Report

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The use of radiography in the diagnosis of oral conditions in children and adolescents

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ABSTRACT

Radiography can serve as a useful aid in the diagnosis of numerous oral conditions, with a place in nearly all of the disciplines of dentistry. As such it can have a beneficial role in caring for the oral health of children and adolescents.

The following review discusses the use of radiography in the diagnosis of oral conditions in children and adolescents, with particular reference to the diagnosis of dental caries, dental trauma, growth and development and in other dental scenarios, along with the importance of incidental findings. The risks associated with radiation exposure from the use of radiography are discussed, how these need to be balanced with the possible benefits associated with such use, as well as how risks could be minimised. Summary recommendations are also presented, providing an overview of the use of radiography for oral diagnosis in various clinical scenarios for children and adolescents.

INTRODUCTION

Radiography is an essential aid in the diagnosis of oral conditions in children and adolescents. Radiographic evaluation can support the diagnosis of the presence and extent of dental caries, dental and jaw trauma, stages of tooth and jaw development, pain or developmental anomalies. The use of radiographs should be individualised and guided by the findings of the clinical examination and the patient's medical and dental histories. The approach should be systematic, using defined decision-making processes in the selection of type of radiograph used, and based on the outcome of previous radiographic diagnoses to determine the frequency of subsequent radiographs. The clinician should appreciate that radiography has associated risks and thereby follow the 'as low as reasonably achievable' (ALARA) principle, which serves to minimise patient risk and maximise patient benefit.

RADIOGRAPHY IN THE DIAGNOSIS OF DENTAL CARIES

In caries diagnosis, posterior bitewing radiographs (PBWs) provide an additional diagnostic yield to the clinical examination in both primary and permanent dentitions (Coutinho and Costa 2014; Edward et al. 1973; Hintze and Wenzel 1994; Hopcraft and Morgan 2005; Stecksen-Blicks and Wahlin 1983). PBWs may also assist in monitoring caries progression, regression, risk and experience. They have been shown to be valid in improving detection of recurrent caries (Rudolphy et al. 1997). In comparison with PBWs, panoramic radiographs are not accurate in diagnosing caries (Akarslan et al. 2008; Kamburoglu et al. 2012) particularly because of the varying magnifcation of teeth. However, they may help in diagnosis of severe caries with pulpal infection. In caries diagnosis, lateral oblique radiographs provide more accurate information when patients cannot tolerate intraoral radiographs (the former shown to have fair to good agreement ($\kappa = 0.53$-0.72) with caries diagnoses made from PBWs (Townsend 2000)).

When examining teeth, a clinical examination should be undertaken and a provisional diagnosis made, including assessments of clinical caries, caries experience and risk including oral hygiene, dietary practices, fluoridation status, fluoride use, and epidemiology of caries in the local population. The American Academy of Pediatric Dentistry and the European Academy of Paediatric Dentistry (AAPD and EAPD) have developed evidence-based guidelines regarding the use of radiography in children and adolescents (AAPD 2012; Espelid et al. 2003).

These guidelines recommend that PBWs should be considered for new patients in the primary dentition if there are closed posterior contacts and the proximal surfaces cannot be assessed via visual/tactile examination. In the mixed and permanent dentitions, PBWs should be taken for all new patients. This helps to identify any carious lesions not evident clinically, including early enamel lesions that can be remineralised. These initial PBWs serve as a baseline to record and monitor lesion extent, progression or regression, all of which will assist in deciding the timing of subsequent radiographs. The timing of PBWs should always be based on individual caries-risk and the presence and extent of carious lesions identified on baseline (or pre-existing) PBWS and clinically. The extent of a carious lesion should be classified according to defined criteria, such as the P-lesion system (Mejare et al. 1998). This classifies the severity of interproximal carious lesions from 1-5: P1 (lesion limited to the outer half of enamel), P2 (inner half of enamel, to the dentino-enamel-junction (DEJ)), P3 (just beyond the DEJ with lateral spread), P4 (outer one third of dentine), P5 (inner two thirds of dentine, to the pulp) (Figure 1). Staging lesions allows decisions to be made about timing and type of intervention or prevention and the timing of future radiographs. The AAPD (2012) guidelines incorporating appropriate prevention and restorative measures, recommend, 6-12-monthly PBWs for all patients with clinical caries or increased caries risk (risk based

Figure 1. P-lesion classification system (adapted from Mejare et al. 1998).

on individual caries risk assessment); 12-24-monthly PBWs for patients without clinical caries and without increased caries risk.

In patients with increased caries risk, periapical or anterior occlusal radiographs might also be considered to detect early interproximal lesions in anterior teeth, particularly in the young permanent dentition. Early detection of lesions allows a much more focussed local preventive approach.

Younger children may find intraoral radiographs difficult but with careful placement, usually children manage quite well by four years-of-age (Figures 2 and 3). Occasionally there may be a need to gradually introduce the experience to a younger child over several visits. Holders can be adapted to fit in small mouths and traditional film based radiography allows for bending corners to make the process easier. The use of foam bites or cardboard/adhesive bitewing flaps may help in a younger child's first posterior bitewing experience (Figure 4). With the advent of phosphor-plate (PSP) digital intraoral radiography, imaging plates are available in all of the sizes of traditional intraoral films, with equivalent thickness and are compatible with some existing film holders, while there are also PSP holders that are compatible with the specific digital receptor. This is in contrast to the charge-coupled device (CCD) system, with sensors that are often bulky, limited in size, and placement restricted due to the connected electrical cord, making the CCD system more difficult in children. If using digital radiography, the PSP system should be considered when a dental practice is treating many younger children. It may help to have films/receptors attached to something the child can hold such as clipped in a haemostat or taped to a wooden ice-block stick (Figures 5, 6 and 7), or the use of foam bites and bitewing flaps as already mentioned. If children are unable to cooperate, it is recommended that this is noted in the patient record and accept that treatment has to be based on clinical diagnosis and history. Producing poor radiographs with limited diagnostic capacity should be avoided. A further consideration is using the lowest possible exposure. This can be achieved by using digital radiography (shown to reduce the mean radiation dose by a factor as much as 2.8x and the mean exposure time by as much as 0.4s, compared to conventional film (Alcaraz et al. 2009)) or by using faster speed film (a 20% reduction of mean radiation dose and up to 0.1s reduction in exposure time, when using F-speed film instead of D-speed film (Alcaraz et al. 2009)).

DIAGNOSIS OF DENTAL TRAUMA

The use of radiography in the diagnosis of dental trauma in children and adolescents assists initial diagnosis and also serves as a baseline to diagnose future sequelae of the trauma.

Figure 2. Intraoral placement of the 'RINN' PBW holder in a four-year-old patient.

Figure 3. Intraoral placement of the 'Kwik-Bite' PBW holder in a four-year-old patient.

Figure 4. Adhesive soft foam and cardboard bitewing flaps.

Figure 5. Radiographic film clipped in a haemostat.

Figure 6. Intraoral film placement in a four-year-old patient – film clipped in a haemostat.

Figure 7. Intraoral film placement in a four-year-old patient – film taped to a wooden ice-block stick.

The International Association of Dental Traumatology (IADT) has produced evidence-based guidelines where possible[1]. It is very helpful if unclear about appropriate radiographs for a traumatic injury to consult the IADT endorsed website: dentaltraumaguide.org, which gives a step-by-step approach to diagnosing and managing different dental injuries. The benefit of this site is that it is continually being updated.

When diagnosing dental trauma, injuries to dental coronal, and radicular structures and the surrounding tissues should be considered. Not all signs of injuries will be evident clinically and radiographs will aid more accurate diagnosis. Following clinical examination of teeth, it is recommended that at least two periapical radiographs with different angulations are taken. In the anterior region one of the radiographs may include an occlusal view (which if taken with a standard size 2 film, may be a more tolerable examination than a periapical view in a younger patient). This will improve diagnosis of root fractures that might not be visible in a particular x-ray beam projection/alignment. The IADT recommends taking up to three periapical radiographs at different angles of beam alignment[1]. This is to improve diagnosis of the extent of coronal fractures, radicular fractures and/or periodontal ligament space changes. The diagnosis of luxation injuries is improved particularly in the young permanent dentition when the stage of eruption of teeth may not be clear and clinically it is difficult to know if a tooth has been extruded or intruded. If there is a lip or cheek laceration or swelling with evidence of missing tooth tissue, a radiograph of the soft tissues may be taken to examine for tooth fragments or foreign debris (the film placed in the vestibule between the soft tissues involved and the dental arch, with 25% of the normal exposure)[1].

In children it is important to consider injuries to the supporting bone also, and it is important to note that newer panoramic machines have child panoramic options offering reduced collimation. It is recommended that if there has been a chin injury, or a bony step is detected or there is an alteration in the occlusion, a panoramic radiograph should be taken to allow wider examination of the mandible, maxilla and temporomandibular joint (TMJ) areas.

Following the initial trauma diagnosis and management, and based on the diagnosis/classification of the dental injury, guidelines recommend a systematic follow-up with radiographs (to pursue a standardised, reproducible technique), in order to monitor/diagnose healing, failure of healing, continuing root development and eruption or development of pathological sequelae such as root or bone resorption. The timing of radiographs varies according to the type of dental injury sustained, but it has to be noted that the clinical evaluation at each recall plays a major part in determining what radiographs are needed. Current and easy-to-follow guidelines are available at the dentaltraumaguide.org.

DIAGNOSIS OF GROWTH AND DEVELOPMENT

Radiography is a very useful adjunct to diagnose orofacial features and conditions that can impact on growth and development. All radiographic views including periapical, occlusal, PBW and panoramic views may assist in diagnosing/confirming many conditions. Examples include ectopic and/or impacted teeth, anomalies in tooth shape, supernumerary teeth, radio-opaque and radiolucent lesions, missing teeth, delayed/accelerated development and eruption (Cholitgul and Drummond 2000; Katsnelson et al. 2010; Whittington and Durward 1996) (Figures 8 and 9). In many instances, early diagnosis can allow intervention to prevent potential problems developing or becoming more severe.

When tooth impaction or ectopic eruption is discovered clinically or on a periapical or PBW radiograph, further radiographs should be considered to assess the whole developing dentition to diagnose or exclude associated anomalies or problems. Recommendations of appropriate radiographs can be found in the literature for most dental anomalies. For example, in terms of impacted maxillary canines, Ericson and Kurol (1988) proposed that if the maxillary canines cannot be palpated clinically by 10 years-of-age or if impaction or ectopic eruption are suspected, then a panoramic radiograph should be taken alongside periapical or occlusal views.

Together with clinical findings, radiographs are very useful

1 *IADT (2014). Dental Trauma Guide. http://www.dental-traumaguide.org/. Accessed: 15 September 2015.*

in confirming or identifying anomalies in tooth number, with the potential to diagnose, for example, hypodontia and supernumery teeth on panoramic radiographs (Cholitgul and Drummond 2000; Ezoddini et al. 2007) (Figure 10).

Lateral cephalometric radiographs are used in orthodontic skeletal analysis, when diagnosing malocclusion and in assessment of skeletal growth. Panoramic radiographs may also confirm patterns of skeletal growth and tooth development and position, which are critical in planning orthodontic treatment.

DIAGNOSIS OF OTHER DENTAL CONDITIONS

Radiography plays a significant role in improving diagnosis of many other dental conditions, for example, cause of and location of pain and infection. Specific radiographic techniques and approaches have been developed in specific areas of dentistry such as periodontics, restorative dentistry, endodontics, oral surgery and oral medicine.

PBWS, periapical or panoramic radiographs may assist in the visualisation and confirmation of bone loss in periodontal disease; changes in the pulp chamber, root and periapical area; or may confirm the state/condition of previous treatment. Poorterman et al. (1999) identified 86.2% of inadequate restorations on radiographs alone, compared with identification clinically, which demonstrates the usefulness of radiographs in assisting clinical decision-making. The panoramic radiograph plays an important role in diagnosing oral pathology and changes in TMJ anatomy, because it produces a view of both dental arches on a single image, offering a comprehensive view of the dentition and supporting structures. Furthermore, in some cases it may be easier to achieve a panoramic exposure than an intraoral exposure in younger children, and newer panoramic systems offer ½ panoramic, extraoral PBW and child-specific programmes, resulting in improved radiation safety. Cone beam computed tomography (CBCT) might be helpful in diagnosing oral conditions where a three-dimensional appreciation proves to be useful (e.g. localisation of oral anatomy, oral pathology and dental structures). It is important to note that the radiation dose in a CBCT exposure is up to 15 times greater than a panoramic (Deman et al. 2014) and the effective dose has been shown to differ from one CBCT machine to another (Hirsch et al. 2008). The utilisation of radiography in these other scenarios should be based on the presenting history and clinical findings and also in consideration of the potential benefit that the use of radiography may provide.

One other radiographic view that warrants mention is the lateral oblique radiograph. This view is an extra-oral projection, obliquely through the angle of the mandible, resulting in a view focussing on the posterior sextants of the maxillary and mandibular arches, as well as the TMJ. Lateral oblique radiographs may be taken to assess, in amongst other things, the TMJ (Smith et al. 1989), when conducting special investigations such as sialography (Pellegrini et al. 1992), and in situations where patients cannot tolerate the placement of intraoral films or the taking of a panoramic radiograph (e.g. patients with special needs or developmental delay).

INCIDENTAL FINDINGS ON RADIOGRAPHS

Radiographs are useful in the diagnosis of conditions that may be unsuspected clinically and unrelated to the primary reason for taking the radiograph. Bondemark et al. (2006) found that pathology (e.g. radiopacities, periapical inflammatory lesions, and dentigerous cysts) or other abnormal finding(s) were evident on panoramic radiographs in 8.7% of a study of routine orthodontic patients. This does not of course suggest panoramic radiographs should be taken as a screening tool for incidental findings, but it demonstrates their use in identifying many oral conditions, and this should be appreciated when considering the benefits of taking a radiograph in any particular situation.

Figure 8. A panoramic dental radiograph that identified a dens evaginatus on the unerupted 45.

Figure 9. A panoramic dental radiograph that identified a vertically impacted 35 and 45.

Figure 10. A panoramic dental radiograph that confirmed the presence of an erupted supernumery tooth distal to 62 and identified an unerupted supernumery tooth distal to 22.

THE RISK-BENEFIT RATIO

Radiography can be a useful aid (provide a benefit) in the diagnosis of oral conditions in children and adolescents, but is also associated with risks to the patient, which establishes a risk-benefit ratio that should be considered in the prescription of every radiograph. Dental radiography involves x-radiation and therefore can have damaging effects in radiosensitive human cells. The doses absorbed from dental radiography range from 7.75μGy for a single bitewing (Underhill et al. 1988) to 890μGy for a single panoramic (Hayakawa et al. 2001), and a CBCT exposure as much as 15 times that of a panoramic (Deman et al. 2014). Therefore, strict protocols for the use of CBCT should be established, acknowledging that children are more sensitive to radiation as their cells are rapidly dividing, and children live longer so the effects of radiation have more time to become visible (for children younger than 10 years there is a 3x multiplication factor for cancer risk, which is relatively higher for females than males (Shimizu et al. 1988, cited in ICRP 1991)).

Potential errors involved in the radiographic procedure may influence the risk-benefit ratio and should be remembered when taking radiographs. Errors may be due to film/sensor positioning (e.g. Versteeg et al. (1998) found a greater number of re-takes required when using digital sensors (CCD) compared with conventional intraoral film); or even influenced by patient behaviour (e.g. Poorterman et al. (2010) found it impossible to take bitewings for 18% of a sample of 5-6 year-olds, and that 14% of surfaces were unreadable on bitewings). Positioning errors can be minimised with the use of beam aiming devices (Figures 2 and 3), which may also assist with reproducibility and longitudinal comparability, and these have been shown to be well tolerated by 3-15 year-old children/adolescents (Pitts et al. 1991).

In order to ensure maximal benefit to the patient when using radiography, it needs to be appreciated that radiographs have limitations, for example, bitewings cannot differentiate between an arrested and active carious lesion (Wenzel 2004), or a cavitated and non-cavitated surface (Nielsen et al. 1996). Also, the positive predictive value of dental radiography has been found to decrease with disease prevalence in low-prevalence populations (White and Yoon 1997). Furthermore, radiographs are a two-dimensional representation of a three-dimensional object; therefore, artefacts may be evident (e.g. cervical burnout and non-carious triangular-shaped radiolucencies (the latter being evident in up to 60.3% of bitewings (Kuhnisch et al. 2008)). Therefore, clinicians should be able to recognise and distinguish between actual pathology and these limitations and it is recommended that radiographs be examined in a systematic manner, under adequate/appropriate magnification and lighting conditions.

ALARA (DOSE REDUCTION) AND RADIATION SAFETY

No discussion regarding the use of radiography in the diagnosis of oral conditions in children and adolescents is complete, without mentioning the ALARA principle (dose reduction) and radiation safety. The ALARA principle is based on keeping radiation exposure to any individual patient as low as reasonably achievable. This suggests not taking radiographs unless the benefits outweigh the radiation risk, and not unless the potential findings may change the clinician's treatment approach. The ALARA principle also suggests that the associated radiation dose be minimised by any means possible, but still to allow sufficient image quality for accurate diagnosis. Dose reduction can be achieved by using rectangular collimation (a dose reduction of up to 70% (Underhill et al. 1988)), varying tube voltage (using 60-70kV instead of 50kV (Napier 1999)), decreasing exposure time (Horner and Hirschmann 1990), using digital radiography instead of conventional film (a dose reduction by a factor of up to 2.8x (Alcaraz et al. 2009)) and using faster speed film (a dose reduction of 20% when using F-speed instead of D-speed film (Alcaraz et al. 2009)). Abiding by the ALARA principle should influence the risk-benefit ratio, so as to minimise risk and therefore tip the balance towards patient benefit.

When utilising radiography for oral diagnosis, patient protection should be maximised using recommended protective equipment such as lead aprons and thyroid shields (shown to reduce the absorbed dose to the thyroid gland by up to 55% (Whitcher et al. 1979)). Radiation exposure to clinical personnel should also be minimised in accordance with the regulations specified by the Office of Radiation Safety, Ministry of Health NZ (Office of Radiation Safety 2010) – which will be reviewed as part of the Radiation Safety Bill that was recently referred to the New Zealand Parliament[2].

[2] *Dental Council of New Zealand (2015). Radiation Safety Bill–Dental Council. http://dcnz.org.nz/resources-and-publications/publications/newsletters/view/14?article=2. Accessed: 15 September 2015*

SUMMARY RECOMMENDATIONS

Table 1. Radiographic use in caries diagnosis

Radiograph type	Recommendations		
	New patients	**Recall patients** (based on individual caries risk and baseline bitewing findings)	
PBWs	Primary Dentition (closed posterior contacts)	Low caries risk	12-24 mthly
	Mixed Dentition	Medium caries risk	12-mthly until low risk
	Permanent Dentition	High caries risk	6-12-mthly until med risk
Periapical(s) (anterior)	Consider for all high caries risk patients in conjunction with clinical findings		
Panoramic	Not usual, unless patient cannot tolerate intra-oral radiographs and need to exclude severe caries problems (risk-benefit ratio to be closely considered due to higher radiation dose)		

Table 2. Diagnosis in growth & development
**Prescribed on an individual case-by-case basis*

Radiograph type	Examples of potential findings
Panoramic	Anomalies in tooth number; tooth impaction; ectopic teeth; anomalies in tooth morphology; oral pathology; periodontal ligament status; root development status; anatomical landmarks; TMJ anomalies; skeletal fractures; maxillary sinus lining changes
Lateral cephalometric	Craniofacial dimensions (indicating a skeletal basis for malocclusion)
Periapical	Anomalies in tooth number; tooth impaction; ectopic teeth; anomalies in tooth morphology; oral pathology; periodontal ligament status; root development status
Anterior occlusal	Anomalies in tooth number; tooth impaction; ectopic teeth; anomalies in tooth morphology; oral pathology; periodontal ligament status; root development status
Lateral oblique	Anomalies in tooth number; tooth impaction; ectopic teeth; anomalies in tooth morphology; oral pathology; TMJ anomalies
CBCT	Localisation of tooth position and anatomical structures.

CONCLUSION

The preceding summary has discussed the use of radiography in the diagnosis of oral conditions in children and adolescents; namely in the diagnosis of caries, dental trauma, growth and development and in other dental scenarios, as well as acknowledging that incidental findings may also be found. Any approach to utilising radiography for such diagnosis should take into consideration the associated risk-benefit ratio, which should be influenced (where possible) by the principles of radiation safety and ALARA, in order to minimise patient risk and allow maximal patient benefit.

Understandably, the use of dental radiography in these age groups will add to the associated lifetime radiation load, but "childhood is also the stage of development where the long-term preventive benefits of avoiding the initial placement of restorations (which may need to be replaced and maintained throughout later life) are greatest" (Pitts 1996 p. 8).

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