Dental Görüntüleme Cihazları ve Diş Hekimliğinde Yapay Zekanın Kullanımı Üzerine Kısa İnceleme
Mini Review on Dental Imaging Devices and Use of Artificial Intelligence in Dentistry

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***Özetçe*—X-Işınlarının keşfi, yıllar içinde gelişen ve çeşitlenen tıbbi görüntülemenin başlangıç noktasıdır. X-Işınlarının keşfinin ilk günlerinden beri, dişlerin görüntülenmesinde de kullanılmaktadırlar, 1896'da Dr. Otto Walkhoff ağzını X-Ray ile görüntülemiştir. Röntgenler, diş hekimlerinin diş çürüklerini ve kemik kaybını teşhis etmesine, diş yapılarını incelemesine ve bu yapıların anormalliklerini belirlemesine yardımcı oldu. Günümüzde teknolojideki gelişmeler farklı görüntüleme teknikleri ile sonuçlanmıştır, X-Ray'ler Projeksiyonel Radyografi ve Bilgisayarlı Tomografi için kullanılmakta, ayrıca yaygın olarak kullanılan Nükleer Görüntüleme, Manyetik Rezonans Görüntüleme ve Ultrason Görüntüleme bulunmaktadır. Bu incelemede, yapay zeka uzantısı ile dental uygulamalar için görüntüleme teknikleri incelenerek kısa bir bilgi verilecektir.**

Anahtar Kelimeler—Dental görüntüleme; Tıbbi görüntüleme teknikleri; Yapay zeka.

***Abstract*—Discovery of X-Rays is the beginning point of the medical imaging which developed and diversified in years. Since early days of X-Ray discovery they are used in also for imaging of teeth, in 1896, Dr. Otto Walkhoff imaged his mouth with X-Ray exposure . X-Rays helped the dentists to diagnose tooth decays and bone loss, examine dental structures and identify abnormalities of these structures. Today developments in technology resulted in different imaging techniques, X-Rays are used for Projectional Radiography and Computed Tomography, besides there are Nuclear Imaging, Magnetic Resonance Imaging and Ultrasound Imaging that widely used. In this review, imaging techniques for dental applications with the extension of artificial intelligence is examined to provide a brief information.**

Keywords—Dental imaging; Medical imaging techniques; Artificial intelligence.

I. INTRODUCTION

In 1895, Wilhelm Conrad Roentgen accidentally discovered a different type of rays which can penetrate the human body and inform about the structures inside it. These rays named as X-Rays and are one type of ionizing radiation. They can be used in medicine to monitor the internal structures without invasion. For this procedure first X-Rays are sent to the body, then the rays pass through the body, some of their energy is absorbed by the tissues and the remaining attenuated rays captured with a film to form an image. Discovery of X-Rays is the beginning point of the medical imaging which developed and diversified in years. Since early days of X-Ray discovery they are used in also for imaging of teeth, in 1896, Dr. Otto Walkhoff imaged his mouth with X-Ray exposure [1]. X-Rays helped the dentists to diagnose tooth decays and bone loss, examine dental structures and identify abnormalities of these structures. Today developments in technology resulted in different imaging techniques, X-Rays are used for Projectional Radiography and Computed Tomography, besides there are Nuclear Imaging, Magnetic Resonance Imaging and Ultrasound Imaging that widely used. In this review, imaging techniques for dental applications will examine to provide a brief information.

II. RADIOGRAPHY METHODS

A. Digital Radiography

First radiographs obtained by beaming the target area and receiving attenuated beams with a film to form an image, by years to detect attenuated beams image receptors made from solid-state sensors started to use and instead of films, images created digitally [2]. Thus radiography carried one step further with digital radiography. The benefits of it like lower radiation dose, time reduction for image formation, increased storage capacity of digital images, digital radiography preferred for imaging applications [3], [4]. Dental radiography also took the advantage of digitalization and by the placement of the receptor two different types of radiography arose in this field; extraoral and intraoral digital radiography [2].

1) Intraoral Radiography: Intraoral dental radiography first introduced in 1984, in this technique receptors are placed into the patient's mouth to obtain the image. It is a widely used imaging modality and has two sub-branches as bite-wings and periapical. Bite-wings used to detect caries between neighbouring teeth and examining alveolar bone levels, which is the part of the jaw bone that holds the teeth [5], [6]. Periapical radiographs provide information about the degree of decay, root canal morphology and surrounding tissues since whole

tooth and bone are imaged [1], [5]. Periapical radiography is useful for endodontic treatments and examinations before treatment [1]. The limitation about intraoral radiography is two-dimensional images. Imaged structures are three-dimensional, however, since images are two-dimensional they cannot give enough information for overlapping anatomical structures [7].

2) Extraoral Radiography: Intraoral radiography is useful for different dental procedures, however placing a sensor inside of mouth sometimes can be problematic for patients. Some anatomical difficulties, age or neurological problems restrict imaging procedure [8]. By considering these issues different techniques started to use like placing the sensor outside of the mouth and this procedure called as Extraoral Radiography. This modality helps examine larger areas and provide panoramic views, therefore, development and growth of structures can be monitored. This group of radiographics are subdivided projection radiography and tomographic imaging [7]. Tomography is another medical imaging technique that uses X-Rays. For tomography, two-dimensional radiographs are taken as slices of the object and used for constructing a three-dimensional image with back-projection methods. Therefore issues arose from two-dimensional images are solved with this method. Employing dose, extraoral radiography has an advantage due to lower dose compared to intraoral radiography [9].

B. Computed Tomography

As described before tomography aids to understand better the structures in our body. For medical imaging Computed Tomography (CT) is in use since 1973 and for dental applications since 1987 [1]. CT is a prominent assessing tool for maxillofacial skeleton injuries; it helps to diagnose fractures which cannot be diagnosed from panoramic radiographs. Images obtained from CT have better image qualities like high contrast resolution which allows a better differentiation of tissues, less noise or less grainy images. Also with software, captured images can be engineered for colours and visualize pathological region better while also enable examining each cross-section easily [1]. On the other hand, CT scans require extra radiation dose to the patient and it is not always possible to diagnose dental fractures [1].

1) Tuned Aperture Computed Tomography: Tuned Aperture Computed Tomography (TACT) is an imaging technique based on optical aperture theory which developed in 1997 by Webber and colleagues [10]. TACT is an effective alternative method for projectional radiographic methods and gives more diagnostic information, by radiation doses TACT is not higher than two times of other film-based radiographs and resolution of images is similar with two-dimensional techniques [1].

2) Micro Computed Tomography: Micro Computed Tomography is a clinical CT scanner which produces nearly one million times smaller volume images with a better spatial resolution. Micro-CT devices use high spatial resolution detectors and micro focal spot X-Ray sources [11]. This imaging modality is useful for many different applications, one of them is measuring tooth dimensions. Micro-CT is stated as an effective tool for measurement of enamel thickness [12]. Not just the tooth dimensions but these scans provide further information about anatomical structures. For root canal treatment, which is widely used treatment in dentistry, the anatomy of must be understood well and Micro-CT provides required information without invasion [11]. These measurements also used for implant studies. Micro-CT is also a useful tool for biomechanical studies, structures can be modelled 3D and these models can help to demonstrate stress distributions [13]. Tissue engineering is another field that uses Micro-CT applications. For tissue engineering Micro-CT used for the analysis of scaffolds by structural and mechanical [14]. Mineral structures of teeth also can be studied by Micro-CT scans and it is stated as a very sensitive characterizing technique [11].

3) Cone Beam Computed Tomography: Cone Beam Computed Tomography (CBCT) devices have cone-shaped beams that allow 3D visualization of maxillofacial structures and compared to 2D imaging techniques it has lower radiation dose [1], [7]. CBCT provides patient comfort because during imaging patient can sit, stand or lying down and these comfort results in a reduction of patient movement, therefore, fewer artefacts on the image which caused by the patient moving [15]. This imaging modality may be used for maxillofacial surgeries, in this field CBCT helps to locate tumours, bone lesions and also calcified regions that may be a lead of cysts and tumours [16]. Endodontics also utilizes CBCT because it provides more accurate identification of root canals and their location for treatments [17]. CBCT not just only provides reliable information for endodontics but also implant dentistry applications. Measurements of bone and virtual planning with CBCT helps presurgical diagnosis and predict treatment results of implants [16], [18]. CBCT for orthodontics also have applications like diagnosis, treatment planning and progress, risk assessment while stated as a valuable tool for these applications [19]. Temporomandibular joint imaging, periodontics and forensic dentistry are some other fields of CBCT applications in dentistry In general, CBCT is less expensive and have smaller dimensions when compared to CT, more accurate images obtained in shorter times with this technique [16], [19].

C. Nuclear Imaging

Nuclear imaging is another field of medical imaging; it uses radioisotopes which emit another form of ionizing radiation, gamma rays. Radioisotopes are given to the patient and the emitted rays of radioisotopes from the body used to form an image by special gamma cameras. In this imaging modality, there are two different subgroups as Positron Emission Tomography (PET) and Single Photon Emission Tomography (SPECT) and used for diagnosing and treatment of diseases. Nuclear imaging helps to detect metabolic activities of hard tissues for dentistry, so calcification problems can be studied with this method [27]. Also tooth caries, periodontium diseases, alveolar bone loss, diagnosed with the Nuclear imaging [28]. Especially, temporomandibular joint imaging is ideal for SPECT where also implant dentistry uses these methods [28]. Nuclear imaging, similar to X-Ray based techniques, has risks induced from ionizing radiation, additionally, the radioisotopes create waste products that harm the environment.

Described methods of dental imaging are all uses ionizing rays for imaging however, in years as technology developed different imaging techniques evolved and also started to use in dentistry.

D. Magnetic Resonance Imaging

Magnetic Resonance Imaging (MRI) is one of the medical imaging techniques and does not use ionizing rays as a source. Principle of MRI based on using radio frequencies and magnetic properties of atomic nuclei. For imaging, the body, hydrogen nuclei are used since the body contains exceedingly water molecules. MRI gives high-quality cross-sectional images of the body, also provides soft-tissue contrast which is valuable for diagnosing [20]. MRI is generally used for imaging soft tissues and organs since they contain more water molecules than hard tissues like bones. For dentistry applications, MRI is not suitable for imaging the teeth however X-Ray based techniques fail to image salivary glands and soft tissues, therefore to image these areas MRI is started to use. Nowadays soft tissue lesions, odontogenic cysts and tumours can be observable in magnetic resonance imaging better [2]. Studies both in vitro and in vivo demonstrate MRI is a promising tool for dentistry in assessment of Temporomandibular joint, orthodontic and endodontic treatments, jaw lesions and for prognosis [2], [20]–[22]. Magnetic nature of this imaging modality restricts some patient who has pacemakers or implantable defibrillators, also patient with dental alloys may be affected from the high-frequency magnetic field. In different studies, the effect of MRI to dental alloys investigated and as results showed that some metal alloys may exhibit artefact on images [23].

E. Ultrasound Imaging

Ultrasound Imaging (US) uses sound with a frequency 2 to 20 Megahertz (MHz) to create an interior image of the body. This method is relatively low cost and painless, also it does not use ionizing radiation so it is safer for patients [24]. Piezoelectric material converts electrical impulses to sound waves and these waves transmitted into tissues, every tissue has different acoustic properties which lead to different absorption and reflection of waves that help to form images. For dentistry applications frequencies between 3 MHz-12MHz used and both hard and soft tissue can be imaged [24]. In dentistry, differentiation of cystic lesions, measuring enamel thickness, to demonstrate tooth cracks and caries and to identify periodontal bony defects the US can be used according to studies [2], [24]–[26].

F. Thermography in Dentistry

Thermography is the method of measurement of skin temperature distribution on the body over a given period [29]. Chemical reactions in the body change the temperature these changes are observable by thermography and helps to understand metabolism, dynamics of blood flow [30]. For dentistry, thermography is a relatively new method and has advantages like fast scanning, non-ionizing, low cost and patient comfort [30]. Temporomandibular joint disorders, chronic orofacial pains, nerve deficits and myofacial symptoms can be diagnosed by thermography and mandibular disorders can be detected [29], [30].

III. Dentistry and Artificial Intelligence

Artificial intelligence is a branch for developing computer algorithms to mimic the cognitive abilities of the human brain [31], [32]. In this field, learning and problem solving are skills that machines need to have. Artificial intelligence has sub-branches like machine learning and deep learning which diversified according to capabilities of the algorithm. Artificial intelligence techniques started to use in medical applications also. Machine learning and deep learning algorithms used to analyze the medical data and make predictions about if there is a disease or not, prognosis, to estimate healing time. Not just medical applications but also in dentistry artificial intelligence applications are trying to use for many different purposes, detection of abnormalities, to provide information about the functional performance of tissues, classifying diseases [31]. First, artificial intelligence-based virtual assistants used to coordinate appointments, alerting patients for their checkups and treatment planning [33]. Besides these, artificial intelligence tools can assist diagnosis from radiographic images by analyzing the signs which human eye cannot detect easily. In orthodontics, again analyzing radiographs can aid in diagnosing and treatment. Prosthetic applications may use artificial intelligence to design the best prosthesis by using different variables like facial calculations of the patient [33]. Within years, the number of publications about machine learning-dentistry is increasing, there are studies for oral cancer predictions, classification for dental plaque and treatment planning for orthodontic surgeries [34]. However, there is still a gap for a device which also includes software to combine both dental imaging and image analysis with artificial intelligence to ease the diagnosis and treatment processes for the dentists. Artificial intelligence may be not yet enough by its own, however, it is a useful tool to aid the professionals in different phases of diseases and can be used more in this field with combined devices.

IV. CONCLUSION

Thermography is a novel and promising tool for dentistry applications and has advantages mainly being non-ionizing. Other non-ionizing methods such as MRI and US have more common applications for dentistry. Studies of US for dentistry shows the benefit of US to patients from many aspects and also the potential of US to use both hard and soft tissue makes the US suitable for dental examines which includes both soft tissues like salivary glands and hard tissues like a jawbone. Where MRI has disadvantages of not being able to visualize hard tissues because of their lack of hydrogen molecules compared to soft tissues, even with this lack still MRI has a variety of applications and advantages for dentistry. Nuclear imaging is suitable for more limited applications in dentistry and its disadvantage to both patient and environment makes it less suitable for dentistry. Digital radiography techniques also ionizing techniques and have harmful effects

on patient however, with lower dose principles they are still popular techniques in dentistry. CBCT have a wide range of applications and helps to diagnose and treat dental diseases and disorders. Appropriate use of radiography techniques and other advantages like cost-effectiveness makes still radiography a corner-stone.

KAYNAKÇA

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