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Review Article

Dentistry Section

Radiation-free Imaging in Paediatric Dentistry: A Review

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ABSTRACT

Radiography is considered one of the most valuable diagnostic tools in dentistry, and new modalities are on the rise that offer greater precision and clarity. Traditional methods often fail to provide the required diagnostic information; hence, high-resolution, three-dimensional imaging modalities are necessary. Computed Tomography (CT) and Cone-Beam Computed Tomography (CBCT) produce precise images, but the radiation exposure involved is far greater than that of conventional radiographic modalities. Children are more susceptible to radiation effects than adults. Hence, clinicians should acquire knowledge of non ionising imaging modalities and their various applications, particularly in paediatric dentistry, so as to employ them in clinical practice. The present review encompasses details of various radiation-free imaging techniques, based on clinical evidence from original research and case reports.

Keywords: Maxillofacial imaging, Non ionising imaging, Oral radiology, Paedodontic radiology

INTRODUCTION

Dental radiography is believed to be the most effective and valuable diagnostic tool for an accurate and comprehensive assessment of a child's oral cavity. In paediatric dentistry, radiographs of teeth and supporting tissues are typically taken for four main purposes, such as caries identification, dental trauma, disturbances in tooth development, and investigation of pathological disorders other than caries [1]. Ionising imaging techniques, such as conventional two-dimensional (2D) radiography and commonly used advanced three-dimensional (3D) modalities like CT and CBCT, involve the use of X-rays, which may cause deterministic and stochastic effects on body cells [1,2]. Due to the intricacy of the maxillofacial skeleton, the anatomy being evaluated cannot be precisely represented by two-dimensional radiographs. Periapical radiographs can be challenging to interpret due to anatomical or background noise resulting from the superimposition of surrounding structures. The 2D radiography underestimates the extent of bone loss. The relationships between soft and hard tissues are not visible on such radiographs [3].

The advanced modalities, such as CT and CBCT, overcome many of the aforementioned disadvantages. However, one of their biggest drawbacks is the high radiation exposure, reported to be 2.07 mSv for CT and 10.3 mSv for CBCT [4,5]. Children are more vulnerable to radiation hazards than adults. Separate protocols for children should be followed for diagnosis and treatment, keeping in mind development and life expectancy following exposure [2,3]. To overcome this limitation, non ionising imaging techniques are gaining relevance. Ultrasonography (USG) was the first non ionising technique used in dentistry by Baum et al., in 1963, while Magnetic Resonance Imaging (MRI) was introduced in this field by van Luijk in 1981 for detecting caries [1,2]. In June 2024, at the European Congress of Dentomaxillofacial Radiology (ECDMFR) in Germany, the first MRI system, MAGNETOM Free, exclusively designed for dentistry, was unveiled. Siemens Healthineers and Dentsply Sirona collaborated to develop the Max Dental Edition [6].

The MRI is widely used for diagnosing soft-tissue lesions and for assessing the temporomandibular joint, and it has recently found applications in studying dental morphology. USG is often used to diagnose salivary gland pathologies and is also highly beneficial for evaluating the contents of cysts and tumours. Optical Coherence Tomography (OCT), which is mainly used by ophthalmologists, has paved its way into paediatric dentistry by enabling clinicians to diagnose early carious lesions. Thermography is mainly used to detect periapical lesions by assessing temperature changes. Near-infrared Imaging (NIA) is another radiation-free modality that has gained ground in recent years, mainly for the detection of caries [1,2].

Therefore, the aim of the present review paper is to study the evidence related to radiation-free imaging techniques—MRI, USG, OCT, thermography, and NIA—based on their various applications in paediatric dentistry. Original studies conducted in paediatric and adolescent populations (0-21 years, according to the American Academy of Paediatrics [7]) pertinent to the subject were included.

RADIATION-FREE IMAGING TECHNIQUES

Magnetic Resonance Imaging (MRI)

Principle: MRI is a radiological technique that uses non ionising radiation from the electromagnetic spectrum's radio-frequency range to create images of bodily structures. The patient is placed in a 1.5-3.0 T magnetic field, which influences the hydrogen atoms in the human body. These hydrogen atoms rotate in a specific direction, speed, and magnitude, producing signals that vary for different tissue types. The resting state of hydrogen atoms is restored when the magnetic field is removed. The signals are processed into a grayscale image, making it easy to distinguish between soft tissues. Various sequences are employed to produce images with different tissue appearances, such as T1-weighted sequences for fat and T2-weighted sequences for fat and water [1-3].

Advantages and disadvantages: MRI offers better contrast and the ability to scan in all planes. It also allows clinicians to assess structures that may be obscured by bone-related artifacts seen in CT images. MRI scanners produce loud noises (often exceeding 95 decibels), requiring the patient to wear hearing protection. Claustrophobia is a concern, since the patient is frequently enclosed by the bore and surrounded by coils, which may require sedation. Any metallic prosthesis or implant may be contraindicated for this imaging modality. MRI is also time-consuming, sensitive to motion, and expensive [1,2].

Applications:

a) Growth and development of head and neck: Greenberg RS et al., in 1998, studied MRI of children up to the age of 17 years and inferred that the length of the oropharynx can enable clinicians to determine age [8]. Condylar characteristics can be utilised as a criterion for staging the developing mandibular condyle in children

[9]. Dental age estimation can be performed with MRI, and it has been shown to be as efficacious as conventional panoramic radiographs [10].

b) Dental morphology: Position and morphology of malformed teeth can be determined with MRI [11]. It also helps in assessing the state of the dental pulp in the root canal and is sensitive and accurate enough to identify morphological deviations such as extraneous roots [12].

c) Orthodontics: Assessment of the disk-condyle-fossa relationship of the TMJ can be done using MRI, following myofunctional therapy [13]. Lateral cephalograms obtained through MRI have been found to be as reliable as conventional lateral cephalograms, which are prerequisites for orthodontic treatment [14].

d) Developmental defects of face: In cleft patients, the velopharyngeal mechanism post-palatoplasty can be well studied with MRI, and it can be further utilised to formulate a treatment plan for patients with velopharyngeal incompetence [15]. MRI has also enabled early detection of cleft palate in a 15-month-old infant and was used to study the arrangement of muscles and velopharyngeal function during speech [16].

e) Interaction with various dental materials: The interaction of different dental materials with MRI has been assessed, and it was found that stainless steel and cobalt-chromium are incompatible. This knowledge is crucial for screening patients before MRI, as stainless steel crowns and appliances fabricated with stainless steel wires of varying diameters are widely used in paediatric dentistry [17].

f) Anatomy and defects of temporomandibular joint: MRI is considered one of the best diagnostic tools for determining TMJ disorders, such as internal derangement, synovial enlargement, and juvenile idiopathic arthritis in children [18,19].

g) Cysts and tumours: Soft-tissue cysts and tumours can be easily investigated with this technique, as exemplified in some case reports [20,21]. MRI is also recommended for evaluation of swelling and inflammation after trauma [22].

The characteristics of all the original studies and case reports on MRI are tabulated in [Table/Fig-1,2], respectively [8-22].

Ultrasonography (USG)

Principle: Ultrasound imaging (USG) uses high-frequency sound waves to emit echoes from tissue surfaces and to receive echoes from the body. Acoustic waves in the clinical range are 2-20 MHz. The probe containing the piezoelectric transducer acts as the ultrasonic source. Echogenicity is assessed from the echoes received by the transducer; these are transformed into electrical signals and displayed as real-time, two-dimensional, black-and-white B-mode images. Strong echo-producing areas are described as hyperechoic, and echo-free areas as anechoic (no echo). Lower echogenicity than surrounding structures characterises hypoechoic regions, whereas isoechoic areas have the same echogenicity as the surrounding tissues. Colour Doppler is a feature that enables visualisation of vascularisation, aiding in assessing healing tissue or recognising pathology (for example, hypervascularisation in a tumour) [23].

Advantages and disadvantages: The method is operator-dependent, and different transducer pressures can yield different images, making it technique-sensitive [1,2]. As a non ionising modality, USG offers major advantages such as easy portability and cost-effectiveness. However, the equipment can be expensive, and image resolution is relatively lower. Ultrasound has limited application in the evaluation of hard tissue [3].

Applications: The USG is of great diagnostic value for the evaluation of salivary gland pathologies, tumours, cysts, and swellings.

a) Salivary gland pathologies: The accuracy of USG in detecting parotid gland tumours was reported as 100% in a study of 61 patients from Yugoslavia [24]. USG was found to perform better than sialography and should be the first choice of investigation, according to Shimizu M et al., (1998) [25].

b) Cysts, Tumours and Swellings: USG has shown substantial diagnostic potential for cysts, tumours, and other soft-tissue pathologies, as illustrated by several case reports [26-29].

c) Endodontics: Ultrasound with colour Doppler has been shown to be effective for assessing healing of periapical lesions after surgery [30]. In comparison with conventional radiography, ultrasound imaging is limited in detecting periapical lesions in the posterior region due to the increased thickness of cortical bone [31].

d) Temporomandibular Joint (TMJ): Ultrasound can be used to assess TMJ inflammation. USG has been reported to be as efficient as MRI in diagnosing TMJ synovitis in paediatric arthritis patients [32]. Ultrasonography has also been useful for locating trigger points in the masseter muscle [33]. However, this modality is considered insufficient for visualising peripheral TMJ structures prior to surgery [34].

e) Others: USG is seldom used for fracture detection; however, it has been found to be effective in determining nasal bone fractures [35]. USG has demonstrated exceptionally high accuracy in detecting nasal bone fractures, with sensitivity ranging from 90% to 100%, specificity from 98% to 100%, and strong predictive values [36]. This modality has also been used to assess gingival inflammation and the presence of subgingival calculus [37]. Details of the applications of this technique are given in [Table/Fig-3,4] [24-34,38].

Authors	Year/ Country	Sample size	Objective	Findings
1. Growth and development of head and neck				
Greenberg RS et al., [8]	1998, Baltimore	200 MRI scans of 0 to 17-year-old children	Assessment of oropharyngeal length in children using MRI and create algorithms to predict the distance based on age, weight, and gender.	Age, weight, and gender can be used to predict the length of the oropharynx in children as determined by midline sagittal magnetic resonance image of the airway.
Morimoto Y et al., [9]	2004, Japan	21 children 9 to 14-year-old	Assessment of MRI characteristics of mandibular condyles in growing children.	The double-contour-like structure and the periods of conversion from red to yellow marrow may be able to be used as part of the criteria for the staging of mandibular condyle development in children
De Tobel J et al., [10]	2017, Belgium	16 participants (14 to 26 years)	MRI was used to study root stage assessment of third molars in age estimation and to compare this with panoramic radiographs, in order to provide considerations for converting 2D staging into 3D staging and to determine the decisive root.	MRI of third molars is advantageous as compared to panoramic radiographs, in forensic age estimation
2. Dental morphology				
Tymofiyeva O et al., [11]	2013, Germany	16 participants-mean age 10.8 years	Assessment of teeth, dental pulp, mandibular canal, and cortical bone using natural contrast MRI and determination of the position and shape of malformed teeth in all 3 spatial dimensions.	Dental MRI is better than conventional radiographs in assessment of anatomical structures and dental anomalies as it provides the advantage of 3D morphology.

3. Orthodontics				
Chavan SJ et al., [13]	2014, India	30 patients 9 to 14 years	Assessment and comparison temporomandibular joint changes especially disk-condyle-fossa relationship following functional treatment of skeletal Class II division 1 malocclusion using Twin Block and Bionator appliances.	The MRI findings at the end of six months follow-up period suggested that the condyles acquired a more anterior position in the fossa while the disk moved more posteriorly in relation to the condyle when compared to the pretreatment positions of the condyle and disc
Heil A et al., [14]	2017, Germany	20 patients (13.95 years ± 5.34)	Comparison between lateral cephalograms using Magnetic Resonance Imaging (MRI) and conventional X-rays for cephalometric analysis	MRI is equally effective as lateral cephalograms in performing cephalometric analysis
4. Developmental defects of face				
Kao DS et al., [15]	2008, Ohio	3 children of 7, 9 and 11-year-old	Assessment of velopharyngeal mechanism post palatoplasty of patients with cleft lip and palate	MRI is a potential imaging tool for refining the management of patients with velopharyngeal incompetence secondary to cleft palate.
5. Interaction with various dental materials				
Tymofiyeva O et al., [17]	2013, USA	Four classes of dental materials were grouped-metals, ceramics, polymers and composites	Assessment of potential influence of standard dental materials on dental MRI (dMRI) by estimating the magnetic susceptibility	Composite, Glass ionomer cement, gutta percha, zirconium dioxide were found to be compatible. Stainless steel wire and brackets and Cobalt-Chromium materials were incompatible with dental MRI.
6. Anatomy and defects of temporomandibular joint				
Moe JS et al., [18]	2016, Atlanta	87 patients (mean age, 11.2 years)	Assessment of temporomandibular joints in children	In majority of the children synovial enlargement was detected.
Tonni I et al., [19]	2023, Italy	29 children (13±2.8 years)	Assessment of temporomandibular joints in patients with Juvenile Idiopathic Arthritis (JIA) using USG and MRI	MRI performed better than USG

[Table/Fig-1]: Characteristics of original studies done on MRI [8-11,13-15,17-19].

Authors	Year/ country	Findings
1. Cysts and tumours		
Emmerling MR et al., [20]	2018, USA	Assessment of melanotic neuroectodermal tumour of infancy in an eight-week-old male. Extraosseous components were better visualised on MRI.
Galvão NS et al., [21]	2019, Brazil	Diagnosis of plexiform ameloblastoma was done with MRI in an 18-year-old male where T1and T2 MRI showed regions of a hyper signal within the lesion which confirmed the presence of fluid.
2. Trauma		
Matsumoto-Takeda S et al., [22]	2011, Japan	Assessment of inflammation of facial trauma in the mental region of a nine-year-old female. To assess the degree of inflammation and the existence of abscess formation in the mental region, MRI was carried out.
3. Developmental defects of face		
Perry JL et al., [16]	2012, Illinois	Early detection of submucous cleft palate in a 15-month-old infant. The arrangement of muscles and the velopharyngeal function during speech was assessed with MRI.
4. Supernumerary tooth		
Golež A et al., [12]	2021, Slovenia	Detection of supernumerary tooth radix paramolaris in a seven-year-old boy with Class II malocclusion. The case demonstrated that MRI could be used to assess the presence and state of dental pulp in the root canal and was sensitive and accurate enough to identify morphological deviations like extraneous roots.

[Table/Fig-2]: Case reports on applications of MRI in paediatric dentistry [12,16,20-22].

Authors	Year/country	Sample size	Objective	Findings
1. Salivary gland pathologies				
Cvetinovic´ M et al., [24]	1991, Yugoslavia	61 patients of age 4 to 73 years	Determination of utility of Ultrasonography (USG) in evaluation of pathologies of parotid gland	USG revealed the tumour's presence in every patient with a parotid gland tumour. This approach was 100% accurate in identifying malignancies of the superficial lobe but less precise in identifying tumours of the deep lobe. The USG results demonstrated remarkable precision in estimating the size of tumours.
Shimizu M et al., [25]	1998, Japan	14 patients of age 5 to 15 years	Comprehension of sonographic features of recurrent parotitis in children to clarify a relationship between sonographic and sialographic findings in this disease.	USG performed better than sialography and it should be the first choice of investigation.
2. Endodontics				
Tikku AP et al., [30]	2010, India	15 patients between the age of 15 to 40 years	Evaluation of efficacy of USG and conventional radiography is assessment of postsurgical healing of periapical lesions of endodontic origin	Ultrasound with colour doppler is an effective tool for assessment of healing of periapical lesions after surgery.
Arslan ZB et al., [31]	2020, Turkey	80 patients of age between 14 to 75 years	Comparison between digital orthopantomography and USG in detection of periapical lesions	USG is a good alternative to digital orthopantomography in detection of periapical lesions but their application is limited in the posterior region due to the presence of thick cortical bone, lack of anatomical landmark and probe size limit.
3. Temporomandibular joint				
Kirkhus E et al., [38]	2016, Norway	55 patients (mean age 12.4±3.5 years)	Determination of the reliability of USG to assess TMJ inflammation using contrast-enhanced MRI as reference standard.	In paediatric arthritis, a moderate correlation was found between the MRI-assessed synovitis and the USG. USG could be a useful diagnostic technique for determining the degree of inflammation in the TMJ.

Azlag Pekince K et al., [32]	2020, Turkey	15 patients of age 18 to 46 years	Determination of the effectiveness of USG in locating spasm points in the masseter muscle.	USG demonstrated in detail the internal structure of the masseter muscle in all patients and provided precise localisation of the spasm points on the muscle.
Erturk AF et al., [33]	2023, Turkey	100 patients of age 18 to 55 years	Determination of features of TMJ and surrounding structures.	When it is necessary to assess the TMJ in patients who will be scheduled for advanced surgical intervention US will not be adequate owing to lack of precision and clarity.
4. Trauma				
Al-Bahrany ZM and AL-Nakib LH [34]	2011, Baghdad	53 patients at age range 14 to 40 years	Comparison between conventional radiography and USG in detection of nasal bone fractures	USG is a good and reliable alternative to conventional radiography in detection of nasal bone fractures.

[Table/Fig-3]: Characteristics of original studies done on Ultrasonography (USG) [24,25,30-34,38].

Authors	Year/ country	Findings
Cysts, tumours and swellings		
Guissa VR et al., [26]	2018, Portugal	Assessment of salivary glands with USG in 7 year and 10 year old children with juvenile Sjögren's syndrome. USG helped to visualise the size, irregular contours and calcifications of the salivary glands.
Kakade A et al., [27]	2021, India	Assessment of a gingival swelling in a three-day-old neonate. Ultrasound of the mandibular symphysis area verified the existence of four deciduous tooth buds and one structure that resembled a tooth, measuring around 8 mm, situated in the supra-alveolar region
Anand GS et al., [28]	2022, India	Diagnosis and assessment of the rare Congenital Granular Cell Tumour (CGCT) in the oral cavity of a two-day-old baby. The lesion appeared as a hypoechoic area in the oral cavity.
Papadopoulou E et al., [29]	2024, Greece	Investigation of a cystic swelling on the floor of the mouth of a six-month-old baby. An irregularly formed cystic lesion measuring a maximum of 5 mm in diameter and a maximum of 13 mm in craniocaudal length was discovered through USG.

[Table/Fig-4]: Case reports on applications of Ultrasonography (USG) in paediatric dentistry [26-29].

Optical Coherence Tomography (OCT)

Principle: OCT is a non invasive imaging modality that uses near-infrared light to investigate internal structures up to a depth of 2-3 mm, including ocular, skin, intravascular, and oral soft and hard tissues. The working principle is the same as that of USG, but light replaces sound. In both modalities, an incident beam is projected, and the backscattered signal is measured. It produces two-dimensional optical tomographic cross-sectional images (B-scans). When multiple B-scans are obtained in the Y direction, a 3D image can be produced [35,36].

Advantages and disadvantages: OCT is painless and well accepted by patients, and high-resolution images can be obtained. It is more effective at differentiating between normal and precancerous/cancerous tissue at a 1300 nm wavelength because of its greater ability to pass through the keratinised layer. However, compared with newer technologies, its imaging speed is slower. It is motion-sensitive, so artifacts may be produced, and the OCT probe's access to the posterior parts of the mouth is restricted. It is also expensive [35,36].

Applications:

a) Caries detection: OCT has been applied to caries diagnosis and is known to detect early carious changes in enamel. A study in 22 paediatric patients assessed the accuracy of OCT in diagnosing secondary caries and found it to be accurate, with sound and infected enamel differentiable by high signal contrast [37]. Another study in 29 patients aged 6-20 years investigated structural changes in early occlusal caries of primary teeth over six months during fluoride application, demonstrating good precision in visualising remineralisation [39].

b) Mineralisation changes in enamel: OCT has been shown to measure the degree of demineralisation around orthodontic brackets [40]. It also demonstrated high precision in Molar Incisor Hypomineralisation (MIH) diagnostic imaging, indicating its potential as a reliable diagnostic tool [41]. It can be inferred that OCT is a promising technique for diagnosing white-spot lesions and early caries, thereby aiding clinicians in selecting preventive and minimally invasive treatment modalities to halt disease progression. The characteristics of all original studies on OCT are tabulated in [Table/Fig-5] [39-42].

c) Thermography: Modern imaging technology called thermography has a number of potential uses in dentistry. With the help of non contact devices, thermal data may be acquired and analysed. The technology relies on infrared electromagnetic radiation, which is emitted by objects at temperatures above absolute zero. The temperatures of individual locations within a region of interest at a given time can be documented by charting temperature changes on a two-dimensional image. At typical physiological temperatures, human tissues are nearly perfect infrared emitters. The majority of infrared radiation emitted by the human body lies in the long-wavelength range (approximately 8-15 μm). The radiation can be converted by infrared cameras into electrical signals, which can subsequently be displayed using colours to indicate temperature levels. Ultimately, a quantitative temperature map of the region is produced, and this map can be used to distinguish between various disease conditions. Thermography aids in the early identification of anomalous regions. It is affordable and enables rapid scanning. It is generally well-accepted by patients because of its comfort. It also offers the advantage of a quantitative approach. A major disadvantage of the technique is its sensitivity to external factors [42].

A study by Aboushady MA et al., involving 80 patients, aimed to compare the efficacy of thermography with conventional radiography for detecting periapical lesions and to evaluate temperature changes in inflammatory endodontic lesions with the former modality. It was found that thermography was as efficacious as conventional radiography in terms of diagnostic potential. The study also showed that it can be used for early detection of lesions by assessing the thermal changes in the preclinical period [43].

Near Infrared Imaging (NIR)

Principle: Berg RA et al., described the NIR scattering characteristics of dentin and enamel in 1995. Most near-infrared light can pass through healthy enamel with only slight scattering, depending on the wavelength. The ideal imaging wavelength is 1310 nm, as it balances water attenuation and enamel scattering [44]. By contrast, demineralised structures and carious lesions scatter traversing NIR light, which appears as dark patches. Dark and translucent areas can be compared at different angulations and illumination modes, and thus NIR wavelengths allow thorough investigation of the depth of cavities and other aspects. It is also straightforward to visualise tooth cracks in the near-infrared spectrum [44]. The DEXIS CariVuTM (DEXIS, LLC, Hatfield, PA) and the VistaCam iX

Authors	Year/ country	Sample size	Objectives	Findings
1. Caries detection				
Lenton P et al., [39]	2012, USA	22 paediatric patients	Assessment of subsurface tooth-composite and detection of secondary caries in paediatric patients.	OCT was efficient in the evaluation of enamel integrity of enamel-composite restorations. The underlying sound and carious enamel below the interfaces could be differentiated with high signal contrast which helped in detection of secondary caries as well.
Zhu Y et al., [40]	2023, USA	29 patients of age 6 to 10 years	Assessment of changes in the structure and activity of early occlusal caries on primary teeth over a six-month period during fluoride intervention using Short Wavelength Infrared Imaging (SWIR) reflectance imaging and Cross-Polarisation Optical Coherence Tomography (CP-OCT).	Changes in lesion activity and structure, such as the emergence of a heavily mineralised transparent surface layer suggestive of arrested lesions following non surgical intervention, were seen by OCT. The dehydration kinetics of active and arrested lesions differ, was demonstrated by time-resolved SWIR reflectance imaging.
2. Mineralisation changes in enamel				
Nee A et al., [41]	2014, USA	10 patients of age between 13 to 43 years	Use of OCT to assess demineralisation in the peripheral regions of orthodontic brackets	OCT measured a significant increase in demineralisation at the base of orthodontic brackets over a period of 12-months.
Ferezin AN et al., [42]	2023	20 teeth Patients of age group 6 to 12 years	Descriptive and qualitative evaluation of teeth affected by enamel hypomineralisation using OCT.	OCT processing techniques demonstrate improvements in MIH diagnostic imaging, indicating the image texture analysis may be a valuable and promising diagnostic tool.

[Table/Fig-5]: Characteristics of original studies done on OCT [39-42].

Author	Year/ Country	Sample Size	Objective	Findings
Berg RA et al., [44]	2017, Japan	30 subjects aged 18 years and above	Comparative evaluation between CariVu and Bitewing radiography in detection of proximal caries	CariVu showed promising results in caries detection and it can serve as an adjunct to bitewing radiography.
Alaryyes S et al., [46]	2021, USA	22 subjects aged from 6 to 11 years	Evaluation of sensitivity and specificity of NIR imaging in detection of interproximal caries on primary molar surfaces.	The sensitivity and specificity of this modality was found to be low and hence was stated to be unreliable.

[Table/Fig-6]: Characteristics of original studies done on NIR [44,46].

(Dürr Dental, Bietigheim-Bissingen, Germany) are two examples of the relatively few commercial devices that use NIR technology. DEXIS CariVu utilises a CCD sensor and NIR light optimised at 788 nm for fixed-angle transillumination imaging of the occlusal surface. The camera on the DEXIS CariVu is pointed directly at the occlusal surface, and two light sources illuminate both the buccal and lingual surfaces of the target tooth for transillumination [43].

Advantages and disadvantages: It is useful in detecting multiple types of caries, and no cleaning of the tooth surface is required prior to imaging. However, this modality requires a series of processing steps. The image produced is of low contrast and resolution. It is highly expensive [43-45].

Applications: It is primarily used in the detection of caries, as exemplified in [Table/Fig-6] [44,46].

DISCUSSION

Radiation is classified as ionising radiation and non ionising radiation, which is based on the energy of the emitted particles. A sequence of energy waves composed of oscillating electric and magnetic fields moving at the speed of light is referred to as non ionising radiation. The ultraviolet, visible light, infrared, microwave, radio frequency, and very low frequency spectrums are all considered non ionising radiation [1-3]. Non ionising radiation does not have sufficient energy to remove electrons from atoms; by contrast, ionising radiation can ionise atoms by destroying bonds, disrupting Deoxyribonucleic Acid (DNA) and removing electrons to produce ions [46]. With the advent of numerous non ionising imaging techniques, their applications in dentistry are still under investigation. Some of them are hyperspectral imaging, photoacoustic imaging, and terahertz technology. However, non ionising radiation is not completely hazard-free, particularly Near-infrared (NIR) and thermography. They generally pose two main risks: photochemical reactions to the skin and retina of the eye, and tissue heating (thermal effects). The frequency determines the extent of the biological hazard [47]. These modalities are technique-sensitive, and therefore require skilled and trained personnel to operate the instruments. More studies should be encouraged to evaluate their efficacy, risks, benefits, and applicability in paediatric dentistry. This is the first review to encompass the literature on these modalities in the field of clinical paediatric dentistry.

CONCLUSION(S)

Many non ionising imaging modalities have been developed, but their applications in paediatric dentistry are still under investigation. With proper application of the appropriate imaging technology and its interpretation, and adhering to the As Low As Reasonably Achievable (ALARA) principles, newer radiation-free techniques can aid in the early detection of pathologies, thereby reducing morbidity and mortality and improving patients' quality of life.

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