Digital Planning In Dentistry

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Abstract

One of the most recent developments in dentistry, encompassing all specialties from orthodontics to restorative, is the use of fully computerized processes that have been streamlined. With the use of in-office computerized procedures, digital dentistry is expected to enable dentists to work more precisely and efficiently while also offering the option of all-in-one sessions. Imaging is a key component in this system for transmitting and replicating dental treatments. Both optical imaging and 3D low dose radiography are dominant in the market and play important roles. New design platforms, as well as small, incredibly quick milling and printing machines, are now widely available and quickly being implemented in real-world applications. However, even with their simplification, many of the processes in this digital dentistry process.

Introduction

The quick adoption of digital workflow has changed daily practice in every area of dentistry. In an interactive 3D environment, it enables surgeons to plan implants and their restorations more precisely and effectively, generate surgical guides, and, if desired, start rehabilitation right away in a single session. Similar to this, dentists can quickly perform accurate and long-lasting CAM (computer-aided manufacturing) restorations since chairside computer manipulation of digital impressions of preparations may be done almost instantly and automatically. The production of whole dentures or the quick prototyping of detachable partial dentures with metallic frameworks can both be done using the same procedure that uses digital impressions. However, virtual CAD (computer-aided design) libraries can also be used in endodontic treatment[1].

One finding throughout the many study publications on digital dentistry is that, generally speaking, the digital workflows used in the various dental specialties appear to be at least as exact and unquestionably as effective as traditional workflows. However, it also appears that the literature frequently presents results on accuracy and precision of virtual treatments that are contentious. With the variety of technology available, the multiple processes involved in manipulation, and the numerous clinical concerns in this digital workflow, this is simply explained. Therefore, it remains impossible to develop precise standards and suggestions for fully digital procedures as of this writing . Since there are several variables and a wide gap between science and practice, it is crucial to maintain critical thinking[2].

When considering the general digital workflow in dentistry, three major processes are actually being followed: the acquisition of digital information, the processing of all this data and finally the transfer to the clinical environment. These steps can also be described under the respective categories as the digital patient, the virtual patient and the real patient. It is clear that imaging technology will have to most influence in the process since it is part of the initial workflow. Since not only the technology itself but also how the clinician will use these images will largely influence outcomes, it may be better to address these critical imaging steps in the following subdivisions :(Figure 1)

1) **Imaging:** the initial clinical examination supplemented by optical and radiographic images;
2) **Diagnosis**: manipulation of the acquired data for diagnosis and treatment plan set-up;
3) **Planning**: simulating the desired treatment in a virtual environment;
4) **Transfer**: manually or by means of computerized aids transferring the planned treatment;
5) **Follow-up**: verifying the actual treatment remains successful over time[3].

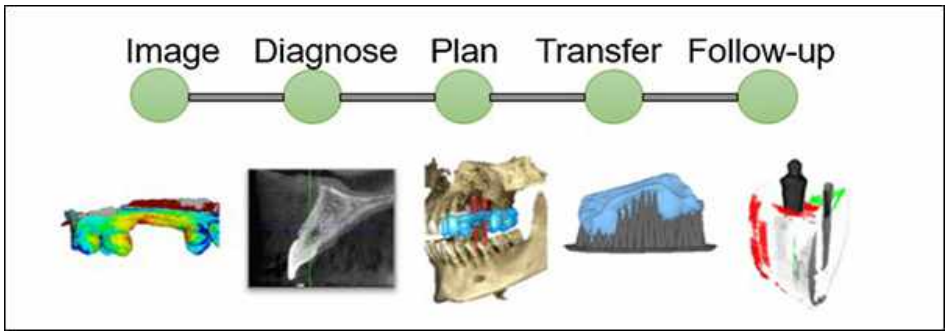


Figure 1 :The different stages in the digital dental workflow

Digital Applications in Endodontics

The dental specialty of endodontics focuses on identifying and treating conditions affecting the periapical tissues and dental pulp with the goal of maintaining the structural integrity and overall health of the natural tooth. Among the oral tissues, the pulp and periapical tissues are distinct in a number of ways. Even with magnification, they are invisible to the clinician in most disease situations and normal circumstances. The pulp area has intricate neurophysiology and a very small volume. Furthermore, permanent pathosis often leaves the pulp devoid of essential tissues and host responses. With the exception of surgical treatments, the periapical tissues are not directly altered clinically; instead, they react to pulpal disease and its treatment. Endodontic disease is caused by secondary infection of the periapical tissues and pulp.

Digital Diagnostic Technologies

Pulp Vitality Versus Sensibility Testing

Pulp testing is one of the most crucial procedures in endodontic diagnosis. This straightforward process, which has been around for many years, enables the medical professional to assess if the pulp is necrotic or vital and, on rare occasions, to replicate the patient's main complaint. Rather than vitality, pulp sensitivity, often referred to as sensibility, can be determined using the most widely used pulp-testing techniques. It is assumed that heat or electrical stimuli can readily activate the actively conducting neurons found in the crucial pulp. But sometimes, as with catastrophic injuries, this assumption is incorrect.

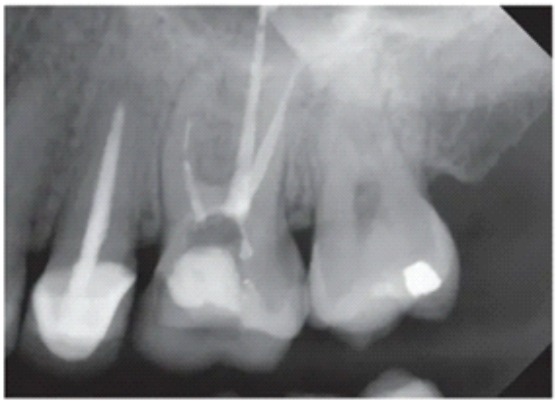
Various digital methods have been employed to quantify pulp vitality by identifying a pulp's intact vascular supply. The first of these technologies, laser Doppler flowmetry, is still a good choice when it's available and has sufficient tooth isolation (Setzer et al. 2013). Long before the EPT registers a response, laser doppler has demonstrated the ability to identify the restoration of vitality in injured teeth (Gazelius et al. 1988; Mesaros and Trope 1997). Nevertheless, this technology has not been widely adopted because the pulp chamber must extend into or close to the tooth's crown in order to allow direct reflection of the Doppler signal, the probe must be stabilized with respect to the tooth to prevent inaccurate measurement, and gingival blood flow may be detected (Polat et al. 2004). Furthermore, it has been demonstrated that the pulpal blood flow, as determined by laser Doppler flowmetry, is highly influenced by the pulp chamber's size and the existence of restorations (Chandler et al. 2010).

More than 20 years ago, pulp vitality was measured using pulse oximetry (Schnettler and Wallace 1991; Kahan et al. 1996; Noblett et al. 1996). In order to determine pulp vitality, this approach uses pulpal blood to quantify oxygen saturation. According to one study (Gopikrishna et al. 2007), a pulse oximeter that was custom-made had a sensitivity of 1.00 as opposed to 0.81 for the cold test and 0.71 for the electrical test. According to more recent research, the mean oxygen saturation levels were 92.2% for the normal pulp, 87.4% for reversible pulpitis, 83.1% for irreversible pulpitis, 74.6% for pulp necrosis, and 0% for teeth that had endodontic treatment (Setzer et al. 2012).The most accurate pulp-testing techniques were found to be laser Doppler flowmetry and pulse oximetry, according to a recent systematic review and meta-analysis of all available techniques (Mainkar and Kim 2018).

Cone Beam Computed Tomography

Cone beam computed tomography (CBCT) has become widely used and accepted in endodontics over the last 20 years. According to Cotton et al. (2007), there are numerous benefits in clinical endodontics when it comes to the ability to observe the tooth and its surrounding structures in the coronal, sagittal, and axial planes (Figure 2). In addition to providing enhanced imaging and visualization of the number of root canals present, aberrant or unusual canal anatomy, congenital anomalies, root resorption, procedural errors, maxillary sinus pathosis, and traumatic injuries, among other conditions and anatomical structures, CBCT not only allows the detection of small lesions not visible on other forms of radiographic imaging (Kruse et al. 2015).

(a)



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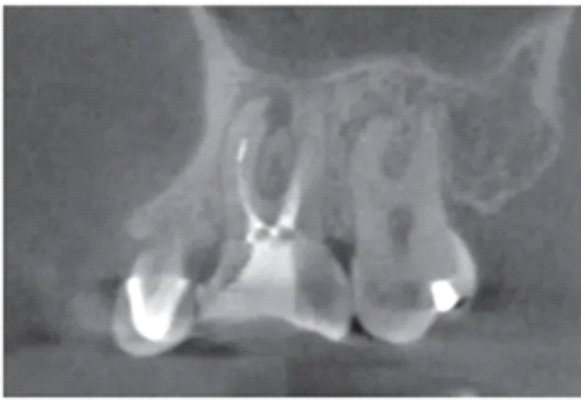

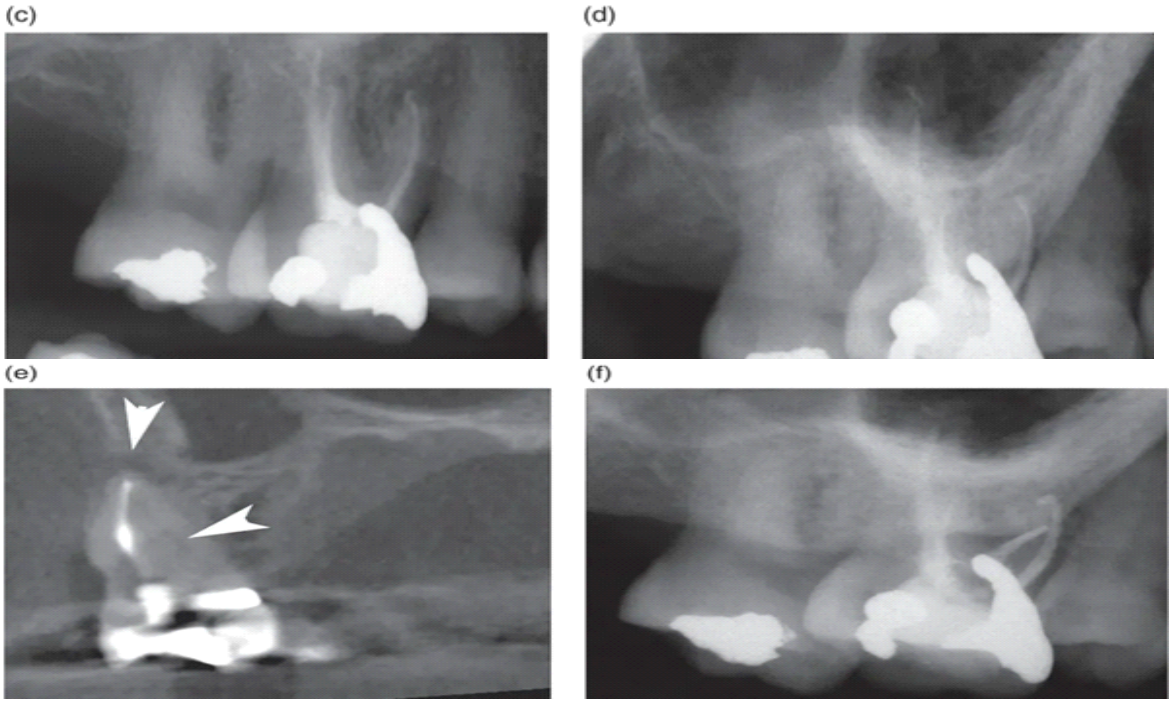

Figure 2 :(a) Traditional radiograph; (b) cone beam computed tomography (CBCT) radiograph of maxillary left first molar (in a) with previous endodontic treatment and a separated instrument in the mesio-buccal (MB) canal; note that the CBCT image showed a large periapical lesion that the periapical radiograph did not show; root end surgery confirmed that there was a thick cortical plate of bone and a lesion present in the medullary bone; (c) and (d) show two angles using periapical radiography in a different case that suggest a missed MB2 canal and a periapical lesion; (e) CBCT confirms that a missed canal and a lesion existed and shows their location and extent (arrows); (f) completed retreatment of MB1 and MB2.

Digital Technologies in Root Canal Treatment

Magnification Technologies: Microscopes, Videoscopes, and Endoscopes

Over the past thirty years, endodontics has seen a significant increase in the usage of magnification technology. While many dentists now use magnifying loupes, particularly those with additional lighting sources, endodontic applications require a higher level of illumination and magnification that can only be achieved by surgical operating microscopes and endoscopes (AAE 2012). According to one study, endodontists who used dental loupes or microscopes were equally likely to locate MB2 canals in maxillary molars. However, the detection rate using both technologies was nearly three times higher than when no magnification was used (Buhrley et al. 2002).More recently, research has demonstrated that treating maxillary first molars without the use of microscopes is, in fact, linked to a notable rise in the number of missing MB2 canals and the prevalence of MB root apical radiolucency (Khalighinejad et al. 2017).

Figure 3 : The Mora Vision video imaging system is an example of digital illumination, magnification, and recording during dental (including endodontic) procedures: (a) the main mount and arm system of the camera; (b) the lenses and illumination interface of the multi-lens video camera system; (c) the foot pedal.

Research has indicated that the application of the microsurgical approach in endodontic surgery has led to a notable enhancement in the prognosis of the procedure in the past few years (Azarpazhooh 2010, Setzer et al. 2012b). However, it should be highlighted that the microsurgical technique uses considerably more biocompatible materials for filling—mineral trioxide aggregate—and lessens the angle at which the root is resected. Additionally, ultrasonic root end preparation minimizes the size of the osteotomy. technologies to facilitate improved case documenting, patient communication, and dental referrals.

According to Taschieri et al. (2006), there were no statistically significant differences observed in the surgical results between endoscopes and dental loupes in a randomized analysis. Von Arx et al. (2010) demonstrated that endoscopy at 64***x*** magnification was superior to microscopy at 16***x*** and 24***x*** magnification in terms of accuracy for diagnosing root end cracks. In addition to the obvious benefit of magnification, using microscopes in treatment enables the integration of several digital technologies for improved case documentation, patient communication, and referral dentistry.

Videoscopy, often known as video microscopy, is another digital technology that is becoming somewhat more and more popular. With this method, illumination magnification is possible at a power similar to that of microscopy. Furthermore, it permits complete recording of the process, which can then be viewed by the provider, assistants, and/or trainees on one or two high-definition monitors. Foot pedals are used to regulate the location and magnification, allowing for unrestricted practice (FIGURE 3).

Endodontic practitioners have found that magnification is helpful for a variety of tasks in endodontics, including identifying calcified and bifurcating canals, removing obstructions like pulp stones, posts, and separated instruments, and visualizing the root apex or complex anatomical features during surgical endodontics. Objective demonstrations of the value of magnification in endodontics are also helpful.

Digital Applications in Orthodontics

Over the past thirty years, the phrase "digital dentistry" has gained popularity and recognition among dental professionals. The term "digital dentistry" refers to the application of any dental technology or apparatus that is not solely powered by electricity or mechanical means, but also incorporates digital or computer-controlled components. Digital technology that uses computer-based algorithms is essential in dentistry because it provides high predictability and better precision than conventional techniques. Historically, the "godfather" of digital dentistry, French Professor Francois Duret, only developed computer-aided design/computer-aided manufacture (CAD/CAM) systems, imaging, and practice/patient administration systems in the 1970s. Prof. Duret, Francois. Digital work processes have been adopted recently across a wide range of disciplines[4].

Figure 4 lists the numerous uses of technology in modern Orthodontia.

A Apps	I Imaging	R Rapid protolyping
A number of apps on the Android and iOS platforms for management, diagnostics, communication and professional interactions	*CBCTs *Facial 3D WT. Scans *3D photography *Intra oral scanning *E models	Various applications in orthodontics *Aligner Fabrications *Surgical splints *Bruxism splints *Auto transplantation templates
Appliances / adjunds *CAD CAM customized appliances * Aligners *Robotic arch - wires *Customized adjunts	Volumetric data sets and integrated wraps *Professional Companies / software that integrate data and provide 3D volumetric data sets are a great potential for research and planning in orthognathics.	*Customized appliances *Indirect bonding trays *Diagnostics for impacted teeth *3D printed jaws (orthognathics) *Cranofacial / cleft planning

Figure 4 : Broad overview of technological applications in

Applications of Digital Orthodontics in Diagnosis:

1. Digital photos

In general, 2D extraoral and intraoral pictures of orthodontic patients are precise, high-quality, and show proper posture. 2D pictures are easy to use and straightforward as a baseline reference for soft tissue and face structure, but they are limited in their ability to provide diagnostic information and are influenced by several factors, such as the angle and distance at which the photo is taken. The conventional 3D topography of a patient's face surface anatomy has recently been made possible by facial scanners. This, along with a digital model and CBCT image, allows for the creation of a full 3D virtual patient.

The way we perform cephalometric analysis has altered as a result of the digital paradigm. There are four acknowledged methods for interpreting cephalometric x-rays :

1. In the past, it was completed by hand. landmark identification, skeletal, soft tissue, and dental feature tracing, as well as linear and angle measurements between landmark positions, are all done with anacetate over a cephalometric radiograph.
2. The second method was digitizing the traced paper into a digital format using a digitizer connected to a computer.
3. The third method involved manually localizing landmarks before directly digitizing lateral cephalometric x-rays using a digitizer connected to a computer
4. At the moment, the direction of interpretation evolution is toward total automation of landmark recognition with the use of artificial intelligence[5].

Digital Models

They have typically been made of stone or plaster. Digital models have been invented to avoid several disadvantages of traditional models in terms of lifetime, portability, and storage and retrieval, offering various advantages namely, no laboratory procedure needed, the ability to create multiple diagnostic setups, no physical storage space required, fast and efficient retrieval at any location, no risk of physical damage, can be used to create indirect bracket bonding setups, precision in measurements such as tooth size, arch length and width, space analysis etc., and can be easily shared with other dental practitioners via email to facilitate interdisciplinary treatment planning, Ideal marketing tool because it enables virtual treatment objective (VTO) communication with patient, visualization of treatment outcome, and help the patient better understand the treatment process. These can be obtained directly by intraoral scan or indirectly by scanning an impression or plaster model. Software enables free toggling in all planes of space and even opened to allow upper and lower models to be viewed and manipulated separately .

One of the commonest scanners is the iTero Element 5D by Align Technology that provides Invisalign result simulator feature which gives full scan of the mouth in 1 min and the patient can see an example of a possible result after orthodontic treatment[6].

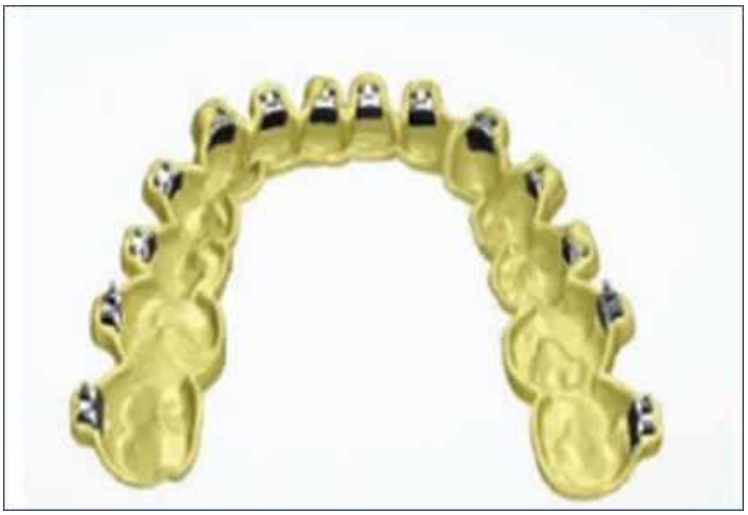

Figure 5 : Internal view of the virtual indirect bonding tray with gingival open architecture for easy transfer tray removal.

Applications of Digital Orthodontics in Treatment Indirect bonding

One of the imperative phases of orthodontic treatment is the finishing and detailing phase, which involve a series of steps that essentially begins with ideal bracket positioning. Lawrence F. Andrew advocated six keys of normal occlusion 10 and based his straight

wire appliance (SWA) to achieve minimal wire bending never the less controlling tooth movement and alignment in three spatial planes through ideal bracket positioning. ideal bracket positioning is the ultimate treatment outcome providing shortest treatment time together with minimal bracket repositioning, eliminating wire bending as well and definitely reducing relapse chances. Brackets can be positioned clinically either directly with an instrument or indirectly with a transfer tray. Indirect bonding (IDB) was first proposed in 1972 Silverman and Cohen described the indirect bonding technique for the first time and identified Few years later the claimed advantages of indirect bonding were questioned in a roundtable discussion. Gorelick and co-workers 12 responded rationally that having the teeth in your hand looking freely from any direction would facilitate ideal bracket positioning. Several publications were conducted to evaluate (IDB) accuracy, chair time and bond failure. Previous studies of Aguirre, Koo et al were consistent with Sabbagh , findings in systematic

review that indirect bonding as a technique allowed achieving planned bracket positions with high overall accuracy. However these conclusion were inconsistent with Hodge et al[7], that stated that there were no significant difference between mean bracket placement errors of both techniques . Conversely in, a systematic review by Li and his colleagues presented weak evidence that the direct and indirect bonding techniques had no significant difference in bracket placement accuracy. Upon studying bond strength, according to several studies, indirect bonding had a similar or lower bond failure rate than conventional direct bonding .Also, claims of reduced chair time were inspected, to truly conclude that chair time is reduced, but on the expense of extra laboratory working time with additional equipment. This overly complex chairside and laboratory phase contributed to minimal percentage of orthodontists that employ indirect bonding as part of their daily practice, with prevalence of only 18% among clinicians. Other advantages included less physical stress and improved productivity of orthodontist as all bracket placement decisions have been previously made in the laboratory. The latest advances in digital technology, such as intraoral scanning, 3D printing, and virtual setups, made indirect bonding a much easier and more predictable procedure that was worthwhile for clinicians to explore. STL files is utilized to produce the models needed for indirect bonding techniques. After digital bonding through orthodontic modules provided by several softwares 11 as OrthoAnalyzer i , OrthoCAD®ii ,SureSmile®iii (Orametrix, Inc., Richardson TX), a 3D-printed transfer tray or vacuum formed tray on 3d printed bonded models is constructed and delivered to patient mouth.[8]

Aligners

By the late 1990s, clear aligner therapy was introduced by Align Technology as Invisalign and led the way in using a virtual model, creating a virtual treatment plan, virtual setups, and manufacturing appliances with the help of software developers. Currently, many companies, like clear correct, 3M™ (3M ESPE) and Clarity™ (Straumann) Aligners, and many others are offering the same service. The digital workflow enabled clinicians to design and create their own in-house aligners. A low to moderate level of evidence exists regarding the efficiency of clear aligner therapy for certain tooth movements, especially rotational and extrusive movements. Papageorgiou et al[9] that reported that current evidence does not support the clinical use of aligners as an orthodontic approach that is as effective as the gold standard of conventional orthodontic treatment. On- going studies are working on adding attachments with the help of software predictability to control tooth movement in three spatial planes; hopefully in few years, well-conducted trials will provide a robust conclusion. Clear aligners may produce clinically acceptable outcomes comparable to fixed appliance therapy for minor buccolingual inclination of upper and lower incisors (low level of evidence). The treatment time required to achieve similar results (compared to fixed appliances) has not been investigated yet.

Digital Applications in Periodontics

Periodontitis is an inflammatory disease of the periodontal tissue or the supporting tissues of the teeth. Periodontitis is caused by the formation of bacterial biofilms on teeth, root surfaces and periodontal pocket. The biofilm triggers host-derived immune and inflammatory reaction to the pocket. When we focus light on periodontology, diagnosis is integral step towards treatment of the disease. Diagnosis of periodontal disease starts with probing depth, attachment loss, bleeding on probing and moving further with radiographs. Studies have shown conventional methods results in errors, precision in reading is required which can be achieved by digital methods which help in diagnosis of periodontal disease.

3D advancement in periodontal probing

The Periodontal pocket is measured using a calibrated metal instrument, periodontal probe. As it is a conventional method manual periodontal probing includes many drawbacks as the pressure applied by the clinician may vary during each session and person, this can lead to overestimation or underestimation of periodontal probing depth. Constant force periodontal probes which are the first pressure-sensitive probe were designed to provide uniform and continuous pressure during examination of periodontal pocket depth and minimize variations. However, the lack of tactile sensitivity is another drawback. This is because the tip of the probe can penetrate the junctional epithelium at the site of inflammation. The third generation periodontal probe combines automated measurements, controlled force application' and digitized data capturing. Digital recordings of the periodontal pocket depth measurements is saved in the system. Digitization becomes essential while using such periodontal probes but these probes don't give 3D information about the disease . Ultrasonography periodontal probing is the method for periodontal ultrasonic diagnostics involving the projection of maximum frequency arrow ultrasonic beam to periodontal pockets. The periodontal ligament reflects the echoes of the ultrasound waves which is captured by the transducer positioned within the handpiece which is transferred to the system for evaluation. The ultrasonic image is built and the software converts data for estimating periodontal pocket depth . However, this approach is challenging, as the interpretation requires visualization and analysis of an echo wave. Endoscopic capillaroscopy is

versatile endoscopes that utilize fibre optics to visualize distant inaccessible internal structures. Optical fibre technology may obtain higher resolution picture of the periodontal pocket microcirculation[10,11].

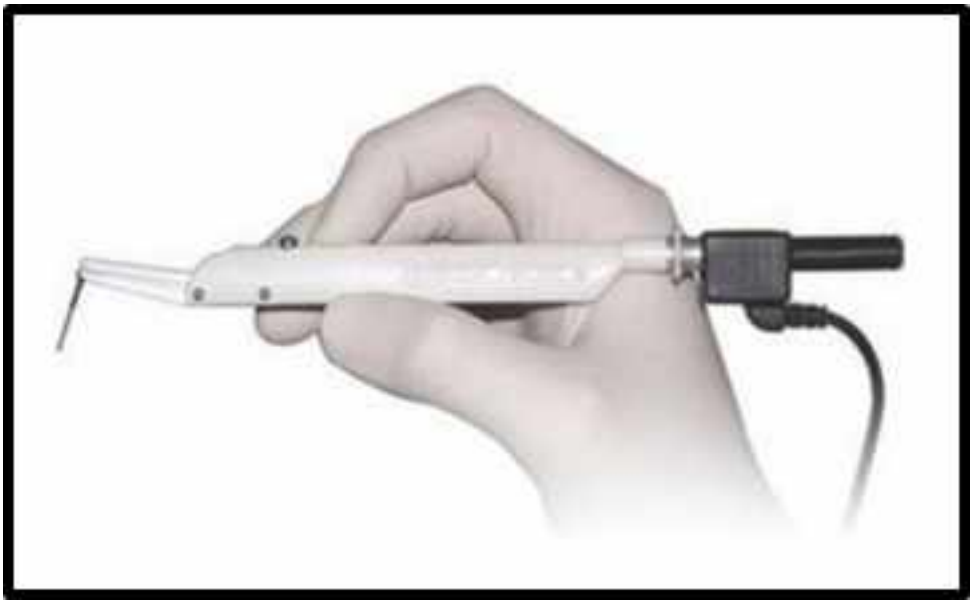

Figure 6 - Florida Probe

Utilization of AI Technology in Detection of Dental Plaque

The term —artificial intelligence (AI) was coined in the 1950s and refers to the concept of creating device which has the capability of performing tasks that are usually performed by humans. Dental plaque' comprises of bacterial masses on dental surfaces; these mass typically occurs on the gingival margins and interproximal areas. Usually, _dental plaque' is identified by practitioner using an explorer or by means of disclosing agents. All these evaluation methods becomes uncomfortable and time consuming for the clinician. Consequently it is important to establish a cost effective and convenient method for detecting plaque, according to the studies, in order to compare the effectiveness of artificial intelligence in the detection of plaque. The _AI model' used was developed on a the basis of _conventional neural network' (CNN) and trained using images to fine-tune the system based on transfer learning method. Photographs of primary teeth were taken using intraoral camera after this disclosing agent was applied and photographs of the discoloured teeth were taken. Areas with plaque were marked on natural teeth and discoloured teeth. The adopted plaque detection model then gathered the features of _dental plaque' from these images. The _dental plaque' observed by the _AI model' was compared to the actual dental plaque areas to enable the AI model' to compare the results and learn from its errors . When observation was made in detecting the plaque by the clinician and AI model, better and accurate results were obtained from the AI model. This would become more helpful in prevention of accumulation of plaque and progression of periodontitis.[12]

Conclusion

Digital dentistry is a paradigm shift in dentistry that offers many benefits to patients and dental professionals:

- Improved patient care: Digital dentistry offers more efficient, accurate, and comfortable care.
- Enhanced patient experience: Digital dentistry can improve the patient experience by offering faster diagnosis and more customized care.
- Improved communication: Digital dentistry can improve communication with patients by allowing them to virtually try out their treatment plan.
- Same-day restorations: Digital dentistry can restore teeth in the same day with implant restorations.
- Less invasive treatments: Digital dentistry can offer less invasive treatment methods.
- Improved outcomes: Digital dentistry can improve outcomes by offering more precise and efficient care.
- Improved practice management: Digital dentistry can optimize practice management.
- Improved accessibility: Digital dentistry can improve accessibility for remote consultations and patient monitoring.
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