagnosis, implant planning and treatment. Digitization methods in future will gain more importance because of the ability to save time, efforts, reduced variability and increased accuracy.

**Keywords**

Digital Techniques, CBCT, T-Scan, Automated Probe.

**Clinical Relevance**

The current review focuses on latest advances in digitization of periodontal disease and its importance in clinical practice. Digital evaluation mainly increases the accuracy for measurement of periodontal parameters which in turn will influence the proper diagnosis and treatment plan for the disease.

## Introduction

Periodontitis is an inflammatory disease of the periodontal tissues characterized mainly by the destruction of the periodontium resulting in an irreversible loss of periodontal ligament fibers and alveolar bone. Gingivitis if not treated at early stages may lead to periodontitis. Clinically, periodontitis is identified by detailed examination of probing pocket depth, clinical attachment level, gingival recession and bone loss. The proper clinical and radiographic diagnostic procedures will help us to frame a proper treatment plan for the patient and will further help in the success of the treatment. Clinical evaluation methods as they are carried manually result in errors and bias and may vary amongst clinicians. Radiographs are a 2D dimensions and lack the 3D image design of the required area. Digital dentistry can be defined as any dental technology or device that incorporates digital or computer-controlled components in contrast to that of mechanical or electrical alone. Digitally designed methods help us to view a 3D image of the area and thus are more accurate than that of the previous good old methods. Therefore this review shows the different methods of digital evaluation for diagnosis of the periodontal disease and to view a bigger picture of the periodontium.

## Methods For Detecting Periodontal Pocket

Periodontal probing method is a very important clinically, not only for a periodontitis but also for restorative, endodontic and oral surgery. The preservation of the periodontal attachment is an important factor for determining the long term prognosis of a restored tooth, overhanging restoration margins, improper contacts points, as poor contour and iatrogenic factors will eventually lead to periodontal tissues breakdown and loss of attachment due to plaque and calculus accumulation.

The evolution of periodontal probes went through different generations which reduced bias and errors in further generations. The effectivity and accuracy of readings depends on the probe tip design, probing pressure, degree of inflammation of the examined tissues and reading and documentation precision [1,18]. Periodontal probes have been grouped in five generations [19]. The first generation includes conventional periodontal probes, which present a handle, a shank and an active part (a round tip) and different types of gradations in millimeters. The accuracy of measurements taken by conventional manual probes is +/-0.82 mm [20]. UNC-15 periodontal probe is an example of conventional probe which is the most used periodontal probe. One major drawback in this type of probes is inconsistent uncontrolled pressure which leads to over penetration of the probe tip through the thin epithelial attachment in the sulcus floor which may cause increased variability, pain & discomfort for the patient. It has been suggested that probe forces between 0.20 and 0.25 N/mm2 enable accurate diagnostic readings [22]. The second generation of periodontal probes represents pressure-sensitive probes to overcome variability in applied pressure of that in first generation but the major drawback they still suffer is lacked tactile sensitivity. The third generation of periodontal probes includes electronic, computerized probes. These probes are composed of hard component which is the probe tip, and a software component, which receives and analyses the transmitted readings. Transmission takes place through a wired or wireless connection. Automated periodontal probes were developed due to the necessity to use standardized probing forces which improved accuracy of probing measurements in periodontal clinical examination[1]. Automated probes permit a single user concept eliminating errors caused by transfer and documentation of the readings between the operator and the assistant. The fourth generation of periodontal probes includes 3-dimensional probes and the fifth generation presents non-invasive probes, still in the research phase, based on the principle of echography.

**Automated periodontal probe PA-on** (Orangedentalgmbh & Co. KG) belongs to the third generation. PA-on probe has a graphic display and a flexible tip with ball shaped fitted tip diameter of which is 0.5 mm. PA-on provide calibrated measurement with exactly 20 N/mm2 pressure force. The flexibility of the PA-on tip has an advantage of probing tight vertical defects and can better follow the curvature of the root. But the flexibility also carries the disadvantage of reduction of orientation and tactile sensation [1]. PA-on has an advantage of immediate electronic store and analysis of measurements, along with other periodontal health indicators. In addition, the automated probe provided immediate charting for other clinical features such as bleeding on probing, pain sensation and loss of attachment[25].PA-on probe also has higher pocket depth measurements electronically compared to manual probe[26]. The electronic periodontal probing proves effective for clinicians with lack of experience. The limitation of PA-on design prevents it from measuring deeper pockets more than 11 mm, which make it useless in diagnosing severe periodontal conditions with major loss of attachments and pocket depth. Nader Masarwa et al studied the speed and accuracy of automated periodontal probe (PA-on) in comparison with a manual conventional periodontal probe (Williams) on a cadaveric porcine model and they observed that there was a three times decrease of probing time. They concluded that PA-on automated periodontal probe is an efficient method of detecting periodontal pockets depth in less time and provides more accurate measurements.

The body of the 5th generation probe is manufactured similarly to other dental hand pieces, with the 10 MHz piezoelectric transducer located in the head of the probe. The fabrication of the probe allows water, which is the ultrasonic coupling agent, to be funneled through the custom-shaped tip. The rest of the components used to control the probe, including the general purpose pulsar receiver and the custom built water flow interface device [41].

Application of ultrasound in dentistry, a periodontal probe, is being developed as a spin-off of NASA technology [41,42,43]. Periodontal disease is caused by bacterial infections and in advanced stages can cause tooth loss when the periodontium has undergone destruction[44]. Periodontal disease is so widespread worldwide that 10-15% of adults has advanced stages of the disease with deep periodontal pockets that put them at risk of tooth loss [45].

**The Ultrasonographic periodontal probe** uses high-frequency ultrasound to determine the depth of the periodontal ligament non-invasively. An ultrasonic transducer projects high frequency (10-15 MHz) ultrasonic energy between the tooth and the gingiva and detects echoes of the returning wave. In the usual practice of Ultrasonography [41], the time delay of the reflection is converted to a distance measurement by using the speed of sound in water (1482 m/s). However, both experimental and simulation waveforms show that the echoes from the anatomy of interest are smaller than the surrounding reflections and noise.

Previous work with the Ultrasonography periodontal probe by Hou developed the Dynamic Wavelet Fingerprint (DWFP) method to transform wavelet coefficients to 2D binary images [41,43].The method is general, but when directly applied to data obtained from a 4th generation ultrasonographic periodontal probe tested on 14 patients [41,47], the authors used image recognition techniques to resolve at best 60% of the pocket depths accurately within a tolerance of 1mm.

**Intrabony Pockets**

Periodontal pocket occurs with the destruction of the supporting periodontal tissues. Progressive pocket deepening leads to destruction and loosening and exfoliation of the teeth[37]. Two types of pockets exist which are the Suprabony pockets and the Intrabony pockets. In Suprabony pockets the bottom of the pocket is coronal to the underlying alveolar bone. In Infrabony pocketthe bottom of the pocket is apical to the level of the adjacent bone. In this pocket, the lateral pocket wall lies between the tooth surface and the alveolar bone[37].

DICOM datasets were imported into an open source medical image processing software **(3D Slicer©)** for image segmentation. The goal of segmentation was to create 3D reconstructions of alveolar bone and teeth to allow easier analysis. Combination of semi-automatic thres holding tools (Level tracing), interpolation algorithms (Fill between slices) and manual segmentation tools (Draw, Erase), found in the Segment editor module were utilized to create separate regions of interest (ROI) for teeth and for alveolar bone. Three-dimensional polygon models are generated from the ROIs and were exported as stereo lithographic. Further occasional mesh repairs were done with an open source CAD based mesh modeling software (Mesh mixer®, Autodesk, San Rafael, California, USA). For more accurate digitalization of the clinical situation soft tissue model derived from an intraoral scan which can be superimposed over the 3D model created from the CBCT dataset3D rendering and is based on a process called Segmentation, which is described as the virtual separation of the anatomical region with the removal of all other structures of noninterest for better visualization and analysis [36]. Segmentation can be performed both manually and automatically. The manual approach is user-dependent and is performed slice by slice with the software pooling all slices to reconstruct a 3D volume. Conversely, the semiautomatic segmentation is a computer-aided approach (hybrid). The procedure usually starts with two user-guided interactive steps, i.e., the placement of initial seed regions in all three slices and the selection of a threshold interval (Hounsfield units), to provide information on the texture and background for the software [35,36]. Then, the software automatically selects the voxel of the interested region and excludes the surrounding structures.

Manual segmentation represents the gold standard for the 3D rendering of maxillofacial structures (CMF) since it allows for the detection of areas with low bone density or with no well-defined boundaries due to their low contrast and proximity to other structures [36]. However, semiautomatic segmentation is faster than a manual approach, which is relevant from a clinical perspective. Furthermore, semi-automatic segmentation is not influenced by intra-operator reliability [36], which plays an important role for clinical and research purposes.

**Clinical Attachment Level**

Pocket depth is the distance between the base of the pocket and gingival margin. The level of attachment on the other hand, is the distance between the base of the pocket and a fixed point on the crown, such as the Cement enamel junction CEJ. Changes in the level of attachment can be caused only by the gain or loss of attachment. And thus provide a better indication of the degree of periodontal destruction.

**Determining The Level Of Attachment**

When the gingival margin is located on the anatomic crown, the level of attachment is determined by subtracting from the depth of the pocket the distance from the gingival margin to the CEJ. If both are the same, the loss of attachment is zero.

When the gingival margin coincides with the CEJ, the loss of attachment equals the pocket depth.

When the gingival margin is located apical to CEJ, the loss of attachment is greater than the pocket depthand therefore the distance between the CEJ and the gingival margin should be added to the pocket depth.

**The Florida probe** is one such system which provides measurement of relative attachment level relative to fixed reference point. While the Florida probe is used, relative attachment level (RAL) is recorded relative to fixed reference points such as the occlusal surfaces of the teeth (disc probe) or a prefabricated stent (stent probe).). It is desirable to measure CAL using the CEJ as the reference point [38] recently, a modification of the Florida Probe i.e. CEJ probe was introduced to detect the CEJ to improve the accuracy and consistency.

**The CEJ probe** was initially tested by Preshaw et al [38].His results showed that the CEJ probe had reproducibility and reliability in detecting the CEJ in human skulls and measuring CAL in humans. Karpinia et al. (2004) evaluated the performance of CEJ probe in detecting CEJ as a landmark and compared with Florida disk probe and standard manual probe. He concluded that CEJ probe proved more efficient than traditional probes [40]. The CEJ probe has a modified sleeve, which includes a 0.125 mm prominent edge to facilitate a ‘‘catch’’ of the CEJ. The width of this edge was considered small enough not to interfere with probing depth measurements offering clinicians, measurement of CAL and probing depth concurrently [38.39.40].R. Deepa, Shobha Prakash et al studied the performance of the newly introduced cemento enamel junction (CEJ) probe in detecting CAL, using CEJ as a fixed reference point, and to compare the CEJ probe with the Florida stent probe (FSP) as well as with a standard manual probe, University of North Carolina 15 (UNC 15). Their study showed that the CEJ probe provedto have the greatest potential for accuracy and reliability for measurements of CAL than FSP and manual probe (UNC-15),and FSP had been proved to be better than manual probe (UNC-15), indicating that automated probes are better as far as accuracy, consistency, and reliability and can be considered for measurements of attachment levels[6].

**Recession**

Gingival recession is the exposure of the root surface following an apical shift in the position of the gingiva beyond the cemento-enamel junction (CEJ)[48,49]. It is generally seen in adults, and can be localized or generalized, involving one of more teeth. The etiological factors of gingival recession are anatomical abnormalities (thin gingival biotype or aleveolar bone, deficient keratinized mucosa, tooth drifting or pathologic migration, inappropriate renal attachment), trauma (tooth brushing), inflammation (due to presence of local factors) and from iatrogenic factors such as improper removable denture design, placement of orthodontic appliances or restorations [48,54,55]. In a healthy periodontium, the gingiva is positioned 0.5 to 2.0 mm coronal to the CEJ, and a shift from its normal position beyond the CEJ results in gingival recession [56]. Clinically, gingival recession is measured in millimeters from the gingival crest to the CEJ, using a dental probe; however, this method is thought to be semi-quantitative and inaccurate[57]. Plaster models can prove useful in cases where it is difficult to measure recession intraorally or interdental recession, as they provide a three-dimensional (3D) view allowing for detailed assessments of the impressions obtained during clinical examination without interference from soft tissues within the confines of the oral cavity [58].The disadvantages of study casts are physical and chemical damage during handling, wear and tear, and distortion when preserved for long duration[59].Therefore, digital models were introduced in the late 1990s. The advantages of using digital models are ease of storage and handling, time-effectiveness and reduced human errors and variations since data can be electronically transferred and stored.

**Digital models** may be obtained via scanning of the intraoral tissues (creating virtual models) or study casts (creating digital cast models). Intraoral scanners are devices used for capturing direct optical impressions in dentistry [48,60]. The dental arches are scanned, images of the oral tissues are captured and processed, and a 3D virtual model is finally created [61]. Similarly, plaster models are scanned using 3D scanners to create digital images. These advances in technology have proved extremely useful as diagnostic tools in dentistry. Hytham N. Fageeh et al studied the accuracy and reliability of digital measurements of gingival recession versus conventional methods. Their study concluded that the variations in measurements between examiners can be reduced by using digital technologies when compared to conventional methods. They observed that with intraoral scanning there was improved reproducibility of measurements with increased validity and reliability [48].

**Occlusion**

Occlusion is "the static relationship between the incising or occlusal surfaces of the maxillary or mandibular teeth or tooth analogues. The occlusion should be stable and as stress free as possible". The idea of occlusion is not restricted to morphological contact interactions between teeth. It embraces the harmonious relation of the masticatory system, including teeth, periodontal tissues, the neuromuscular system, the temporo-mandibular joint and the craniofacial bones (McNiel).When occlusal forces exceed the adaptive capacity of the tissues, tissue injury results .The resultant injury is Trauma from Occlusion[37]. Thus it is important to understand that trauma from occlusion refers to the tissue injury and not the occlusal force. An occlusion that produces such injury is called Traumatic Occlusion. The signs and symptoms of non-physiologic occlusion include damaged teeth and restorations, abnormal mobility, fremitus, a widened periodontal ligament, pain and subjective sense of bite discomfort[37].Nunn and Harrel in a series of studies published in 2001 and 2004 reported that two specifically defined occlusal parameters consisting of either an occlusal discrepancy between centric relation occlusion and centric occlusion and/or a non-working side contact. These studies reported that these occlusal discrepancies are an independent risk factor for the progression of periodontal disease. Burgett 1992 studied the effect of occlusal adjustment in treatment of periodontitis, 50 patients following examination at baseline were treated with root debridement and flap surgery, out of whom 22 received comprehensive occlusal therapy. He concluded that on re-examination those with occlusal therapy had on average 0.5 mm greater attachment gain than those who did not receive occlusal therapy. The true occlusal contact time by description suggests that a time of 0 s elapses between the first and the last occlusal contact, i.e., all the occluding surfaces should encounter at the same instant during the mandibular closure. Occlusal therapy aims at achieving this simultaneous occlusal contact relationship.

**T-scan occlusal analysis** system provides one option to assess occlusal forces (Chapman and Kirsch, 1990). The T-Scan system is a computerized dental device which can quantitatively analyze occlusal contacts (position, strength, and frequency of occlusal contacts)[63]. In 1987, Tekscan developed T-Scan, the first ever grid-based sensor technology precisely designed for occlusal analysis. Tekscan is a powerful diagnostic tool for the dentist seeking an accurate way to dynamically measure occlusion[63,64]. The evolution of pressure sensitive ink - Mylar encased sensor technology, was introduced with the T-Scan® I computerized occlusal analysis system by Maness et al in 1984. In 1987, Tekscan developed T-Scan®, the first ever grid based sensor technology specifically designed for occlusal analysis. The T-Scan computerized system can rapidly determine prematurity, high points, regions of excessive force and non-uniform force concentration. It can also analyze dis occlusion time accurately. It was developed as the first ever grid-based sensor technology specifically designed for occlusal analysis. Till now the advancement is reached up to t-scan version -5. The occlusal data is characterized as dynamic 2D and 3D images with colored columns ranging from BLUE (optimum force) to RED (high force) seen on the computer screen when the patient bites on the occlusal sensor. This measurable occlusal data enhances the clinician's ability to make precisely targeted adjustments during occlusal equilibration following prosthetic, restorative, orthodontic or implant procedures. T-Scan III software version 8.0 is the latest generation of this occlusal analysis technology that permits the clinician to record and explore the patient's occlusion with precision.

The system components include a sensor and support, a handle assembly, the system unit, computer software and a printer. The T-Scan permits the quantification of occlusal contact data by registering parameters such as bite length as well as the timing and force of tooth contact, and stores the data on a hard drive which can be played incrementally for data analysis in a time-based video[63,64,65].The sensor is the key component. It is 60 micrometers thick and made of a polyester film. T-Scan sensors are available in two sizes: 1. Large and 2. Small. Large size sensor can accommodate arch up to 66 mm wide and 56 mm deep and contains 1370 sensels whereas small size sensor can accommodate arch up to 58 mm wide and 51 mm deep and contains 1122 sensels. The thickness of the sensor is 0.1 mm[65] .The patient bites of a thin (75 micron) sensor. The sensor is made up of columns and rows of pressure sensitive ink, trapped in a Mylar sandwich. The sensor is attached to a handle which scans at thousandth of a second time intervals. The handle reads the data from the sensor and passes it to the computer software which presents the data in an easy to understand visual display. The system can be operated on two modes, time analysis and force analysis.

Time analysis: This mode gives information on the location and sequence of occlusal contacts, showing in a different color the location of the first, second and third or more contacts. On the top of the monitor screen is displayed the timing of each successive contact with regard to the first.

Force analysis: This mode offers the operator with data on the location and relative force of tooth contact. On the bottom of the screen, bite length can be read Within force analysis, two additional modes can be selected, instantaneous (which registers mandibular positions) and sequential (which registers the intensity of contacts during mandibular movement)[66].

Recording technique: The recording handle with the sensor and arch support is placed between the maxillary central incisors of the patient. The recording is initiated by pressing the button on the recording handle. The patient is asked to close the mouth till complete intercuspation is reached, without making any excursive movements. For this, the sensor is inserted into the patient's mouth in such a way as to make its support aligned centrally with the midline of the upper incisors. The patient is then asked to bite on the sensor in a maximum intercuspation position. After the handle button is pressed the arch model is automatically created on the screen. It should be taken into account that this model is an approximation of the patient's arch and therefore uncertainty exists as to the exact location of the contact on the screen [63,64]. Data interpretation - The data recorded is shown as a force film, in which the center of force trajectory shows the history of the path of the center of the force from the beginning of the force movie recording to the current displayed frame [63,64].

**Uses Of CBCT In Periodontology**

Diagnosis of periodontal disease depends mainly on the clinical and radiographic examination. However, in the case of bone destruction, radiographs are valuable diagnostic tools as an adjunct to the clinical examination. Two dimensional periapical and panoramic radiographs are routinely used for diagnosing periodontal bone levels and pathologies. In two dimensional imaging, evaluation of bone craters, lamina dura and periodontal bone level is limited by projection geometry and superposition's of adjacent anatomical structures. Those limitations of 2D radiographs can be eliminated by three-dimensional imaging techniques such as computed tomography. Cone beam computed tomography (CBCT) generates 3D volumetric images and is also commonly used in dentistry. All CBCT units provide axial, coronal and sagittal multi-planar reconstructed images without magnification. Also, panoramic images without distortion and magnification can be generated with curved planar reformation. CBCT displays 3D images that are necessary for the diagnosis of intra bony defects, furcation involvements and buccal/lingual bone destructions.

CT can be categorized into two groups according to the geometry of X-ray beam: 1-Fan beam and 2-Cone beam. Cone beam computed tomography (CBCT) generates 3D volumetric images and is commonly used in dentistry[67,68]. CBCT technology has developed rapidly since it was first used in 1982 at Mayo Clinic Biodynamic Research Laboratory for angiography, radiotherapy and mammography applications. In CBCT technique, a cone-shaped X-ray beam rotates around the patient's head and collects base images used to construct 3D volumetric data from which multi-planar (axial, sagittal, coronal and cross-sectional) reconstructions can be generated[67,68]. Voxel sizes affect CBCT image quality and alveolar defects can be evaluated with highest accuracy when smaller voxel sizes are utilized[69].Accuracy of alveolar bone height measurements are inversely proportional to voxel sizes of CBCT images evaluated[70] which provide a scan of the entire region of interest [71,72]. The collimation of the X-ray beam to the area of interest minimizes the radiation dose. Most CBCT units offer different field of view (FOV) options with various sizes. The use of small FOV lowers the effective radiation dose[67-73]. The voxels in CBCT units are isotropic that enables sub-millimeter geometric resolution, thereby; a high degree of measurement accuracy can be obtained. This feature determines the high diagnostic capacity of CBCT images obtained from high-density dento-maxillofacial structures such as teeth and bone[67]. Whereas medical CT requires multiple rotations entailing high effective radiation doses, with CBCT, a single rotation is sufficient for the acquisition of base images[67]. Panoramic images can also be generated with curved planar reformation. Multiplanar image can be thickened by increasing the number of adjacent voxels and it is also possible to apply 3D volume rendering and modeling by use of appropriate software package[72]. In comparison to medical CT, CBCT offers lower radiation dose and cost along with smaller space requirement. CBCT has better spatial resolution when compared with medical CT[76,77]

**Furcation involvement**

An accurate diagnosis of inter ridiculer bone loss is an important step before the decision making of various treatment options. Conventional two dimensional radiographs can be advantageous in evaluating periodontal tissue support and inter ridiculer bone due to superposition of anatomical structures. However, 3D images provide detailed information about areas of multi rooted teeth. CBCT images of maxillary molars provided detailed information of furcation involvement and a reliable basis for treatment decision[79]. Walter et al studied the intrasurgical furcation involvement measurements which were compared by using CBCT images and it was reported that CBCT images demonstrated a high accuracy in assessing the loss of periodontal tissue and classifying the degree of furcation involvement in maxillary molars.

**Soft tissue assessment**

CBCT is a more appropriate tool for evaluating mineralized tissues than soft tissues[67]. However, Januário AL reported a practical method named soft tissue CBCT (ST-CBCT) and utilized it to examine the dimensions and relationships of the structures of the dentogingival unit. The tongues were retracted toward the floor of patients' mouths and a plastic lip retractor was used to retract the soft tissues away from the teeth and gingiva during CBCT scans and the images that were obtained provided clear information for the analysis of various dentogingival unit measurements. Mentioned method was used in another study in which the average thickness of the palatal mucosa according to ages and specific localizations were determined on thirty one patients. The thickness of palatal mucosa has a major importance for the treatment planning of soft tissue grafts. However, this technique provides only quantitative assessment, thus the differences between the epithelial, fat and connective tissues cannot be distinguished on ST-CBCT images.

**Alveolar Bone Defect**

Radiographs are frequently utilized to diagnose the amount and shape of alveolar bone destruction that affects treatment planning in periodontal therapy. 2D radiographs can be insufficient for the detection of intra-bony alveolar defects due to obstruction of spongious bone changes by cortical plate. Thus, three-dimensional imaging is required for mapping of alveolar defect. Periodontal defects in pigs and human mandibles were displayed using intraoral radiography, panoramic radiography, CT and CBCT which were compared with histological specimens. The results of the mentioned study showed that 3D imaging had high accuracy in the detection of alveolar defects.

**Regenerative Periodontal Therapy and Bone Grafts**

Bone grafting is commonly used for maxillary sinus lifting and treatment of intra bony defects but evaluation of osseous defect regeneration with conventional radiography can be insufficient due to superimpositions. Furthermore, histological evaluation of a sample of the graft is not a preferred method due to its quite invasive procedure. CBCT was found to be significantly more accurate than digital intraoral radiographs when direct surgical measurements served as the gold standard for the evaluation of intra-bony defects' regenerative treatment outcomes. CBCT can replace surgical re-entry by providing 3D images and measurements that are almost equivalent to direct surgical measurements[82]. Dimensions of alveolar process should be examined in detail prior to dental implant placement to avoid various complications and evaluation of CBCT images has a major importance in preoperative planning and postoperative localization of dental implants[83]. Moreover, the evaluation of CBCT images are preferred method to observe bone graft healing prior to dental implant placement[67]. Van Assche Net al studied the accuracy and reliability of CBCT and MSCT with the specific implant planning software package and the stereo lithographic drill guide, authors applied implant surgeries in a one-stage flapless procedure. The authors concluded that the deviations were acceptable and no complications were observed. Chen LC et al concluded that CBCT may be deceptive compared to direct caliper measurements and they found that ridge mapping method gave more accurate results than CBCT[84]. However, ridge mapping technique is an invasive technique whereas CBCT is not. CBCT evaluation can be used for determining the width, height and distance to the anatomical structures of alveolar process in pre-surgical dental implant planning.

**Implant Stability**

Osseointegration is a measure of implant stability [86,88]. A successful implant reflects good bone to implant contact and is determined both by primary and secondary stability of the implant. Primary stability is attained by mechanical engagement of implant within the cortical bone[88,89] This depends on bone density, surgical technique and implant geometry. Secondary stability mainly results from regeneration and remodeling of bone and tissue around the implant which is influenced by primary stability, bone maturation, remodeling, and bone density with time [86]. Primary stability has been identified essential to achieve osseointegration and is positively related with secondary stability [90]. The achievement of direct contact between implant and bone influences implant stability at the time of surgical insertion and also in the lack of micro motion during the healing period [91]. Implant stability is the absence of clinical mobility which also suggests osseointegration[92].

**Resonance Frequency Analysis** is a noninvasive diagnostic method that measures implant stability and bone density at various time points using vibration and structural principle analysis. Primary implant stability is most frequently determined by using cutting torque measurements or resonance frequency analysis (RFA) [93], which evaluates the micro motion or displacement of the implant in bone under a lateral load, applying microscopic lateral forces to the implant with a vibrating transducer [94,95]. Results are given as implant stability quotients (ISQs) [96], which are affected by three main factors: the stiffness of the implant fixture and its interface with surrounding tissue, the design of the transducer, and the total effective implant length above bone level [97]. ISQs range from 0 to 100, with higher number indicating greater stability. No definitive threshold value has been established to differentiate a stable, integrated implant from a failing/failed implant; however, it has been suggested that an ISQ value above 57 at 1 year after loading represents a successful implant outcome [98], with a value below 50 indicating a risk of implant failure [99]. Various in vivo studies have been performed on the reliability of RFA to predict implant success, on the influence of bone quality on ISQ values, and on a cut-off point to predict implant failure [86]RFA has gained popularity as it is a non-invasive diagnostic method that measures implant stability. The most recent version of Osstell® resonance frequency analysis system now features the Osstell Mentor®, a type of electronic tuning fork that automatically converts kHz to ISQ values [87]. It is a portable, hand-held device that uses the magnetic frequencies between the transducer (a magnetic peg or smart peg) and the resonance frequency analyzer.

The transducer is a metallic rod with a magnet on top that is screwed onto an implant or an abutment with a force of 5-10 Ncm. The magnet is activated by a magnetic pulse of approximately 1-ms duration from a wireless probe. After excitation, the peg vibrates freely, and the magnet induces an electric voltage in the probe coil. This voltage is the measurement signal sampled by the resonance frequency analyzer. The results of an RFA are expressed as an implant stability quotient (ISQ) on a scale from 1 to 100 which represents a standardized unit of stability. In the early studies, the hertz was used as the measurement unit. Later, Osstell created the implant stability quotient (ISQ) as a measurement unit in place of hertz. Resonance frequency values ranging from 3,500 to 8,500 Hz are translated into an ISQ of 0 to 100. A high value indicates greater stability, whereas a low value implies instability. The manufacturer's guidelines suggest that a successful implant typically has an ISQ greater than 65. An ISQ <50 may indicate potential failure or increased risk of failure.

Peter Andersons in 2019 studied the influence of patient- (age, gender, jaw, indication, bone density, and bone volume) and implant related (diameter and length) factors on implant stability as assessed by RFA measurements and the 5-year implant survival in 334 consecutive implant patients. In addition, the influence of stability (ISQ value) at placement and abutment connection on implant survival was also evaluated. Their study showed that, a significantly higher risk for implant failure, showing an ISQ value below 70 and 75 at placement or after 3-4 months of healing. They also concluded that RFA measurements can be used to identify implants with increased risk for failure[87].

Pedro Hernandez-Cortés study designed to explore relationships of resonance frequency analysis (RFA)—assessed implant stability (ISQ values) with bone Morphometric parameters and bone quality in an ex vivo model of dental implants placed in human femoral heads and evaluated the usefulness of this model for dental implant studies. Their study concluded that although RFA-determined ISQ values are not correlated with Morphometric parameters, they can discriminate bone quality[85].

**Periotest**

It is a device which is an electrically driven and electronically monitored tapping head that percusses the implant a total of 16 times. The entire measuring procedure takes about 4 s. The instrument includes a tapping rod that impacts the abutment/implant assembly. The rod is drawn by a propulsion coil toward the impacting surface and essentially moves at a constant velocity from the moment it leaves the hand piece until it impacts the surface. This means that over a certain distance (approximately 4 mm), the tapping rod is moving at the same velocity and is designed to impact the surface at any time during this constant velocity travel. The end of the rod inside the hand piece is rigidly connected to an accelerometer, which produces an output proportional to its acceleration. The readings are from −8 to +50 and are interpreted[99]. The factors that influence the periotest value are the quality of the hard tissue in the region of the implant, so that no specific values can be deemed as appropriate for higher or lower degrees of integration.It is a function of the distance from the implant flange to the point at which the rod impacts the abutment. These variations suggest that for implants, there is no absolute value that can be regarded as acceptable; rather, variations that occur over time may be more meaningful[98,99]. [Refer Table-1]

**Conclusion**

The importance of digital techniques will increase more in future years due to its advantages of accuracy, elimination of bias and errors, consumption of less time and decreasing clinician efforts. Digitization also helps enhancing & detecting the appropriate esthetic outcome, treatment plan and prognosis of the case. This review has therefore focused on the importance of digital methods in Periodontics and their use.

**References**


1. Nader Masarwa *, Ayman Al-Shawabkeh*, Waddah Al-Naji *, FadiMdanat *, EhabRassas*:Measuring Periodontal Pocket Depth using Manual and Automated Probe Systems. Journal of the Royal Medical Services • December 2018 DOI: 10.12816/0052728
2. Alexandra M, C Popa, I.A. Luchian, Ioana M, Cornelia O, Silvia M.Evaluation of the Efficiency of 2 Types of Periodontal Probing. Balk J Dent Med 2015: 19; 163-166.
3. Kour A, Kumar A, Puri K, Khatri M, Nansal M, Gupta G. Comparative evaluation of probing depth and clinical attachment level by using a manual probe and flourifa probe. J Indian society periodontal. 2016;20(30;299-306.)
4. RajashriKolte, AbhayKolte, PoojaWattamwar: Clinical and postextraction evaluation of periodontal disease indicators ; Journal of Indian Society of Periodontology Vol 20, Issue 2, Mar-Apr 2016 Downloaded free from http://www.jisponline.com on Sunday, October 18, 2020, IP: 120.138.116.69]
5. Hans R Preus1*, Gerald Ruiner Torgersen2 , Odd Carsten Koldsland1 , BjørnFrode Hansen1 , Anne Merete Aass1 , Tore Arne Larheim2 and LeivSandvik: A new digital tool for radiographic bone level measurements in longitudinal studies ; Pr
6. Deepa, ShobhaPrakasheus et al. Accuracy of probing attachment levels using a new computerized cementoenamel junction probe R. BMC Oral Health (2015) 15:107 DOI 10.1186/s12903-015-0092-9
7. Preshaw PM, Kupp L, Hefti AF, Mariotti A. Measurement of clinical attachment levels using a constant-force periodontal probe modified to detect the cement enamel junction. J ClinPeriodontol 1999;26:434-40
8. Karpinia K, Magnusson I, Gibbs C, Yang MC, Primosch L, Hoskins R. Probing attachment levels using a CEJ probe versus traditional probes. J Dent Res 2002;81:121

9. Periodontal Probing Systems: A Review of Available Equipment
10. SrinivasSulugoduRamachandra, MDS, Dhoom S. Mehta, MDS, NagarajappaSandesh, MDS, VidyaBaliga, MDS, JanardhanAmarnath, MDS
11. Nicola AV, Sebastiano A. Peri-implant disease: what we know and what we need to know. JPeriodontal Implant Sci. 2016, Jun;46(3):136-151.
12. Quality guidelines. Quality guidelines for endodontic treatment: consensus report of theEuropean Society of Endodontology. Int Endo Jour 2006; 39, 921–930.
13. Vandana K. L., Ira Gupta. The location of cemento enamel junction for CAL measurement:
14. A clinical crisis Journal of Indian Society of Periodontology 2009 Jan-Apr 13:1; 12-15.
15. Onur O, M Cenk H, Gulsah S. Inter examiner variances of pocket depth probing betweenperiodontists and referring epecialists. J. Periodontal 2007;4(2):123-127.
16. Theil EM, Heaney TG. The validity of periodontal probing as a method of measuring loss ofattachment. J ClinPeriodontol. 1991;18:648-53).
17. Kwthar AS, Wendy T, David G. Periodontal probing: A review. Prim Dent J. 2014;3(3):25-29
18. Holtfreter B, Alte D, Schwann C, Desvarieux M, Kocher T. Effects of different manualperiodontal probes on periodontal measurements. J Clinic Periodontol. 2012;39(11):1032-41.
19. Alexandra M, C Popa, I.A. Luchian, Ioana M, Cornelia O, Silvia M.Evaluation of theEfficiency of 2 Types of Periodontal Probing. Balk J Dent Med 2015: 19; 163-166.
20. Buduneli E, Aksoy O, KoseT, Atilla G. Accuracy and reproducibility of two manualperiodontal probes: An in vitro study. J ClinPeriodontol 2004;31:815-819.
21. N. P. Lang, E. F. Corbet. Periodontal diagnosis in daily practice. Int Dent J. 1995 45; 5–15.
22. K.N. Al Shayeb , W. Turner, D.G. Gillam. Accuracy and reproducibility of probe forcesduring simulated periodontal pocket depth measurements The Saudi Dental Journal 2014, 26;50–55
23. Nield-Gehrig JS. Fundamentals of Periodontal Instrumentation and Advanced RootInstrumentation. 6th ed 2008.Philadelphia Lippincott Williams and Wilkins.
24. Sul-Hee K, Se-RyongK,Hee-Jung P, Jun-Min K, Won-Jin Y, Tae-Il K. improved accuracyin periodontal pocket depth measurement using optical coherence tomography. J PeriodontalImplant Sci. 2017 Feb;47(1):13-19.
25. Ingvar M. Computerized periodontal probing. Periodontology 2000. 12: 40-43.
26. Kour A, Kumar A, Puri K, Khatri M, Nansal M, Gupta G. Comparative evaluation of probing depth and clinical attachment level by using a manual probe and flourifa probe. J Indian society periodontal. 2016;20(30;299-306.
27. Alexandra M, C Popa, I.A. Luchian, Ioana M, Cornelia O, Silvia M.Evaluation of the Efficiency of 2 Types of Periodontal Probing. Balk J Dent Med 2015: 19; 163-166.
28. Kour A, Kumar A, Puri K, Khatri M, Nansal M, Gupta G. Comparative evaluation of probing depth and clinical attachment level by using a manual probe and flourifa probe. J Indian society periodontal. 2016;20(30;299-306.)
29. RajashriKolte, AbhayKolte, PoojaWattamwar: Clinical and postextraction evaluation of periodontal disease indicators ; Journal of Indian Society of Periodontology -Vol 20, Issue 2, Mar-Apr 2016

Downloaded free from http://www.jisponline.com on Sunday, October 18, 2020, IP: 120.138.116.69]

30. Deepa, ShobhaPrakasheus et al. Accuracy of probing attachment levels using a new computerized cementoenamel junction probe R. BMC Oral Health (2015) 15:107 DOI 10.1186/s12903-015-0092-9
31. Preshaw PM, Kupp L, Hefti AF, Mariotti A. Measurement of clinical attachment levels using a constant-force periodontal probe modified to detect the cement-enamel junction. J ClinPeriodontol 1999;26:434-40
32. Karpinia K, Magnusson I, Gibbs C, Yang MC, Primosch L, Hoskins R. Probing attachment levels using a CEJ probe versus traditional probes. J Dent Res 2002;81:121
33. Antonino Lo Giudice 1, Vincenzo Ronsivalle 1, Cristina Grippaudo 2, Alessandra Lucchese 3, Simone Muraglie 1, Manuel O. Lagravère 4 and Gaetano Isola 1,* : One Step before 3D Printing—Evaluation of Imaging Software Accuracy for 3-Dimensional Analysis of the Mandible: A Comparative Study Using a Surface-to-Surface Matching Technique Materials 2020, 13, 2798; doi:10.3390/ma13122798. www.mdpi.com/journal/materials
34. Engelbrecht, W.P.; Fourie, Z.; Damstra, J.; Gerrits, P.O.; Ren, Y. The influence of the segmentation process on3D measurements from cone beam computed tomography-derived surface models. Clin. Oral Investig. 2013,17, 1919–1927. [CrossRef] [PubMed]
35. Fastuca, R.; Lorusso, P.; Lagravère, M.O.; Michelotti, A.; Portelli, M.; Zecca, P.; D'Antò, V.; Militi, A.;Nucera, R.; Caprioglio, A. Digital evaluation of nasal changes induced by rapid maxillary expansion with different anchorage and appliance design. BMC Oral Health 2017, 17, 113. [CrossRef]
36. Chen, X.; Xu, L.; Yang, Y.; Egger, J. A semi-automatic computer-aided method for surgical template design.Sci. Rep. 2016, 6, 20280. [CrossRef]
37. Newman and Carranza's Clinical Periodontology: 13th Edition
38. Preshaw PM, Kupp L, Hefti AF, Mariotti A. Measurement ofclinical attachment levels using a constant-force periodontal probe modified to detect the cement-enamel junction. J Clin Periodontol,1999;26:434-40.
39. Karpinia K, Magnusson I, Gibbs C, Yang MC, PrimoschL,Hoskins R. Probing attachment levels using a CEJ probe versustraditional probes. J Dent Res 2002;81:121.
40. Karpinia K, Magnusson I, Gibbs C, Yang MC. Accuracy of probingattachment levels using a CEJ Probe versus traditional probes.J ClinPeriodontol 2004;31:173-6.
41. C. A. Bertoncini and M. K. Hinders.An Ultrasonographic Periodontal Probe,https://www.researchgate.net/publication/234943982. NDE Lab, College of William and Mary, Williamsburg, VA, 23187-8795
42. M. K. Hinders and J. A. Companion, "Ultrasonic periodontal probe," in Review ofProgress in QNDE, 18b, edited by D. O. Thompson and D. E. Chimenti, AIPConference Proceedings, Plenum Press, NY (1998), pp. 1609–1615
43. J. Hou, "Ultrasonic signal detection and characterization using Dynamic WaveletFingerprints," Ph.D. Thesis, College of William and Mary, (2004).

44. F. A. Carranza and M. G. Newman, Clinical Periodontology, 8th edition, W B Saunders Co, Philadelphia, PA (1996).
45. P. E. Peterson and H. Ogawa, J Periodontol 76, pp. 2187–2193 (2005).
46. N. P. Lang and E. F. Corbet, Int Dent J 45, pp. 5–15 (1995).
47. J. Hou and M. K. Hinders, Mate Eval 60, pp.1089–1093 (2002).
48. Hytham N. Fageeh* , Abdullah A. Meshni, Hassan A. Jamal, Reghunathan S. Preethanath and EsamHelboub. The accuracy and reliability of digital measurements of gingival recession versus conventional methods.Fageeh et al. BMC Oral Health (2019) 19:154. https://doi.org/10.1186/s12903-019-0851-0
49. Joss-Vassalli I, Grebenstein C, Topouzelis N, Sculean A, Katsaros C.
50. Orthodontic therapy and gingival recession: a systematic review. OrthodCraniofac Res. 2010;13(3):127–41.
51. Kassab MM, Cohen RE. The etiology and prevalence of gingival recession. JAm Dent Assoc. 2003;134(2):220–5.
52. Schroeder HE, Listgarten MA. The gingival tissues: the architecture ofperiodontal protection. Periodontol 2000. 1997;13:91–120.
53. Bosshardt DD, Lang NP. The junctional epithelium: from health to disease. JDent Res. 2005;84(1):9–20.
54. Mythri S, Arunkumar SM, Hegde S, Rajesh SK, Munaz M, AshwinD.Etiologyand occurrence of gingival recession - an epidemiological study. J IndianSocPeriodontol. 2015;19(6):671–5.
55. Chrysanthakopoulos NA. Prevalence and associated factors of gingivalrecession in Greek adults. J InvestigClin Dent. 2013;4(3):178–85.
56. Loe H, Anerud A, Boysen H. The natural history of periodontal disease inman: prevalence, severity, and extent of gingival recession. J Periodontol.1992;63(6):489–95.
57. Handelman CS, Eltink AP, BeGole E. Quantitative measures of gingivalrecession and the influence of gender, race, and attrition. ProgOrthod.2018;19(1):5.
58. Correia GD, Habib FA, Vogel CJ. Tooth-size discrepancy: a comparisonbetween manual and digital methods.Dental Press J Orthod. 2014;19(4):107–13.
59. Sweeney WT, Taylor DF. Dimensional changes in dental stone and plaster. JDent Res. 1950;29(6):749–55.
60. Ting-Shu S, Jian S. Intraoral digital impression technique: a review. JProsthodont. 2015;24(4):313–21.
61. Mangano F, Gandolfi A, Luongo G, Logozzo S. Intraoral scanners indentistry: a review of the current literature. BMC Oral Health. 2017;17(1):149.
62. Iñigo de Prado, MikelIturrate, RikardoMinguez, and EnekoSolaberrieta. Evaluation of the Accuracy of a System to Align Occlusal Dynamic Data on 3D Digital Casts.Hindawi,BioMed Research InternationalVolume 2018, Article ID 8079089, 6 pages. https://doi.org/10.1155/2018/8079089
63. M. S. Nalini1* and Manisha Sinha1.Role of T-scan in Digital Occlusal Analysis –A Review: International Journal of Research and Reports in Dentistry 1(2): 1-7, 2018; Article no.IJRRD.47133
64. Dr. KirtiSomkuwar. A descriptive quantitative computerized occlusal analysissystem: T-Scan. IJAR. 2015;3(4):508-513.

65. Pyakurel U, Long H, Jian F, Sun J, Zhu Y,Jha H, Lai W. Mechanism, accuracy andapplication of T-Scan system in dentistry-Areview. J of Nep Dent Assoc. 2013;3:1-5.
66. Cartagena AG, Sequeros OG, Garcia VG.Analysis of two methods for occlusalcontact registration with the T-Scansystem. Journal of Oral BuketAcar, KıvançKamburoğlu: Use of cone beam computed tomography in periodontology.World J Radiol 2014 May 28; 6(5): 139-147,ISSN 1949-8470 (online).DOI: 10.4329/wjr.v6.i5.139
67. Scarfe WC, Farman AG, Sukovic P. Clinical applications ofcone-beam computed tomography in dental practice. J Can Dent Assoc 2006; 72: 75-80 [PMID: 16480609]
68. de-Azevedo-Vaz SL,VasconcelosKde F, Neves FS, MeloSL,Campos PS, Haiter-Neto F. Detection of periimplant fenestration and dehiscence with the use of two scan modes and the smallest voxel sizes of a cone-beam computed tomography device. Oral Surg Oral Med Oral Pathol Oral Radiol 2013; 115:121-127 [PMID: 23217543 DOI: 10.1016/j.oooo.2012.10.003]
69. Sun Z, Smith T, Kortam S, Kim DG, Tee BC, Fields H. Effectof bone thickness on alveolar bone-height measurements from cone-beam computed tomography images. Am J OrthodDentofacialOrthop 2011; 139: e117-e127 [PMID: 21300222 DOI:10.1016/j.ajodo.2010.08.016]
70. Shah MA, Shah SS, Dave DH. CBCT-A Positive Amelioration In Periodontics. NJIRM 2013; 4: 144-148
71. Agrawal P, Sanikop S, Patil S. New developments in toolsfor periodontal diagnosis. Int Dent J 2012; 62: 57-64 [PMID:22420472 DOI: 10.1111/j.1875-595X.2011.00099.x]
72. Tyndall DA, Rathore S. Cone-beam CT diagnostic applications: caries, periodontal bone assessment, and endodonticapplications. Dent Clin North Am 2008; 52: 825-41, vii [PMID:18805231 DOI: 10.1016/j.cden.2008.05.002]
73. Mischkowski RA, Pulsfort R, Ritter L, Neugebauer J, Brochhagen HG, Keeve E, Zöller JE. Geometric accuracy of a newly developed cone-beam device for Rehabilitation.1997;24(6):426-32.
74. maxillofacial imaging.OralSurg Oral Med Oral Pathol Oral RadiolEndod 2007; 104:551-559 [PMID: 17613260 DOI: 10.1016/j.tripleo.2007.02.021]
75. Veyre-Goulet S, Fortin T, Thierry A. Accuracy of linear measurement provided by cone beam computed tomography to assess bone quantity in the posterior maxilla: a human cadaver study. Clin Implant Dent Relat Res 2008; 10: 226-230[PMID: 18384410]
76. Jervøe-Storm PM, Hagner M, Neugebauer J, Ritter L, ZöllerJE, Jepsen S, Frentzen M. Comparison of cone-beam computerized tomography and intraoral radiographs for determination of the periodontal ligament in a variable phantom.OralSurg Oral Med Oral Pathol Oral RadiolEndod 2010; 109:e95-e101 [PMID: 20123402 DOI: 10.1016/j.tripleo.2009.10.023]
77. Eshraghi T, McAllister N, McAllister B. Clinical applicationsof digital 2-D and 3-D radiography for the periodontist. J Evid Based Dent Pract 2012; 12: 36-45 [PMID: 23040338 DOI: 10.1016/S1532-3382(12)70010-6]
78. Loubele M, Van Assche N, Carpentier K, Maes F, Jacobs R,vanSteenberghe D, Suetens P. Comparative localized linear accuracy of small-field cone-beam CT and multislice CT for alveolar bone measurements. Oral Surg Oral Med Oral Pathol Oral RadiolEndod

2008; 105: 512-518 [PMID: 17900939 DOI:10.1016/j.tripleo.2007.05.004]

79. Walter C, Kaner D, Berndt DC, Weiger R, Zitzmann NU.Three-dimensional imaging as a pre-operative tool in decisionmaking for furcation surgery. J Clin Periodontol 2009; 36: 250-257[PMID: 19236537 DOI: 10.1111/j.1600-051X.2008.01367.x]
80. Januário AL, Barriviera M, Duarte WR. Soft tissue conebeam computed tomography: a novel method for the measurement of gingival tissue and the dimensions of the dentogingival unit. J Esthet Restor Dent 2008; 20: 366-373; discussion374 [PMID: 19120781 DOI: 10.1111/j.1708-8240.2008.00210.x]
81. Barriviera M, Duarte WR, Januário AL, Faber J, Bezerra AC.A new method to assess and measure palatal masticatorymucosa by cone-beam computerized tomography. J ClinPeriodontol 2009; 36: 564-568 [PMID: 19538329 DOI: 10.1111/-j.1600-051X.2009.01422.x]
82. Grimard BA, Hoidal MJ, Mills MP, Mellonig JT, Nummikoski PV, Mealey BL. Comparison of clinical, periapical radiograph, and cone-beam volume tomography measurement techniques for assessing bone level changes following regenerative periodontal therapy. J Periodontol 2009; 80: 48-55 [DOI: 10.1902/jop.2009.080289]
83. Van Assche N, van Steenberghe D, Quirynen M, Jacobs R. Accuracy assessment of computer-assisted flapless implant placement in partial edentulism. J ClinPeriodontol 2010; 37: 398-403 [PMID: 20447264 DOI: 10.1111/j.1600- 051X.2010.01535.x
84. Chen LC, Lundgren T, Hallström H, Cherel F. Comparison of different methods of assessing alveolar ridge dimensions prior to dental implant placement. J Periodontol 2008; 79: 401-405 [PMID: 18315421 DOI: 10.1902/jop.2008.070021]
85. Pedro Hernández-Cortés,1 Alberto Monje,2 Pablo Galindo-Moreno,3 Andrés Catena,4Inmaculada Ortega-Oller,3 José Salas-Pérez,3 Francisco Mesa,5 Rafael Gómez-Sánchez,1Mariano Aguilar,6 David Aguilar,6 and Francisco O'Valle6,7.An Ex Vivo Model in Human Femoral Heads for Histopathological Study and Resonance Frequency Analysis of Dental Implant Primary Stability. Hindawi Publishing Corporation BioMed Research International Volume 2014, Article ID 535929, 8 pages http://dx.doi.org/10.1155/2014/535929
86. Lakshmi Kanth K, Narasimha Swamy D., Krishna Mohan T1 , Chakrapani Swarna, Sahitya Sanivarapu, Mohan Pasupuleti2. Determination of implant stability by resonance frequency analysis device during early healing period. Journal of Dr. NTR University of Health Sciences 2014;3(3) 169-175
87. Peter Andersson,1Luca Pagliani,2Damiano Verrocchi,3 StefanoVolpe,4Herman Sahlin, 5 and Lars Sennerby 6. Factors Influencing Resonance Frequency Analysis (RFA) Measurements and 5-Year Survival of Neoss Dental Implants.
88. 1. Branemark PI. An introduction to osseointegration. In: Branemark PI, Albrektsson T, editors. Tissue-Integrated Prostheses: Osseointegrationin Clinical Dentistry. Chicago: Quintessence; 1985. p. 11-53.
89. Meredith N. Assessment of implant stability as a prognostic determinant. Int J Prosthodont 1998;11:491-501.
90. Albrektsson TO, Johansson CB, Sennerby L. Biological aspects of implant dentistry: Osseointegration. Periodontol 2000;2:58-73.

91. Adell R, Lekholm U, Rockler B, Branemark. A 15 year study ofosseointegrated implants in the treatment of the edentulous jaw. IntJ Oral Surg 1981;10:387-416.
92. Barewal RM, Oates TW, Meredith N, Cochran DL. Resonancefrequency measurement of implant stability in vivo on implants witha sandblasted and acid-etched surface. Int J Oral Maxillofac Implants2003;18:641-51.
93. Aparicio C, Lang NP, Rangert B. Validity and clinical significance ofbiomechanical testing of implant/bone interface. Clin Oral ImplantsRes 2006;17(Suppl 2):2-7.
94. Brunski J. Push out (pull out), tensile and reverse torque tests of boneimplant interfaces. Clin Oral Implants Res 2006;1:33-40.
95. Meredith N, Alleyne D, Cawley P. Quantitative determination of thestability of the implant-tissue interface using resonance frequencyanalysis. Clin Oral Implants Res 1996;7:261-7.
96. Gupta RK, Padmanabhan TV. Resonance frequency analysis. IndianJ Dent Res 2011;22:567-73.
97. O'Sullivan D, Sennerby L, Meredith N. Measurements comparing theinitial stability of fi ve designs of dental implants: A human cadaverstudy. Clin Implant Dent Relat Res 2000;2:85-92.
98. GaurangMistry, OmkarShetty, ShreyaShetty, Raghuwar D Singh1.Measuring implant stability: A review of differentmethods. Journal of Dental Implants | Jul - Dec 2014 | Vol 4 | Issue 2
99. Teerlinck J, Quirynen M, Darius P, van Steenberghe D. Periotest: An objective clinical diagnosis of bone apposition toward implants. Int J Oral Maxillofac Implants 1991;6:55-61.

**Table 1:** Readings and Interpretations of Periotest.

| Reading | Interpretation |
|---|---|
| −8 to 0 | Good osseointegration, implant can be loaded |
| +1 to +9 | Clinical examination is required, in most cases loading is not possible |
| +10 to +50 | Osseointegration is not sufficient, implant cannot be loaded |