Australian and Jordanian dentists' knowledge of ionising radiation

Mohammad Miqdadi

A thesis presented to Charles Sturt University in fulfilment of the requirements for the degree of

Master of Health Science

August, 2015

School of Dentistry and Health Sciences, Charles Sturt University

Tables

Certificate of Authorship

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Name : Mohammad Miqdadi

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Acknowledgment

I would like to express my deepest gratitude to my thesis advisor, Dr Xiaoming Zheng, for his clear vision and consistent guidance throughout my Master education. I am especially grateful for his advice on ingenuity and leadership, which will without doubt help me throughout my career.

I am also very appreciative of the entire School of Dentistry and Health Science including but not limited to Professor Boyen Huang. I also thank Professor Robert Davidson for his guidance throughout the first 18 months of my degree.

I am honoured to share this distinguished degree with other members of my family. It is with great comfort that I share my happiness from this accomplishment with those that are closest to my heart. It is always good to think big and try hard.

Finally, I thank my wife Rania Alsulieman, and my kids Ismail and Isaac Miqdadi, who have been most patient and who gave me every encouragement when I needed it most. I also thank Dr. Suleiman Odat for being there for me when I needed encouragement and support.

To my parent Ismail and Afaf Miqdadi for their love.

Human Research Ethics Committee Approval

The research undertaken as part of this thesis was approved by Charles Sturt University's Human Research Ethics Committee (HREC), approved on 17/09/2014, approval number 2014/173.

Abstract

The use of imaging involving ionising radiation in dental clinics over the last decade has increased due to its advantages and its use is anticipated to further expand. A substantial body of academic evidence highlights the dangers of ionising radiation with far reaching implications for dental professionals involved in its routine usage. Legitimate concerns exist regarding the potential detrimental effects associated with ionising radiation in dental practice. Studies have shown that exposure to ionising radiation increases the risk of various cancers, including cancer of the salivary gland, the thyroid gland and brain. Exposure to ionising radiation has particularly been linked with leukaemia in children and poses risks to the foetus of pregnant women while also representing other cancer risks to both dental professionals involved in its administration, and patients. This study assesses the level of knowledge amongst dental professionals concerning ionising radiation, comparing Australia with Jordan. These two countries were selected for the study as both register high rates of cancer and provide an insight into practice in two vastly different countries; an advanced economy, represented by Australia in comparison with a developing nation, in this case Jordan. The study involved the collection of both quantitative and qualitative data from which statistics were extracted. Results from the specifically designed questionnaire formed the basis of an evaluation of the knowledge of professionals and their practice. These results found that while Australian dentists were more knowledgable than their Jordanian counterparts about the effects of ionising radiation and implemented more precautions, in both countries there was a significant and disturbing inadequacy in knowledge relating to the most important bodily organs requiring radiation protection and often a complacency amongst professionals in utilising worker and patient safeguards. Despite awareness of the significant evidence of the carcinogenicity of ionising radiation, dentists' knowledge regarding these health hazards is generally poor. Use of safety measures such as leaded aprons, lead lining in clinics and film handling techniques also varied

considerably and were not optimal in either country with many dentists apparently uncertain or indifferent to potential radiation hazards. The conclusion of this thesis is that dentists and dental practice ought to be fully aware of the negative effects of ionising radiation on both professionals and patients, but are not. As a result the relatively simply precautions designed to minimise the carcinogenic effects from this routine procedure are being either overlooked or worse, ignored.

Introduction

Dental radiography has become one of the most frequently performed radiological procedures (American Dental Association, 2012). The radiation exposure associated with dental radiography is relatively low, compared with radiation exposure associated with other examinations such as chest radiography. However, it is important to justify and optimise any radiological procedure to minimize the risk to health (Preston et al., 2013). It is critical to perform dose assessment regularly to ensure that radiation exposure is kept within the recommended levels, which will also help to identify possible equipment malfunction or inadequate technique (Ayatollahi et al., 2012). However, dose assessment is not practised in many dental clinics, suggesting dentist's lack of knowledge about the detrimental effects of over exposure to ionising radiation. Children are more radiosensitive than adults (Alme et al., 1996; ICRP, 1991), therefore increased attention should be paid to minimising paediatric radiation exposures. All radiological procedures carried out on children must include special radiation protection measures and involve dose reduction strategies to eliminate unnecessary radiation exposure (Fushiki, 2013).

It is the responsibility of a healthcare professional to fully inform patients undergoing radiological procedures and processes. Dentists should have up-to-date knowledge of radiation hazards so they can answer common queries from patients. Also, patients have every right to ask questions about the harmful effects that can be associated with radiation exposure. In such cases, the dentist should be able to answer patients' queries and provide them the correct information. However, studies have shown that dentists are poorly informed regarding the proper use of medical imaging tools and grossly underestimate the associated radiation risks (Khatib et al., 2000; Lguy et al., 2005; Preston et al., 2013; Shahab et al., 2011), suggesting a need for improved dental training and education about ionising radiation.

Only a few studies have addressed dentists' knowledge of ionising radiation and its associated hazards. Khatib and others (2000) interviewed 40 dentists working in East Jerusalem about their perceptions of occupational hazards including ionising radiation. Only two dentists (5%) identified ionising radiation as occupational hazards of dental practice. This study illustrates dentists' lack knowledge about ionising radiation and its effects (Khatib et al., 2000).

Shahab et al. (2011) surveyed participants of a conference organised by the Iranian Dental Association about their knowledge of protection from radiation, instruments and methods of radiography, and about the appropriate management of radiographic waste. Forty-five per cent of the dentists said that they first take the radiograph of the periapical view. The paralleling method of the periapical area was supported by 12% of participating dentists. About 10% of dentists used F-speed film and 62.5% E-speed film; digital receptors were used by only 2%. Shahab et al. (2011) concluded that most of the surveyed dentists were not using the proper methods and materials to avoid radiation exposure.

Lguy and others (2005) conducted a survey of 636 Turkish dentists to measure their awareness of radiation dose reduction methods, identify the radiographic instruments they used and learn about the quality of radiographic services being offered in Turkey. The results indicated that the participants were not aware of the technical details of their equipment. Nearly 90% of them were uninformed about the kVp and the speed of the film of the instrument. Rectangular collimators were used by 6% of the dentists and most were using E-speed film (only 3% were using F-speed film). The authors concluded that there is a need to create awareness among Turkish dentists regarding the risks of excessive radiation (Lguy et al., 2005).

Although several studies have described the hazards associated with ionising radiation in dental practice, no research has evaluated either Australian or Jordanian dentists' knowledge and risks of ionising radiation. In the current absence of research information measuring the depth of knowledge concerning ionising radiation within the dentistry profession, this study will endeavour to assess the current levels of understanding of ionising radiation and its health hazards in Australian dentists, and compare their knowledge against that of Jordanian dentists. The justification for comparing Australian and Jordanian individuals in this present study is that it allows an advanced Western country to be compared with a developing Middle Eastern state, potentially identifying differences in professional beliefs and knowledge amongst dentists. Cancer rates in both Australia and Jordan account for the second most common causes of death (Abdel-Razeq, Asem, & Attiga, 2015; Cancer Australia, 2015) while thyroid cancer rates in Jordan are twice that of Australia (Cancer Research UK, 2015). As ionising radiation in dentistry exposes patients and staff to cancer risks of the thyroid, this study can potentially suggest explanations for this higher rate, if it can be determined that dentistry practice in Jordan is responsible.

The specific survey questions chosen for use in the present study focused upon respondent demographics, including country, age, gender, and current position, along with a series of questions asking respondents to report details relating to their clinic and the practice of dentistry within their clinic. Additionally, respondents were tested with questions serving to determine their level of knowledge in the areas of radiation and dental radiography. This study concludes that a higher and more accurate level of knowledge exists among Australian dentists as compared with Jordanian dentists. Overall, the results of the qualitative and quantitative analyses both indicate that dentists practicing in Australia are substantially more knowledgeable and educated in dental radiography and ionizing radiation as compared with those practicing in Jordan. In the current study, the survey questions chosen relate largely to this conclusion, with the specific items relating to this conclusion consisting of, most importantly, the questions posed to respondents testing their level of knowledge in the areas of ionizing radiation and dental radiography, along with the questions posed to respondents detailing the specifics of their clinic and the practice of dentistry within their clinic. This latter group of questions help indicate whether the appropriate practice of dental radiography is taking place separately on the basis of country.

The main significant findings of this study are presented below. All results presented were derived from the quantitative analyses conducted on the survey data collected with the exception of the final point which was derived from the qualitative results.

- Who takes the X-rays in the respondents' practice
  - This being done by the dental practitioner was much more likely in Australia, with this being done by the dental radiographer or nurse being more likely in Jordan.
- Whether the respondent or their assistant holds the X-ray film with their finger
  - This was found to be significantly more likely in Jordan as compared with Australia.
- Whether they use a film holder while taking radiographs
  - This was found to be significantly more likely in Australia as compared with Jordan.
- The type of radiographic receptor used by the respondent
  - Film was found to be used significantly more often in Jordan, with a digital receptor being used significantly more frequently in Australia.
- Whether the walls of the X-ray room are lead-lined
  - This was found to be substantially more likely in Australia as compared with Jordan, with the percentage of individuals having no idea being substantially higher in Jordan as compared with Australia.
- Whether the respondent uses a leaded apron and thyroid shield when taking radiographs
  - This was found to be the case significantly more frequently in Australia as compared with Jordan.
- How important they feel the role of imaging is in dentistry
  - A response of "very high" was substantially more likely in Australia, with a response of "high", "moderate", or "low" being substantially more likely in Jordan.
- Gonads, bone marrow, and the thyroid consisting of the most important organ in radiation protection in dental radiography

- Respondents in Jordan were significantly more likely to state that the most important organ in radiography was the gonads.
  - Individuals in Jordan were significantly more likely to state that bones were the most important organ as compared with those in Australia.
  - It was significantly more likely for individuals in Australia to indicate that the thyroid was the most important organ in radiography as compared with those in Jordan.
- Whether they would take radiographs from a pregnant patient
  - Individuals in Australia were significantly more likely to respond in the affirmative to this question as compared with those in Jordan.
- Whether they would adjust exposure time from the maxilla to the mandible.
  - A response of "no change" was substantially more likely among Australian respondents, with a response of either "decrease" or "increase" being substantially more likely among those in Jordan.
- A qualitative review of the Jordanian as well as the Australian transcribed interviews revealed that responses provided by Australian individuals suggested a more accurate and comprehensive level of knowledge regarding radiation as compared with individuals working in Jordan.

Literature review

Most dental radiological procedures involve ionising radiation (Watson, 2011). Previous studies have shown that the ionising radiation used in dental radiography increases risks to the salivary gland, thyroid and increases the likelihood of brain tumours. Hence, it is necessary that dentists perform maxillofacial and oral radiology thoughtfully and responsibly to maximise diagnostic benefits while minimising the dose of radiation to the patient. In the past decade, numerous computer-based digital imaging technologies have emerged in the field of maxillofacial radiology, oral radiology, and dentistry. Digital radiography has largely replaced the traditional film-based technique (Watson, 2011). In particular, the introduction of cone beam computed tomography (CBCT) – three dimensional volumetric radiography – generated great excitement among practitioners, as well as concerns. The major concern is to develop a strategy to provide safe services using this and other novel imaging technologies, specifically CBCT (Watson, 2011).

The strategy required to make the best and safest use of radiography in dentistry must recognise that there is no “one size fits all” imaging modality (Ernest & Lam, 2011). This fact must be considered in both one and multiple modalities involving radiological examination. The classic techniques must be evolved or jointly used with new techniques such as CBCT rather than replaced (Ernest & Lam, 2011, p. 3).

Safe and responsible practice of maxillofacial and oral radiology requires that the practitioner is aware of the risk to the patients associated with use of the various imaging modalities (Hall & Giaccia, 2006). Radiation has the potential of harm to human beings as its exposure can cause skin cancer and have other long-term effects on sensitive body organs, including glands. In the literature, this period is known as the latent period of radiation injury (Hall & Giaccia, 2006). Since there has been the realisation of potential risks and harm of ionising radiation or oral radiography, dentists have been required to have a complete awareness of negative effects of X-rays.

Patients worry about their exposure to radiation and the associated risk to their health. Doctors must have enough knowledge regarding the consequences of radiation exposure to satisfy their patients (Mubeen et al., 2008). Dentistry students and other medical students obtain this knowledge during their rotations through different clinics within radiology departments.

For the purpose of diagnostic tests in dentistry or in any other medical tests, radiation is always involved where imagery diagnostics are required (Lam, 2011). Thus, maxillofacial and oral radiology must be carried out responsibly and thoughtfully. The students and professionals of dental departments must be equipped with knowledge regarding the possible outcomes of the exposure of radiation to patients. Doctors and dentists must have accurate knowledge of the dose of radiation in order to minimise the risks to the patient's health. According to previous research, it has been found that the exposure of radiation is the entrenched risk factor for cancer and patient's health. Though, in spite of the fact that most dental clinics and offices contain X-ray machines that are frequently used, the exposure of dental workers to radiation and the related possible risk of cancer have been evaluated in very few studies (Lam, 2011).

This chapter reviews recent literature on the knowledge, assessment of hazards, misunderstandings and misconceptions among students of dental and medical institutions related to the tools that are used for radiation imaging.

Dental radiology

Dental radiology is one of many applications of radiology in the field of healthcare (White, 2008). Radiology or radiography (later—the process; former—the study) is mostly performed for diagnostic purposes; however, radiation is also used as therapy for deeply invasive, advanced, and radiosensitive lesions in the oral cavity. Radiography can be used in combination with surgery and chemotherapy to obtain the best result. Exposure of radiation to any part of the body has a similar level of risk associated with it. Dental radiology is associated with similar hazardous effects on oral tissues (White, 2008).

Radiographic techniques have been revolutionised over the past decade. This is mainly due to a reduction in beam size, the introduction of newer machines, increments in the filtration rate, advancements in film speed and other techniques, along with a steep increase in the utilisation rate (Burns & Grove, 2007). A drawback of this kind of intervention is the possible adverse effects of the radiation usage. The major concern of this therapy is that dental offices neglect to use the proper intensifying screens required for radiation. Secondly, the dose of the ionising radiation has to be identified and customised for each patient in accordance with their needs. This leaves the sensitive organs in the head and neck region in grave danger from over-exposure (Burns & Grove, 2007). Awareness regarding the utilisation of ionising radiation and X-rays in the dental clinic is inadequate. Moreover, the exposure of children to radiation is also a factor that requires attention. It is necessary that radiation usage in children is optimised using proper measures to ensure maximised screening and protection (Byrd, 2011).

Ionising radiation

Exposure to radiation takes place in dental practices for diagnostic purposes (Ida, 2009). Radiographic equipment in dental clinics for diagnostic purposes are commonplace and radiographs are considered an essential part of medical evaluation and assessment. Dentists must have an advanced knowledge of radiation in order to protect dental staff and patients. There are many risks to the health of a patient due to radiation exposure. Radiation has been of rising concern among dentists with the increased use of blue and ultraviolet light to polymerise or cure a variety of dental materials, particularly bonding agents, sealants and composite resin. Exposure to wavelengths of these kinds of radiation can cause harm to the eyes, including the lens, retina and cornea (Ida, 2009).

The effects of ionising radiation have been of major concern since it was first used (Ida, 2009). Health hazards resulting from exposure to ionising radiation are rarely known to medical and dental professionals. Thus, all dentists must be taught about the hazards that are associated with exposure to ionising radiation. Protective barriers must be used effectively in order to reduce the possible risks of these harmful radiations. Safety glasses and shields must be used as protective barriers, which help reduce the risks of patients' exposure to radiation (Ida, 2009).

Ionising radiation can harm the living tissue of patients by damaging DNA and changing the structure of the cell (Mubeen et al., 2008). Dentists and other medical professionals must be familiar with the amount of harm associated with each radiation type and have sufficient knowledge about the risks of exposure to each kind of radiation, including the total energy and total quantity of absorbed radiation. There are many cells which are extremely sensitive to radiation. Radiation can kill cells, and the most serious risk from radiation exposure is the occurrence of cancer in a patient. With increasing doses of radiation, the probability of developing cancer also increases. Cancer caused through exposure to radiation does not become visible until several years after exposure. Radiation exposure has been a major factor in the development of cancer in patients (Mubeen et al., 2008). Radiation exposure has therefore had an adverse impact on the health of the patient and plays a vital role in causing cancer. Thus, dentists' knowledge of the risks of exposure to radiation must be sufficient to reduce a patient's risk of cancer. Genetic mutations can be caused by damage to the genetic material in reproductive cells, and exposing a developing foetus or embryo to radiation can multiply the risk of a birth defect. A person who has been exposed to a significant amount of ionising radiation at one time can die within days or even hours. This exposure level rarely occurs, and only in extreme conditions such as in the event of a serious nuclear attack or nuclear accident (Mubeen et al., 2008).

In diagnostic radiology, the use of X-rays requires skilled practice (Zielinsk, 2008). Dentists and other medical professionals must have a thorough knowledge regarding the doses of radiation for each type of procedure. Guidelines have been established by the US-based National Council on Radiation Protection and Measurements and the Ottawa head quartered International Commission on Radiological Protection for the secured application of all kinds of personnel safety and radiological procedures (Zielinsk, 2008).

A wide ranging literature review reveals a universal concern related to dentist's and doctor's knowledge concerning this matter. According to many researchers, medical students' knowledge about ionising radiations and suitable protection is extremely insufficient. It has been stated that interns have been prevented from accompanying patients in need of medical support during their radiological examinations. Moreover, interns working with pregnant women have been prevented from walking through the department of radiology (Zielinsk, 2008). In addition, many students avoid standing in a radiology area during a session of radiation exposure because they are worried about the dose of radiation in that area. This attitude of students illustrates the lack of knowledge among future dentists and doctors. Thus, the research reveals a lack of knowledge related to ionising radiation, radiation safety and diagnostic imaging. This lack of knowledge needs to be taken into account when planning undergraduate curriculums in order to meet the challenges of the future (Zielinsk, 2008). According to research conducted by Mubeen and others (2008), around 40 percent of students believed that objects present in an X-ray room released radiation after the X-ray procedure.

Dental films

No intensifying screen is required for dental films as they involve direct exposure to radiation (Iannucci & Howerton, 2016). They are known as non-screen films. The disadvantage of non-screen films is that they require a high amount of radiation, but their advantage is that they provide a more detailed output than standard radiographs. Two types of films are commonly used:

1. Ektaspeed "E": the film requires red light and light-purple backing during the process of radiography. It has a large silver halide crystal, which decreases detail and technique sensitivity. The advantage is that it requires less exposure.
2. Ultraspeed "D": the film requires amber light with mint-green backing during the process of radiology. It has a small silver halide crystal, which increases detail and technique

sensitivity. The disadvantage is that it requires more exposure (Iannucci & Howerton, 2016).

Dental radiographs

A technically sound radiograph with no defects is a significant determinant of the quality of diagnosis for any pathology (Shumway & Foster, 2011). Literature shows that technical error in radiographs is common, as most intra-oral periapical (IOPA) radiographs used in dentistry are of low quality. Given that the treatment or diagnosis is unaffected by the technical error only then determining working length in endodontics can be done using radiographs with an existing error (Shumway & Foster, 2011). The rate of errors in IOPA radiographs determined by Jayasinghe, Weerakoon et al. (2013) is 0.968 per radiograph, which is lower than that determined by Peker and Alkur (2009) and by Felippe et al. (2009). In most of the research investigating radiographs, a repeat radiograph cannot be excluded because radiographs are taken from archives. It is extremely important that these technical errors in radiographs are identified, because diagnosis and planning treatment depends on the accuracy of the results. The likelihood of errors are equal for both the right- and left-side radiographs; however, studies have observed varying types of errors (Felippe et al., 2009; Peker & Alkur, 2009). Felippe et al. (2009) claimed that studies done prior to theirs have the most common types of errors. One significant reason for the low rate of processing errors reported in studies is the use of an automatic X-ray developer for processing radiographs (Peker & Alkurt, 2009). In radiographs of the maxillary premolar area, errors are usually due to overlapping, because of the wrong horizontal angle. Other than in the study conducted by Felippe et al. (2009), the wrong vertical angle is not commonly discussed. According to Jayasinghe et al. (2013), the most common error in the root canal of an incomplete or crown cut is due to technical errors in the radiograph rather than diagnosis of the working length. The following section discusses the three types of radiographs.

Periapical radiographs

Periapical radiographs provide a view of the entire surroundings of a tooth structure (Allan, Farman, & Sandra, 2011). This radiography involves two exposure techniques. One is the bisecting angle technique and the other is the paralleling technique. The preferred of the two techniques is that of paralleling, as it reduces the risk of radiation exposure and image distortion. Dentists practice this technique in a majority of cases, and they are not likely to employ the alternative unless necessary. Where this technique is not suitable, for example, for patients with low palatal vaults, the bisecting angle technique is used. The latter technique is not preferred due to the high risk of radiation exposure involving the thyroid gland and eyes from increased angulations. Also, the image obtained via this technique is distorted (Allan, Farman, & Sandra, 2011).

Bitewing radiographs

In 1925, Raper introduced bitewing examinations (Allan, Farman, & Sandra, 2011). The main advantage of bitewing radiographs is that they make early diagnosis possible without clinical examination, particularly the detection of interproximal caries. Penetration of proximal caries and the sixes of the pulp chamber are also revealed in bitewing projections. Bitewings also permit the accurate assessment of changes in bone height when compared with adjacent teeth, and offers a good view of septal alveolar crest, together with assisting in the evaluation of periodontal conditions. However, the use of bitewing is restricted to an area under diagnosis, as it does not show the apices of the tooth, for example (Allan, Farman, & Sandra, 2011).

Occlusal radiographs

Occlusal radiographs provide an extensive view of the mandible and maxilla and are therefore considered to be a supplementary radiographic examination (Allan, Farman, & Sandra, 2011). The information obtained form the result of an occlusal radiograph includes details of fractures and displacement in maxilla and mandible, as well as the determination of the buccolingual extension of pathological conditions. In addition, occlusal radiographs assist in localising calculi in the sublingual and submandibular ducts and salivary glands, and foreign bodies, retained roots, and unerupted teeth. Risks manganates in occlusal radiographs require reduced exposure time when it is involved in imaging soft tissues (Allan, Farman, & Sandra, 2011).

Digital dental radiography

The field of medicine now involves the ubiquitous use of digital radiography (Brian & Williamson, 2007). Since 2000, in the US, more than 75% of medical clinics had adopted digital use. The US government has now made the conversion to digital mandatory. However, only a minority of dentists are using digital radiography (Brian & Williamson, 2007). Cost, location (small cities versus large population centres) and speciality (specialist or general dentist) are the factors influencing conversion to digital radiography in dentistry (Dölekoğlu, Fişekçioğlu, İlgüy, & İlgüy, 2011; Watson, 2011; Russo, Russo, & Guelmann, 2006). The American Dental Association conducted a dental survey in 2006 which revealed that only 36.5% of dentists practised digital radiography, and primarily for periapical and bitewing radiographs. For panoramic studies, only 20% of practitioners followed this practice (American Dental Association, 2006). With the introduction of new innovations in this technology, the number of dentists using digital imaging and radiography has increased. According to Gart and Zamanian (2010), the number of dentists using digital radiography in 2009 is estimated to double by 2016.

At the industry level, there is a continuous process of improving and addressing potential concerns in several areas of digital system usage in dentistry (Butt, Mahoney, & Savage, 2012). The most frequently reported concern relates to the resolution power of the system in terms of pixel size. Improved resolution means that a clearer picture is obtained through smaller pixel sizes. Reduced image clarity and greater signal noise result from using a lesser number of pixels on the sensor (Butt, Mahoney, & Savage, 2012). Diagnostic accuracy and screen display could be improved over current standards if the norm of using smaller pixels in imaging is followed. The quality of diagnosis and the displayed digital image significantly depends on the digital specification of the system used in radiography. Specificity and sensitivity of identifying and diagnosing possible disease via digital radiography is critically subject to the resolution. Several medical studies suggest that reading displayed images is significantly dependent on eye position, ambient light, tone scale, contrast, spatial resolution, and brightness or luminescence of the monitor (Butt, Mahoney, & Savage, 2012).

The brightness required to read standard film from a typical display box is not provided by the display monitors (Elizabeth, 2013). The best available display monitors are only one-fifth as bright as the typical box view. Moreover, in contrast to black-and-white monitors, the dynamic range of blacks and whites is degraded in colour monitors. Most of the monitors that dentists use to detect abnormalities provide a colour display and lack the appropriate spatial resolution and contrast (Elizabeth, 2013).

The resolution of the monitor that comes with a typical desktop computer ranges from 1024 x 1280 pixels to 1200 x 1600 pixels (Librizzi, Tadinada, Valiyaparambil, Lurie, & Mallya, 2011). Dentists often use these typical desktop systems while this resolution provides a result substantiated by assessment of comparison of plain film imaging indirect studies. Therefore, the resolution of a typical desktop monitor is insufficient for identifying abnormalities. Literature provides almost no evidence of research into this issue in a soft-tissue assessment – for example, in CBCT imaging. Such technical issues need to be addressed to determine the standard of a system's technological capacity required for identifying pathologies in hard-structure diseases like those involving teeth. Despite a recommended resolution in medicine of at least 2048 x 2560 pixels, dentists have been reporting using commercial-grade monitors, which affects the accuracy of diagnosis as these monitors lack the required contrast range and are not calibrated (Librizzi, Tadinada, Valiyaparambil, Lurie, & Mallya, 2011).

The American Dental Association (2006) provided two guidelines for monitor specification published by the American Association of Physicists in Medicine (AAPM) and the American College of Radiology (ACR). However, neither of these guidelines include information about what monitors should not be used in the diagnostic process of digital radiography and the consequences of using typical desktop monitors. In future, dental image viewing is likely to involve flat-panel devices, but there are no published guidelines for this kind of device, except for the work of Butt, Mahoney and Savage (2012).

Radiation dose and dosimetry

Uncontrollable natural radiation has always existed, and humans are exposed to a large variety of such radiation (Hall & Giaccia, 2006). The annual radiation dose that a human receives includes a large proportion of radon (^{222}Rn) and other terrestrial sources, cosmogenic radionuclides, and cosmic rays. The level of technologically enhanced sources of radiation are less significant, including radiation from air travel, the use of some building materials and phosphate fertilisers, and the burning of fossil fuels. Radiation from technologically produced sources such as power industries and nuclear weapons are also considered to be a less significant source of exposure for humans. In total, subject to the geographic location, an average human is exposed to 3 to 4 milli-Sievert (mSv) of radiation annually (Hall & Giaccia, 2006).

The effective amount for a dose has been determined by Pauwels, Beinsberger, Collaert, Theodorakou, Rogers and Walker (2012), who assessed the amount of absorbed organ dose from 14 CBCT devices. They used different geometries and protocols for exposure. The effective dose that they determined had a 20-fold range from 19 to 368 μSv. Also, the size of the field – large, medium or small – strongly influenced the received dose. In addition, the positioning of the beam relative to radiosensitive organs, the height and diameter of the beam, and differences in exposure factors also affected measured values. In this study, the thyroid and salivary glands were the organs of concern to relative dose. According to the authors, diagnostic requirements must be considered and appropriate field size and exposure parameters must be selected in order to optimise the dose (Rogers & Walker, 2012).

Ludlow, Brooks, Davies-Ludlow and Howerton (2006) and Ludlow and Ivanovic (2008) provided appropriate doses for selected organs for maxillofacial and oral radiology examinations. Table 1 lists the doses corresponding with various organs:

Table 1:1: Selected organ doses corresponding with oral and maxillofacial radiology examinations

	Salivary gland	Thyroid gland	Bone marrow
64 slice medical spiral CT	15300 µSv	3700 µSv	1031 mSv
Hitachi CB Mercuray	9006 (6”) to 11833 (12”) µSv	1300 (6”) to 10042 (12”) µSv	466 (6”) to 1542 (12”) mSv
Imaging Sciences iCAT	1250 (l) to 1836 (p) µSv	183 (l) to 283 (p) µSv	105 (l) to 147 (p) mSv
Cone beam CT (large field)	956 to 11833 µSv	183 to 10042 µSv	82 to 1542 mSv
PA cephalometric skull radiograph with a PSP sensor	55 µSv	30 µSv	11 µSv
Lateral cephalometric skull radiograph with a PSP sensor	80 µSv	45 µSv	5 µSv
Panoramic radiograph (assorted CCD#-based systems)	up to 761 µSv	up to 67 µSv	up to 20 µSv
4 Bitewing radiographs (ANSI F speed film or PSP with rectangular collimation)	156 µSv	0 µSv	4 µSv
Full mouth series (PSP* with round collimation or ANSI F speed film)	4110 µSv	550 µSv	134 µSv

#charge-coupled device
*photostimulatable phosphor
(l): landscape mode
(p): portrait mode

Various radiological examinations use phantoms to estimate the absorbed radiation dose (Valentin, 2007). Radiation scientists relate the absorbed radiation dose for an individual organ to the radiation dose for the whole body using an absorbed dose equivalent. This equivalent is defined as the sum of the weighing factor for a tissue (symbol: WT or T), the fraction of an irradiated in the imaged tissue volume (symbol: FT), and the absorbed dose of a tissue (symbol: DT). The International Commission on Radiological Protection (ICRP) set the numerical value for the tissue weighting factor. Based on the current information for organ radiobiology, ICRP reviews this value. A dramatic increase has been observed in the calculation of radiation doses since 2007, as a result of a substantial increase in various tissue weighting factors (Valentin, 2007).

Radiation exposure can be controlled using three components: exposure time, milliamperage (MA), and kilovolt peak (kVp) (Warren-Forward, Mathisen, Best, Boxsell, & Finlay, 2008). Exposure time is measured in pulse or seconds, with a pulse equalling 1/60 seconds. MA is a measure of quantity: a high value for MA indicates that more X-rays have been produced over time. kVp is a measure of quantity, the power of an X-ray beam. In other words, kVp is a measure of the penetration of an X-ray through tissue. In oral radiology, there is no significant variation between tissues, therefore dental radiology units are set for constant values of MA and kVp. These components are strong determinants of the absorbed radiation dose (Warren-Forward, Mathisen, Best, Boxsell, & Finlay, 2008).

Unfortunately, in the literature, radiation dose and dosimetry in dental radiology are defined using simple terms understood by non-technical persons (Hall & Giaccia, 2006). Also, explanations include the comparison of different doses of radiation in common life experiences and imaging modalities other than dental. Such explanations assume that ultraviolet radiation and X-rays cause the same type of biological damage, comparing radiation in sunlight to panoramic radiography. However, although the two kinds of radiation influence cellular macromolecules, they do so in different ways. Also, damage from the two sources of radiation is repaired in different ways.

Panoramic radiography and other imaging modalities are often used to compare dosimetric data from CBCT. Such a comparison is potentially misleading and overly-simplistic, as panoramic radiography and CBCT have different purposes. Therefore, such comparison must be avoided (Hall & Giaccia, 2006).

A large number of publications are available on the determination of an effective dose for dental radiography. As different assumptions are made using a number of different dosimeters and phantoms, a comparison of the results is difficult. Moreover, in-depth information on the measurements and calculations involved when performing radiography is not available. Thus, applying these studies to dental radiography is more or less impossible (Lofthag-Hansen, 2008; Okano et al., 2009; Suomalainen, 2009; Roberts et al., 2009; Helmrot & Thilander-Klang, 2010). With time, the weighting factors keep changing. According to ICRP 103, the calculation of a weighting factor must be performed using new data every time (ICRP, 2007). ICRP 103 (ICRP, 2007) and ICRP 60 are commonly used by researchers to determine the effective dose of radiation (Ludlow et al., 2006; Okano et al., 2009; Suomalainen, 2009; Looe et al., 2007; Gregory, Bibbo, & Pattison, 2008). Lofthag and others (2008) have argued that using CBCT is problematic, as an appropriate measure of the dose is not available. There is no generally accepted conversion factor in dental radiology, only suggestions by various researchers. E/PKA is the most commonly suggested conversion factor (Ludlow et al., 2006; Looe et al., 2007, 2008). In dental radiology, unlike whole-body radiology, each X-ray type is studied using fixed or limited irradiation geometry. In this context, a common problem faced when estimating E/PKA is the lack of knowledge about irradiating different oral organs. In dental radiology, imparted energy is used as an alternative when there is no other information available for that part of body (IAEA, 2007). Dose simulation programs have been found to be helpful for conventional X-ray examinations. These include the Monte Carlo-based program, PCXMC, which controls the radiation beam quality and other exposure parameters according to the variation in patient size and X-ray field position (Tapiovaara

& Siiskonen, 2008). For estimating an effective dose, PCXMC can be used with the PKA value or the ESD. CT examination dose can also be determined using computer programs such as ImpactDose and CT-Expo (Tapiovaara & Siiskonen, 2008).

According to Martin (2007), the relative estimations of effective dose in radiography for a reference patient have an uncertainty of approximately ± 40%. Radiologists have to rely on estimations because the measurement of mean organ dose is almost impossible. A conversion factor for the body part under radiography is also required for estimation. This process is more difficult in dental radiography, especially if one side or only part of an organ is irradiated, because of the risk of damage to salivary glands. Dose-simulation programs are likely to underestimate the dose because of the limitations they place on the extending of specific organs and remainder organs in the dental area. Hence, uncertainty is always present within the context of dose estimation (Martin, 2007).

Authorities have been using the diagnostic standard dose (DSD) in implanting and setting the diagnostic reference level (DRL) (Martin, 2008). In several European countries, DRLs are established for CT and conventional X-ray methods, where levels are decided by each radiation protection authority (Martin, 2008). Optimisation of an examination procedure can also be assisted by determining a DSD. Helmrot and Thilander-Klang (2010) and Martin (2008) have presented starting points for DRLs for some of the orthopantomographic and intra-oral examinations.

Why bother with radiography?

Timins (2011) presented an historical perspective of the risks and benefits of medical radiation. Her perspective starts in 1895, when Wilhelm Rontgen discovered X-rays. Within one year, the benefits of X-rays, such as the visualization of fractures, and detrimental effects, such as X-ray dermatitis, were recognised. Nobel Laureates Pierre and Marie Skłodowska-Curie discovered the radioactive element radium in 1898, and a year later the application of radiation to cure cancer was reported. A significant price was paid for this: Marie Curie died of aplastic anaemia related to her radiation exposure, and her daughter Irene Joliot Curie, Nobelist for radiochemical research, died of radiation-induced leukaemia. Internationally, radiation protection recommendations were formalised starting in the late 1920s. The increasing use of ionising radiation in medical diagnosis and radiation therapy has brought significant societal benefits. Known risks of therapeutic radiation include coronary artery disease and secondary malignancy. Recently, concerns have been raised of possible very small but incremental increases in malignancies due to diagnostic medical radiation. Patients are largely unaware of, and referring physicians and even radiologists often underestimate, the carcinogenic effects of radiation. There is a need to determine the appropriateness of imaging tests that use ionising radiation prior to performance; to optimise imaging protocols to reduce unnecessary radiation; to include patients in the decision process and encourage and enable them to track their radiation exposure; and to promote education about medical radiation to patients, referring physicians, radiologists, and members of the public. The basic radiation protection principles of justification, optimisation, and application of dose limits still pertain (Timins, 2011).

Risks associated with radiography

Radiation exposure is the most sensitive concern of radiography. In contrast to the analogue system, digital systems result in significantly less radiation exposure for panoramic, periapical, and bitewing imaging series. CBCT studies comparing radiation exposure from CT imaging and X-rays have observed that exposure from the latter is reduced (Loubele, Bogaerts, Van Dijck, Pauwels, Vanheusden, & Suetens, 2009). Free radicals – the molecular intermediaries – are generated from the interaction between X-rays and water molecules in the human body (Hall & Giaccia, 2006). At least one electron is carried into these unstable molecules or atoms, which has the potential to initiate a cascade of events including damage of cellular molecules such as carbohydrate molecules, lipids, enzymes and proteins, and DNA. If the damage to DNA is in the form of a double-strand break, repair of the damage would still be difficult despite the significant capacity of mammalian cells to repair radiation damage. In human beings, cancerous cells may appear if chromosomal aberrations and point mutations of DNA are misrepaired (Brenner & Hall, 2007). In common medical CT studies, organs exposed to doses of radiation may result in an increased risk of cancer development. Many epidemiological studies have provided evidence of this risk – evidence that is highly convincing for children and reasonably convincing for adults. This is a significant finding, as individual organ doses from dental CBCT may exceed or at least approach doses from medical CT (Ludlow, Brooks, Davies-Ludlow, & Howerton, 2006; Ludlow & Ivanovic, 2008).

The quantity of radiation received from dental radiography is very low, and it is improbable that its effects provide a considerable risk (EPA, 2012). Thus, dental radiography does not play an effective role in generating concern about the risks of the exposure to ionising radiation. During the last decade, techniques of dose reconstruction have been normally used (EPA, 2012). These techniques have shown that brain exposure from four bitewings is around 0.07 mGy and exposure from panoramic assessment is approximately 0.02 mGy. Currently, it has been said that exposure to radiation through CT scans in adulthood and childhood increases the risk of brain tumours and leukaemia. This research has shown that dental radiography has the capability of causing harm to the health of patients (EPA, 2012).

The technology of dental radiography provides a very helpful diagnostic tool for dentists. The benefits of radiography balance the risks (EPA, 2012). Thus, prudent and reasonable dentists must be aware of the risks of exposure to varying forms of radiation. A dentist is responsible for justifying and cautiously considering each and every radiograph. Moreover, a dentist is also responsible for using procedures and means to optimise radiographic imaging so as to gain the greatest amount of information possible with a minimum use of radiation. Thus, the dentist must be familiar with the proper doses of radiation in order to minimise the health risks for a patient (EPA, 2012).

Present intervals must be avoided for radiographs and therefore dental radiography must not be used at preset levels for all patients (EPA, 2012). Rather, after the assessment of the history and compliance of the patient relating to dental disease, the dentist must justify the need for dental radiographs for diagnosis and treatment planning. Dental radiographs must be individually warranted and not employed like screening tools. If the patient is required to get another dental radiograph then the patient's current dental radiographs must be recovered in spite of subjecting the patient to another exposure (EPA, 2012).

Necessary radiographs must be chosen carefully and the examination must be optimised after determining the necessity of dental radiographs for treatment or diagnostic purposes (EPA, 2012). The procedure of ALARA – that is, as-low-as-reasonably-achievable – radiation must be used. This will help the dentist to select the radiographic assessment with the lowest possible dose that sufficiently addresses the needs of diagnosis.

The dentist must focus on minimising the exposure of ionising radiations as much as possible (EPA, 2012). Appropriate procedures must be used in order to reduce the exposure of a patient to radiation during the chosen examination. These procedures will help to gain images containing the maximum information related to diagnosis as well as reduce redundant exposure to radiation (EPA, 2012).

During a typical dental radiography, such as X-ray, millions of photons pass though the tissues of the human body (EPA, 2012). Ionisation of these photons with any molecule could be damaging and for some molecules like DNA, the results are devastating due to the damage of chromosomes. Most of the time, immediate repairing of injury reduces damage to the DNA; however, damage to chromosomes and the alterations due to radiation exposure are likely to be permanent. Such mutation results in the formation of tumours (EPA, 2012).

Dental radiography has evolved over the last decade, with the introduction of new machines, smaller beam sizes, increased filtration, advanced techniques, faster film speeds and large increases in utilisation (EPA, 2012). However, concern remains about the possible adverse effects of dental radiography on humans for a few reasons. First, these procedures remain the only common type of diagnostic radiography that is performed without intensifying screens and which requires higher doses. Second, the target-to-film distances are short. Third, the emitted rays are close to sensitive organs in the head and neck region. In addition, these examinations are among the most common diagnostic radiographic procedures performed today. Previous studies have shown an increased risk for the salivary gland, thyroid, and brain tumours (EPA, 2012).

According the UNSCEAR (2000) report, dental radiography is one of the most common radiological procedures performed. Although the exposure associated with dental radiography is relatively low, any radiological procedure should be justified and optimised in order to keep the radiation risk as low as reasonably achievable. Dose assessment is recommended to be performed on a regular basis to ensure that patient exposure is always kept within the recommended levels and to identify possible equipment malfunction or inadequate technique. Compared with adults, children have been found to be more radiosensitive. Therefore, increased attention should be paid to minimise the exposure of children to medical radiation. All radiological procedures carried out on children must adhere to special radiation protection measures, which aim to recognise and implement possible dose reduction strategies in order to eliminate unnecessary and therefore unjustified radiation exposure (UNSCEAR, 2000).

Risk to children and adolescents

Cases of cancer where the sole cause has been identified as dental diagnostic radiography are rare and the literature provides no conclusive results (American College of Radiology, 2010). The consensus among international and national organisations concerned with radiation safety is to avoid even the lowest radiation exposure. Because the potential harm, even if extremely low, cannot be non-existent, the need for precautions can not be eliminated. Children, when compared to adults, are three to five times more at risk of radiation-induced cancer mortality. This is because the developmental stage of their body's tissues is more radiosensitive. In addition, the greater number of years remaining in a lifetime following a radiographic procedure in children gives more time for a radiation-induced cancer to develop (American College of Radiology, 2010).

A radiation exposure of 10 mSv results in cancer development in 1 out of 1000 individuals that have undergone dental radiography (American College of Radiology, 2010). Relative radiation level (RRL) measured in mSv is helpful in differentiating the radiographic procedure for children from that of adults. Table 2 illustrates the RRL for children and adults.

Table 1:2: Relative radiation level effective dose estimate range (mSv)

	Child	Adult
Medium	0.3 – 3	1 – 10
Low	0.03 – 0.3	0.1 – 1
Minimal	Less than 0.03	Less than 0.1
None	0	0

The figures for RRL in the above table show that all dental radiographic procedures have a minimal risk for children, as the dental radiographic procedures and involved radiation dose depicted in Table 1 are less than 0.03 mSv despite the limitations on the estimation of absorbed radiation dose. However, the risk of radiation exposure from CBCT depends on the scanner used and varies from low to medium (American College of Radiology, 2010).

Literature provides numerous strategies to be followed by dentists using radiography for children (American College of Radiology, 2010). The first strategy, which is commonly found in guidelines and literature, is the decision for radiography to be conducted only when the expected benefits are significantly higher than the risks. In addition to the age of the child, the practitioner must also examine and calculate the area of exposure because in the case of children, sizes vary from that in the guidelines. A thyroid collar is a must for children, and multiple imaging without a specific need is not considered safe practice. Ultrasound and MRI are preferred over CBCT for children's dental diagnoses (American College of Radiology, 2010).

Risk to pregnant women

In the management of pregnant patients, dental radiography has been an area of controversy (Mortazavi1 et al., 2013). General guidelines for radiography do not show any alteration in the procedure of radiography for a pregnant patient. This may be because there is an assumption that the small levels of radiation used in a dental radiographic examination are not likely to cause gross anatomic malformation in the foetus. According to the American Dental Association, pregnant patients' dental radiography must involve minimum radiation exposure and follow every precaution. According to the report of the National Commission of Radiation Protection (NCRP), a 50 mSv foetal exposure has a negligible affect on the likelihood of congenital defects. However, evidence-based research is required in clinician education given the results of surveys which suggest that bitewing radiography of pregnant patients has potential risks (Mortazavi1 et al., 2013).

Although the risks to a foetus during dental radiography is very low because radiation of just a few μSv is involved in the procedure of dental radiography, a 10 mSv dose of radiation can have a severe effect on the foetus (Mortazavi1 et al., 2013). However, the background risk of cancer to the unborn child is thousands of times more than the cancer risk from a 10mSv radiation exposure. Hence, risks to the unborn child from dental radiography of the pregnant mother will depend on the dose. In addition, the age of the foetus and ionisation of radiation can influence the effect of radiation on the foetus. The first trimester is the most vulnerable time for a foetus at risk of radiation exposure. Death of the embryo is likely to occur as a result of a 0.2 Gy dose of radiation during the implementation time of a fertilised ovum. Macroscopic anatomical malformation can result from a 0.2 Gy dose in the first two months of pregnancy (organogenesis). Mental retardation due to a 1 Gy dose has been observed in 50% of foetuses in weeks 8–15 of pregnancy (fetogenesis). The developing nervous system of the foetus is highly radiosensitive during this period of pregnancy. A normal dental X-ray beam provides a radiation dose of 1 μSv and 0.3 μSv to a foetus in a dental X-ray exam (Mortazavi1 et al., 2013).

It has been found that ionising radiation has a severe effect on a newborn baby's birth weight when the mother was exposed to this radiation for diagnostic purposes (Mortazavi1 et al., 2013). Life has evolved in an environment which contains an enormous range of radiation for the purpose of diagnosis. Research has shown that a pregnant woman's exposure to this radiation raises the risk of low birth weight for her newborn baby (Mortazavi1 et al., 2013).

The exposure to radiation has become essential for diagnostic purposes in many medical tests, including dental tests (Mortazavi1 et al., 2013). Such a use for radiation has become a fact of life. Nevertheless, there are many forms of radiation that have an adverse affects on the health of people, including microwaves, radio waves and X-rays. In the case of forms of radiation such as X-rays, which are harmful to the health of patients, dentists and doctors need to be knowledgeable about its use and the protective barriers available in order to reduce the health risks for patients (Mortazavil et al., 2013).

Literature discusses a number of preventive measures and precautions to take into account when referring a pregnant patient for radiography (Mortazavi1 et al., 2013). For example, detailed information about the pregnancy – such as duration and expected complications – must be obtained prior to the decision. A suggestion made to radiologists is to consider every female of reproductive age pregnant unless they have proof otherwise. Also, is would be a safe practice to avoid using radiographic diagnostic methods for pregnant women as much as possible. Optimisation of dose is another safe practice when the decision for radiography of a pregnant female is made. Informing the patient about the level of radiation exposure before the process is carried out is suggested as an ethical practice (Mortazavi1 et al., 2013).

The best film to be used in the radiography of a pregnant woman is Ektaspeed, as the faster speed ensures less radiation exposure (Mortazavi1 et al., 2013). Digital radiography is also preferred as it decreases the exposure of radiation by 47% in full-mouth series radiography. Thyroid shields can also reduce exposure. Moreover, the duration of exposure is an important factor in the absorbed radiation dose, therefore delivering high-beam energy can be helpful in both maintaining the quality of radiation and reducing exposure time. Similar benefits are achievable by using a long rectangular cone for collimation (Mortazavi1 et al., 2013).

Most of the above precautions found in the literature follow the ALARA rule . This as low as responsibly achieved, balance states that continuous monitoring and control of radiation exposure to a human being is needed, given the potential harm of radiation. Minimising the risks to a foetus from radiation exposure is subject to the estimated foetal dose of radiation in a radiographic examination. Dental radiography of a pregnant woman is safe as long as the benefits are significant given her exposure to a low dose of absorbed radiation (Mortazavi1 et al., 2013).

The reduction of radiation risk to patients

Extensive literature deals with strategies and guidelines to reduce the risks of radiation. The technical information that can be used to reduce the risks from radiation through reducing the absorbed radiation dose is generally not accessed by dentists and practitioners. The following is basic information relating to radiographic equipment which dentists need to seriously consider.

Voltage and current of X-ray tube

The energy dose in an X-ray is determined by the voltage of an X-ray tube (Geijer et al., 2009). Energy exposure to the skin is high from low-energy X-rays produced by low-voltage tubes. Although a high voltage might deliver an effective dose with decreased exposure to the skin, it scatters it in a wide range (Geijer et al., 2009). However, the hardening effect of the radiation beam is successfully reduced by high voltage (Ludlow, 2011). The product of exposure time and current in the tube determines the number of photons leaving the energy unchanged. Hence, a high current may increase the dose while leaving the image contrast and beam penetration unchanged. The current and voltage are variable or fixed depending on the CBCT unit in use; nevertheless, a fixed current and voltage are likely to preclude optimisation (Okano et al., 2009; Roberts et al., 2009).

A balance between the quality of the image needed and the exposure time can result in an optimal radiation dose. According to Kwong and others (2008), the voltage and current of an X-ray tube can be adjusted to reduce exposure time without effecting the quality of the image. Studies of head and neck exposures in dental radiography are neglected in the literature. However, a number of studies focusing on oral and maxillofacial radiography and radiography of the whole body report that controlling the current of radiation-generating equipment to reduce absorbed radiation dose does not affect the quality of the image (Kwong et al., 2008).

Collimation and field of view

The size and shape of a reconstructed image depends on the field of view, which is measured in terms of the volume of a cylinder or sphere (Okano et al., 2009; Roberts et al., 2009; Lofthag-Hansen et al., 2010). The field of view in CBCT is variable; thus it can be adjusted to reduce radiation exposure. Collimation of the beam also significantly reduces the area of radiation exposure. The dose of absorbed radiation to the patient is significantly associated with the size of the field of view. Moreover, the image quality of the radiograph is improved if the field of view is small because it reduces the scatter of beams. Dental radiography, specifically for the diagnosis of one or a few teeth, is not aided by the equipment which is large in size and provides no variation of the size of field of view. It is appropriate to use the single field of view option and small-volume examinations in specialised endodontic practices of dentistry (Okano et al., 2009; Roberts et al., 2009; Lofthag-Hansen et al., 2010).

Filtration

Medical X-ray equipment includes a component of aluminium filtration. Copper filtration is also found in some dental CBCT units. Although filtration results in a loss of contrast, it removes a significant number of the lower-energy photons from an X-ray, reducing the absorbed radiation dose (Okano et al., 2009; Roberts et al., 2009). Overall quality of the image is unaffected by the addition of a copper filter, and an increase in copper filtration results in a significant reduction of absorbed radiation dose (Ludlow, 2011). Manufacturers also consider the optimisation of the dose when adding copper filtration (Qu et al., 2010). The literature found in favour of using filtration to reduce the absorbed radiation dose are specific to the equipment used in the study. However, taking into account the thickness and material of the filter is also important when estimating the significance of filtration for reducing the absorbed radiation dose (Qu et al., 2010).

Digital detector

Digital receptors in dental CBCT units are used to capture and form images (Iannucci & Howerton, 2016). The image quality from a CBCT detector depends on important details such as contrast and spatial resolution. In dental CBCT units, two types of digital detectors are used. The first type uses an intensifier for conventional images while the second type uses flat-panel detectors. The contribution of digital detectors in dose limitation and optimisation is significant. In the context of image quality, the optimisation and assessment of a detector's parameter with respect to dose is involved in balancing the dose and image quality (Iannucci & Howerton, 2016).

Voxel size

Voxel is a unit of measurement referring to the three-dimensional quantity of data (Iannucci & Howerton, 2016). The field of view, or the reconstructed image area, consists of a number of isotropic voxels. In CBCT systems, voxels range between 0.1 mm and 0.4 mm in size. Although better spatial resolution is obtained via reducing voxel size in scanning protocols, doing so results in a high absorbed radiation dose (Iannucci & Howerton, 2016). However, the diagnostics that depend on a highly detailed image depend on reducing the voxel size, and the practitioner faces a trade-off between image quality and absorbed radiation dose (Liedke et al., 2009; Kamboroğlu & Kursun, 2010; Wenzel et al., 2009; Hassan et al., 2010; Kamboroğlu et al., 2010; Melo et al., 2010). According to Qu and others (2010), the patient dose of absorbed radiation is significantly reduced by choosing the option of "low resolution" on a CBCT machine. Whenever the nature of the diagnosis allows, the practitioner must choose the low-resolution option. A high probability of motion during the scan with a long scan time does not provide optimal spatial resolution (Qu et al., 2010).

Number of projections

Greater contrast, higher spatial resolution, and increased radiation dose to the patients are associated with a high number of projections (Brown et al., 2009). The linear accuracy of CBCT is unaffected by increasing the number of projections. Reduction in exposure in terms of current leads to reduced patient absorbed radiation dose. This is achieved if the number of projections is reduced to the number necessary to maintain the image quality acceptable for clinical examination (Brown et al., 2009).

Shielding devices

Lead and other high-attenuation materials contained in a shielding device can be used to reduce the exposure of radiation to the patient and thus the absorbed radiation dose (Health Protection Agency, 2010). In dental CBCT, the primary beam and scattered radiation can affect radiosensitive organs such as the thyroid gland. Although the thyroid gland dose significantly contributes to the defectiveness of the dose from CBCT, the effect of external shielding on the internal scatter of beams is unclear. According to the Health Protection Agency (2010), thyroid shielding in dental CBCT examination is not necessary because the gland is not normally exposed to the primary beam.

Information and guidelines

Academic institutions and doctors are using guidelines to an alarmingly low extent (Kantor, 2006). The threat of litigation arising from the incorrect identification of a quiescent intra-osseous abnormality is one explanation for this low use of guidelines. Dentists argue that panoramic radiograph or intra-oral graphs are effective in ensuring that a quiescent disease is screened without any mistake. However, the literature lacks discussion of this fear among dentists. Presence of an abnormality is also an important aspect of a dentist’s capability to interpret the abnormality using this approach. Several factors can assist if a decision regarding radiography is to be taken in the absence of a clinical examination. These factors include the existence of such lesions in the jaw, the probability of a clinically detectable symptom or sign produced by the existence of such a lesion, and the impact on the patient's management due to the existence of such a lesion. A non-example is the abnormality Stafne submandibular, which has no bearing on patient management. Wrong or no detection of a quiescent disease is significantly subject it the justification of mortality and morbidity to patients and the radiobiological and economic cost occurred to the asymptotic patient. The literature provides a significant evidence base to support the use of maxillofacial and oral radiology and its selection criteria. According to such literature, almost all except a small number of entities such as dense bone islands, hypercementoses, retained primary root tooth and resorbed roots are correctly screened given careful use of selection criteria. The entities that are missed do not require any additional management. There is no evidence supporting predetermined radiography at regular time intervals – for example, panoramic radiography every five years for asymptotic patients (Kantor, 2006).

Avadanei, Rosca-Fartat, and Staneuscu (2011) evaluated the education of practitioners on radiation exposures in medicine. They examined the training given to practitioners by surveying them through questions related to radiation exposure during diagnostic practices. The results of this study showed that using a good practice guide had significant effects on the justification process involved in prescribing radiography (Avadanei, Rosca-Fartat, & Staneuscu, 2011).

Knowledge and awareness

Only recently has the lack of awareness about radiation among dentists been raised as a serious concern. Arslanoglu, Bilgin, and Kubal (2007) observed that the ionising radiation dose given to the patients is not known by 93.1% of the doctors who participated in the study. Sove and Patterson (2008) questioned 15 doctors regarding their awareness of ionising radiation. Only 39% of the participating doctors reached an average score. Zhou, Wong and Nguyen (2010) surveyed

331 Australian medical interns and students. Of these respondents, 25.5% and 11.3%, respectively, incorrectly believed that magnetic resonance imaging (MRI) and ultrasound emitted ionising radiation. Furthermore, 54.8% of respondents underestimated the radiation dose. Of greatest concern was that in the opinion of 11.2% of the respondents, knowledge of ionising radiation was either not really important or not at all important. The score of this specific group regarding knowledge of ionising radiation in radiography was observed to be significantly lower than that of the other groups (Zhou, Wong & Nguyen, 2010).

In their study of 112 doctors, Bosanquet, Green and Bosanquet (2011) found that 29.4% of participants accurately estimated the radiation dose, while ionising radiation in ultrasound and MRIs was realised by only 14% of the participants. The authors also assessed the awareness of referrers given no background information about the effective dose of X-ray and about radiation risks and natural radiation (Bosanquet, Green, & Bosanquet, 2011).

Investigations and examinations based on radiology have been used broadly in the management of patients, and these examinations involve the patient’s exposure to radiation (Hagi & Khafaji, 2011). In the past decade, there has been an increase in the number of investigations which are based on ionising radiation. It has been observed that CT tests have increased by a factor of ten in the period of 1980–2005. According to research, CT examinations make up 13 percent of overall diagnostic exposure of radiation. Similarly, the use of radiation for diagnostic purposes in dental clinics has also increased. Technological advancement has led to complicated nuclear medicine investigations and intervention using radiological procedures (Hagi & Khafaji, 2011). Concerns related to patient doses have been raised in response to these technological advancements in the area of dental treatment as well as other medical treatments – even though most, but not all, of these radiation exposures are considered acceptable. Almost all patients are familiar with the risks of exposure to these forms of radiation. Doctors are the major source of this information regarding the risks and consequences of exposure to radiation during their examination (Hagi & Khafaji, 2011).

Thus, doctors and family members need to be familiar with the risks and danger of exposure to radiation. Patients are prepared by their doctors regarding the risks, dose and benefits of the exposure of radiation so as to give proper descriptions to their patients (Hagi & Khafaji, 2011). Doctors' justification for diagnostic imaging requests depends on their knowledge about and experience concerning doses of radiation. The knowledge regarding these doses must be gained by students during their undergraduate training. Since 1989 and still the case today, many studies have questioned the adequacy of medical students' knowledge regarding ionising radiation. They have found that students' knowledge relating to radiation safety and radiation risks is inadequate, and several redundant investigations have been carried out each year because of the lack of this knowledge (Hagi & Khafaji, 2011).

The literature has highlighted the importance of including protective measures against harmful radiation in the medical school syllabus. For example, O'Sullivan and others (1999) argued for radiation protection to be included in the curriculum for medical radiology. They used a questionnaire to analyse radiology teaching and radiation knowledge. Improvement in the knowledge related to ionising radiation was found each year. Those students who received radiology teaching were found to perform better than those who did not receive radiology teaching (Hagi & Khafaji, 2011). Only 60 percent of the students knew that CT uses ionising radiation and only 25 percent of students knew that MRI also uses ionising radiations. Thus, students' knowledge of the risks and consequences of using ionising radiation is essential in order to minimise the redundant use of radiation exposure. Medical schools must include instructions concerning radiation protection as an important element in their undergraduate medical curriculum (Hagi & Khafaji, 2011).

Education about radiation and the effects of exposure to radiation must be given to medical and dental students. Health care service providers must be responsible for protecting patients from the risks of radiation by providing knowledgeable advice to patients. It has been found that students of dentistry have limited and insufficient knowledge regarding radiation risks, sources and protection. However, additional research is needed to further understand the harmful effects of radiation exposure, and provide helpful guidelines for students in their practical work to reduce the risks of radiation exposure.

Although maxillofacial and oral radiology involves low doses of absorbed radiation, it is not a zero amount of radiation. If the radiation absorbed dose is not zero, then the associated risk is also not zero. Hence, it is necessary that practitioners employ every possible means at their disposal so that the safety of patients – especially adolescents and children – is ensured and the risks and benefits of radiology are balanced. Moreover, the risks associated with radiography and the benefits must be compared with the alternatives before permitting exposure.

It is one of the responsibilities of a health care professional to provide first-hand knowledge to patients undergoing all radiological procedures and processes. The dentist must be able to respond to common queries regarding radiation hazards with answers that are reliable and based on knowledge that is adequate and up-to-date. Knowledge related to radiation is taught during undergraduate training in medical colleges. However, dentists grossly underestimate the risks relating to the proper use of medical imaging tools and associated radiation exposure. In addition, incorrect information about a product's safety and effectiveness – promoted by some dentists who are paid and sponsored by the manufacturers of these devices to lecture and give seminars promoting these products – add an extra concern about the safety of these products. The following chapter will discuss the research methodology used in this study.

Aims and significances

It is one of the responsibilities of a health care professional to provide firsthand knowledge to their patients undergoing any radiological procedures and processes. The dentist ought to be able to answer queries of a general nature regarding radiation hazards, which can be reliable provided their knowledge is adequate and up-to-date. This knowledge related to radiation is taught during undergraduate training in medical colleges. The purpose of this study to provide an insight into the current level of knowledge within the dentistry profession regarding the health risks associated with ionising radiation imagery. The significance of this research, to be discussed later, is in concluding that a significant number of dentists grossly underestimate the radiation risks to themselves and their patients.

This study has measured and contrasted Australian and Jordanian dentists' knowledge of ionising radiation and the associated risks. The aims of this study were to:

1. Assess Australian and Jordanian dentists' knowledge about ionising radiation and its hazard to the patient.
2. Identify Australian and Jordanian dentists' level of understanding of the use of ionising equipment.

These aims were developed to assess current understanding and safety practice with results suggesting that the dental profession in both Australia and Jordan require educating concerning the risks of ionising radiation amongst dentists.

The study's hypotheses are:

1. There is no difference in the knowledge of risks associated with ionising radiation in experienced and inexperienced dentists' of Australia and Jordan.
2. There is no difference in the knowledge of risks associated with ionising radiation in Australian and Jordanian dentists.

This study’s main research question consists of:

How familiar are dentists regarding the adverse effects of ionizing radiations?

Research methodology

This study used a quantitative cross-sectional comparative approach to test the hypotheses, involving systematic analysis of data collected using a self-administrated questionnaire, and face-to-face interviews. The questionnaire contained 33 questions to measure dentists' knowledge of ionising radiation and their associated risks. With regard to questionnaire design, two specific studies were used and adapted for the purposes of questionnaire development for the current study. They consisted of Shahab et al. (2012) and Ilguy (2005). Contact information (e.g. names, phones, clinics' addresses, and email addresses) of potential dentists was requested from the Australian Dental Association and Jordanian Dental Association. Despite the fact that dentists advertise their services, the Australian Dental Association refused to provide their member's contact details, citing "privacy concerns," while Jordan's peak body did not provide a list of its members for other reasons. However, for the purposes of this research, contact particulars for dentists in both countries was found through industry indexes. Consequently, neither country's dental industry membership bodies cooperated or assisted in this research; in fact, quite the opposite prevailed. Once dentists' email addresses were sourced, Survey Monkey was used to distribute the questionnaire to the emails of these potential dentists. In addition, five dentists from each country (Australia and Jordan) were interviewed in person, at their clinics. Five dentists from each country were also invited to participate in a face-to-face interviews. The five successful respondents in both countries were selected from approximately 30-40 dentists who were asked if they were willing to participate in further research by a phone call. Dentists who obliged were then personally visited and interviews conducted in their office. Dentists' answers were recorded in English (in both Australia and Jordan) with many answers straying from the actual question but with any useful information also being recorded. The face to face interviews permitted greater clarity of answers and more precise knowledge being gained.

The questionnaire used is included in Appendix A. To prepare the questionnaire, a review of the literature was performed and variables were determined. Study participants were asked questions which fell into five broad groups aiming to determine whether a reflective cross section of the profession were participating in the survey or not and to measure the knowledge and experience of staff, to assess prevailing procedures within dental surgeries including use of technology and precautions taken for professional staff and patients.

The questions fell into these five broad categories:

1. Demographic data
2. Qualification and professional experience
3. Radiographic equipment and techniques
4. Knowledge of radiation protection
5. Method of patient and personnel protection

This study utilized samples collected from both Australia and Jordan. The purpose of using these two samples was to collect data from two groups of respondents residing in countries with diverse cultures in order to provide a direct comparison between these two sets of data. Australia, a country with a Western culture, and Jordan, a Middle Eastern country, was felt to be appropriate choices coinciding with the researcher's interest in comparing dentists' knowledge and attitudes between two different cultures, while simultaneously these two countries also differ vastly with respect to their economic position, which is reflected in their per capita GDP.

With regard to the sample size included within this study, this consisted of 142 respondents in total, with 61 respondents from Australia, and 81 respondents from Jordan. The statistical analysis conducted in relation to the study first consisted of a series of descriptive statistics, which did not incorporate any sample size requirements, along with a series of chi-square analyses. The chi-square test assumes a sufficiently large sample size, as do all other significance tests. The use of small samples when applying the chi-square test produces a higher rate of Type II errors. While no specific cutoff is suggested, a minimum sample size of 50 has been suggested, while sample sizes as low as 20 have been recommended by researchers (David & Sutton, 2011). For the present study, a sample size substantially higher than these minimums was desired. Pearson's chi-square was used in these analyses, with chi-square generally leading to the same decision with respect to significance or non-significance as compared with the Fisher exact test (Sheskin, 2007). Generally, with the exception of very small sample sizes, the probability values reported by the Pearson's chi-square test and the Fisher's exact test will be very similar (Jaykaran, 2011). Therefore, for the purposes of this study, Pearson's chi-square was felt by the researcher to be appropriate.

For the purposes of this study, several different statistical methods were selected. Initially, a series of descriptive statistics were conducted on these data, which consisted of a set of frequency tables summarizing the sample sizes and percentages of responses associated with each response category for all categorical variables included in this study. This was run initially on the entire sample, with this frequency table run a second time separating respondents into the Australian and Jordanian samples. Frequency tables are appropriate when presenting descriptive statistics on categorical variables. In addition to this, further descriptive statistics were conducted on the continuous measures included in this sample, which consisted of age of the machine, the number of radiographs taken in the clinic on a weekly basis, and the youngest age that the respondent would take radiographs of. Similar to the frequency tables, these descriptive statistics were run initially on the entire sample, and then separately by Australian and Jordanian respondents. The descriptive statistics conducted in relation to these continuous measures consisted of the valid and missing sample sizes, along with measures of central tendency which consisted of the mean and median score, along with measures of variability, which consisted of the standard deviation, range, and minimum and maximum scores. Measures of central tendency and variability are appropriate when conducting descriptive statistics on continuous data.

Following this, inferential statistical tests were conducted, which consisted of a series of chi-square analyses. These analyses first focused upon differences by country, with the measures included in the data set being cross-tabulated with country of residence. The results of these analyses were reported, along with cross tabulation tables associated with each significant result. The cross tabulation tables were included here as they were necessary for the interpretation of the results as well as to report additional descriptive data with relation to these tests. The second set of chi-square analyses focused upon the same set of study questions analyzed previously in relation to country of residence, though focused upon whether there was any significant association between this set of questions and years of experience, which was dichotomized for the purposes of these analyses. Similar to the previous set of chi-square analysis conducted, the results of all analyses were presented, along with individual cross tabulation tables associated with all significant tests. The chi-square analysis was selected for this entire set of tests as this specific test is appropriate in cases where it is desired to determine whether there is a significant association between two categorical variables, and is especially appropriate in cases where one or both of the variables analyzed in the test has a nominal level of measurement.

The survey questions included in this study focused upon a number of domains. First, a series of questions focused upon respondent demographics, with a second set of questions focusing upon details relating to respondents' clinics and the practice of dentistry within their clinics. Respondents were also posed questions for the purposes of determining their level of knowledge in the areas of ionizing radiation and dental radiography. This study asked whether a difference in the level of knowledge exists between Australian dentists and Jordanian dentists. Within this study, the survey questions incorporated relate highly to this question. Most importantly, the questions posed to individuals testing the level of knowledge in the areas of ionizing radiation and dental radiography directly relate to this question. Furthermore, the questions posed relating to the specifics of respondents' clinics and the practice of dental radiography within their clinics also help determine whether the practice of dental radiography differs substantially with regard to appropriateness on the basis of country.

Data analysis

The survey data was analysed using the Statistical Package for the Social Sciences (SPSS), version 22.0. Mean scores for knowledge of ionising radiation were compared for dentists from Australia and Jordan and among those with different levels of experience. Chi-square analyses were performed to test this study's hypotheses. A p-value <0.05 was considered statistically significant.

Ethical considerations

In this study, respondents were asked to supply information about demographics, qualifications and professional experience, radiographic equipment and techniques, and knowledge of radiation protection. While the questionnaire provided the necessary measures relating to knowledge, it posed no risk of harm or discomfort to participants. Specific ethical considerations were investigated (and complied with using other local or international ethical forms) in the case of Jordan. This section provides further details on the storage and management of data, dissemination of findings, generalisability of results. The research approval from Charles Sturt Univerity also outlined specific details relating to the ethical form/approval initially submitted to the university’s Ethics in Human Research Committee. The ethical forms have been approved on 17/09/2014 (approval number 2014/173).

It was vital to ensure that participants’ information remained confidential. Therefore, the collected data has been stored in a secured folder on a secure computer. Both the folder and computer are secured by a password known only to the researcher and authorised person (e.g., his supervisor). A backup copy of the data will be kept on a USB device which is securely stored in a locked cabinet.

The participants will be sent the final research report, and the executive summary of the report will be provided online (e.g., Charles Sturt University website). If time and resources permit, the researcher will also meet participants individually to discuss the report's recommendations. The research will result in a thesis that will undergo a peer-review process. Beside the thesis, the student is aiming to submit/publish an article about his analysis/results to a peer-reviewed journal.

Generalisability of results

In order to discuss the reliability and validity of the quantitative analysis, it is important to realise the fact that if a research study is not credible, the rigor and validity of the study is compromised. Additionally, to make this research data reliable, the researcher ensured that the data was obtained through honest means. The aspect of truthfulness is imperative for any research study. Validity is a measure of the quality or value of a scientific research study. The more research is valid, the more reliable its results will be.

This study involved dentists working in Australia and Jordan in 2014. Despite restrictions on data collection to these two countries, the results are likely to be highly generalizable. Australia is a highly-developed Western country, and Australian dental practice is of a very high standard, therefore research results relating to Australia are likely to be applicable to other Western countries. Jordan is a Middle Eastern Arab country, so research results are likely to be applicable to many other Arab and Middle Eastern countries. The next chapter will present and discuss the results of the analyses conducted for this study.

A limitation of this study consisted of bias. First, this study incorporated selection bias as certain individuals were more likely to be selected for sampling in the study than others, producing a biased sample (Merrill, 2015). The extent of this bias and its impact, if any, on the results obtained cannot be determined as nothing specific is known about those individuals who did not take part in the present study. As convenience sampling was used in the current study, individuals who were initially contacted for participation in the study as well as those who chose to take part may have differed in some important way from those who did not. Recall bias was also likely present in this study, which is a type of bias arising from inaccuracies relating to participant recollections (Merrill, 2015). Specifically, individuals taking part in the study may not have accurately remembered or known about the details of their examination rooms.

A second limitation of this study related to the questionnaire being used in this study not having been framed within the context of likely differences in legislation and regulation governing best practice between Australia and Jordan. A comparison of the best practice literature and similar references between Australia and Jordan do indicate a number of important differences. First, with regard to Australia, within the dental industry in this country, a very detailed and specific set of guidelines exist with respect to best practice (Dental Board of Australia, 2016a, 2016b, 2016c). This very detailed set of regulations helps to consistently ensure a high standard of care with respect to dental practices and procedures within this country.

However, when literature relating to best practices in Jordan are reviewed, a different picture emerges. Literature within this area of study generally indicate or suggest, in general, relatively poor standard of care in comparison with the standard of care present within Australia. For example, one study within this area found the provision of sedation services in general and specialist dental practices in Jordan to be inconsistent as well as inadequate (Al-Shayyab, 2013). These researchers conclude that there is a great need for training among both dental assistants and practitioners within Jordan in order to ensure that they can provide sedation to patient safely and effectively (Al-Shayyab, 2013). Similarly, a study conducted by Sawair et al. (2010) focused upon knowledge and observance of proper mercury hygiene and amalgam waste management among general dental practitioners in Jordan. In this study, it was found that the majority of general dental practitioners in Jordan do not strictly follow the mercury hygiene and health and waste management guidelines, with close to one-quarter reporting no undergraduate training in amalgam safety measures, and with similar percentages not having proper ventilation in their clinics as well as not using protective clothing or eye protection. The results of this study serve to further suggest that best practices legislation guidelines are lacking in Jordan in comparison with those present in Australia. In sum, a review of guidelines and associated literature relating to best practices in the field of dentistry in Australia and Jordan suggest large differences between the two countries. This current study and the questionnaire used not having been framed within the context of these differences consists of a limitation of the present study.

Results

This chapter presents and discusses the results of the analyses conducted for this study. Initially, a series of descriptive statistics were conducted on collected data. First, an examination of the data indicated the presence of all missing information with respect to what type of radiographic examination is typically prescribed by the respondent. Next, with regard to personal dosimeter type, only two valid responses were found in relation to this question. One Australian respondent replied with "body", while one Jordanian respondent replied with "for child different for adult about time of exposure and denesty [sic]".

Additionally, frequency tables were constructed for the following questions: What is the aim of radiation protection in dental radiography, with regard to taking radiographs of patients who are pregnant, pregnant under what circumstances, radiographic exposure factors: maxillary molar, radiographic exposure factors: mandibular incisor, and where the respondent stands when taking radiographs. As a very large range in responses was found with regard to these specific questions, the associated list of responses relating to each of these questions is presented in Appendix A.

Next, the following table summarizes the descriptive statistics conducted on all categorical variables of interest included in this study, and incorporating data from the full sample of respondents. If missing data was present in these measures, the valid percentages will be focused upon in this section. As shown, 57% of respondents were located in Jordan, with 43% in Australia. With regard to respondent age, close to 35% of respondents were in their 30s, with close to 25% in their 20s, and 20% in their 40s while close to 20% of respondents were aged 50 or above. Additionally, slightly over 68% of respondents were found to be male, with close to 32% female.

The majority of respondents, close to 78%, were found to be general practitioners, with slightly over 24% being specialists. Following this, 89% of respondents were found to have an X-ray machine in their clinic, with the remaining 11% indicating that they did not have a machine. In slightly over 83% of cases, the dental practitioner took the X-rays in their practice, with a nurse taking the X-rays in slightly over 10% of cases, and a dental radiographer in slightly over 6% of cases. Two thirds of the sample indicated that they had periodic checkups for the X-ray equipment, with the remaining third indicating that this is not done. Respondents were also asked whether they or their assistant holds the X-ray film with their finger while taking the radiographs. Slightly over 31% of respondents provided an affirmative response to this question, with close to 69% indicating that they did not.

Respondents were then asked whether they use a personal dosimeter to measure the radiation dose. Respondents replied affirmatively in slightly over 10% of cases, with a negative response provided in close to 90% of cases. Next, slightly over 56% of respondents indicated that they use a film holder while taking radiographs, while close to 44% indicated that they did not. With regard to the technique used by respondents for periapical radiography, individuals replied with a paralleling technique in close to 64% of cases, and a bisecting angles technique in slightly over 36% of cases. Close to 85% of respondents were found to use a round collimator, with slightly over 15% using a rectangular one. The majority of respondents, slightly over 54%, indicated that they used a 20 cm collimator, with close to 27% using a 30 cm collimator, close to 10% using a 40 cm one, and close to 10% were not using a collimator.

The type of radiographic receptors used by respondents varied, with 50% using a digital receptor, and 50% using film. Film speeds used varied, with close at 42% using type D, slightly over 36% using type E, and slightly over 22% using type F. With regard to whether the walls of the X-ray room are lead lined, slightly over 46% of respondents indicated that they were not, with close to 42% indicating that they were, and slightly over 12% stating that they had no idea. Following this, respondents were asked whether they use leaded aprons and thyroid shields for patient protection. Slightly over 55% of respondents indicated that this was the case, with close to 45% indicating that they did not.

Respondents were then asked how important they feel the role of imaging is in dentistry. Slightly over 69% of respondents felt that this importance is very high, with 21% stating that it was high, slightly over 7% stating that it was moderate, and slightly over 2% stating that it was low. With regard to what respondents felt was the most important organ in radiation protection in dental radiography, 62% replied with the thyroid, close to 22% indicating the gonads, 7% indicating bone marrow, and slightly over 2% replying with the eyes. Respondents were then asked which radiographic technique delivers more radiation. In response to this question, close to 59% of respondents stated that full mouth radiographs deliver more radiation, with close to 42% replying with panoramic in response to this question. Slightly over 63% of respondents stated that they would take periapical radiographs from a pregnant woman, with close to 37% indicating that they would not.

Regarding whether exposure time would be adjusted from an overweight patient to a thin patient, slightly over 66% of respondents stated that there would be no change, with slightly over 24% indicating that there would be a decrease in exposure time, and close to 10% of respondents indicating that there would be an increase in exposure time. Next, respondents were asked whether exposure time would be adjusted when moving from taking radiographs of anterior teeth to posterior teeth. These results indicated that an increase in exposure time would be made in slightly over 48% of cases, with no change in slightly over 40% of cases, and a decrease in exposure time in close to 12% of cases. Finally, respondents were asked whether exposure time would be adjusted from maxilla to mandible radiographs. Respondents indicated that no change would be made in slightly over 61% of cases, with an increase in 27% of cases, and a decrease in close to 12% of cases.

Table 2:1

Descriptive statistics: full sample

Measure	*N*	%	Valid %
Country			
Australia	61	43.0	
Jordan	81	57.0	
Total	142	100.0	
Age			
20-29	34	23.9	24.6
30-39	48	33.8	34.8
40-49	29	20.4	21.0
50+	27	19.0	19.6
Total	138	97.2	100.0
Missing	4	2.8	
Total	142	100.0	
Gender			
Female	43	30.3	31.9
Male	92	64.8	68.1
Total	135	95.1	100.0
Missing	7	4.9	
Total	142	100.0	
Current position			
General practitioner	105	73.9	77.8
Specialist	33	23.2	24.4
Total	135	97.1	100.0
Missing	4	2.8	
Total	142	100.0	
Do you have an X-ray machine in your clinic?			
No	15	10.6	11.0
Yes	121	85.2	89.0
Total	136	95.8	100.0
Missing	6	4.2	
Total	142	100.0	
Who takes the X-rays in your practice?			
Dental practitioner	103	72.5	83.1
Dental radiographer	8	5.6	6.5
Nurse	13	9.2	10.5
Total	124	87.3	100.0
Missing	18	12.7	
Total	142	100.0	

Do you have periodic check ups for your X-ray equipment?			
No	41	28.9	33.3
Yes	82	57.7	66.7
Total	123	86.6	100.0
Missing	19	13.4	
Total	142	100.0	
You or assistant hold the X-ray film with finger while taking radiographs?			
No	86	60.6	68.8
Yes	39	27.5	31.2
Total	125	88.0	100.0
Missing	17	12.0	
Total	142	100.0	
Do you use a personal dosimeter to measure the radiation dose?			
No	107	75.4	89.9
Yes	12	8.5	10.1
Total	119	83.9	100.0
Missing	23	16.2	
Total	142	100.0	
Do you use a film holder while taking radiographs?			
No	52	36.6	43.7
Yes	67	47.2	56.3
Total	119	83.8	100.0
Missing	23	16.2	
Total	142	100.0	
Which technique do you use for periapical radiography?			
Bisecting angles	43	30.3	36.4
Paralleling	75	52.8	63.6
Total	118	83.1	100.0
Missing	24	16.9	
Total	142	100.0	
Which type of collimator do you use?			
Rectangular	18	12.7	15.3
Round	100	70.4	84.7
Total	118	83.1	100.0
Missing	24	16.9	
Total	142	100.0	
What is the length of your collimator?			
20 cm	57	40.1	54.3
30 cm	28	19.7	26.7
40 cm	10	7.0	9.5
No collimator	10	7.0	9.5
Total	105	73.9	100.0
Missing	37	26.1	
Total	142	100.0	

Which type of radiographic receptor do you use?			
Digital receptor	60	42.3	50.0
Film	60	42.3	50.0
Total	120	84.5	100.0
Missing	22	15.5	
Total	142	100.0	
Which film speed do you use for periapical radiography?			
D	39	27.5	41.5
E	34	23.9	36.2
F	21	14.8	22.3
Total	94	66.2	100.0
Missing	48	33.8	
Total	142	100.0	
Are the walls of the X-ray room lead-lined?			
No	53	37.3	46.1
Yes	48	33.8	41.7
No idea	14	9.9	12.2
Total	115	81.0	100.0
Missing	27	19.0	
Total	142	100.0	
Do you use a leaded apron and thyroid shield for patient protection?			
No	52	36.6	44.8
Yes	64	45.1	55.2
Total	116	81.7	100.0
Missing	26	18.3	
Total	142	100.0	
How important is the role of imaging in dentistry?			
High	26	18.3	21.0
Low	3	2.1	2.4
Moderate	9	6.3	7.3
Very high	86	60.6	69.4
Total	124	87.3	100.0
Missing	18	12.7	
Total	142	100.0	
Most important organ in radiation protection in dental radiography?			
Gonads	31	21.8	
Bone marrow	10	7.0	
Thyroid	88	62.0	
Eyes	3	2.1	

Which of the following radiographic techniques delivers more radiation?			
Full mouth	72	50.7	58.5
Panoramic	51	35.9	41.5
Total	123	86.6	100.0
Missing	19	13.4	
Total	142	100.0	
Would you take any periapical radiographs from a pregnant woman?			
No	45	31.7	36.9
Yes	77	54.2	63.1
Total	122	85.9	100.0
Missing	20	14.1	
Total	142	100.0	
Adjust exposure time from fat patient to thin patient?			
Decrease	27	19.0	24.1
Increase	11	7.7	9.8
No change	74	52.1	66.1
Total	112	78.9	100.0
Missing	30	21.1	
Total	142	100.0	
Adjust exposure time from anterior teeth to posterior teeth?			
Decrease	13	9.2	11.6
Increase	54	38.0	48.2
No change	45	31.7	40.2
Total	112	78.9	100.0
Missing	30	21.1	
Total	142	100.0	
Adjust exposure time from maxilla to mandible?			
Decrease	13	9.2	11.7
Increase	30	21.1	27.0
No change	68	47.9	61.3
Total	111	78.2	100.0
Missing	31	21.8	
Total	142	100.0	

Next, the following table summarizes the descriptive statistics conducted on the continuous measures of interest included within this study. These measures consisted of the age of the machine, the number of radiographs taken on average in the clinic on a weekly basis, and the youngest age patient that the respondent would take radiographs of. As shown, age of the machine was found to have a mean of approximately 6.5 years, with a mean of approximately 38 radiographs taken on a weekly basis in these clinics. Additionally, the youngest patient age which would be radiographed on the basis of these data would be approximately 6.7 years of age.

Table 2:2

Descriptive statistics: continuous measures: full sample

Measure	*N* Valid	*N* Miss.	Mean	Med.	*SD*	Range	Min	Max
Age of machine	116	26	6.526	5	4.763	24	1	25
Radiographs taken in clinic weekly	118	24	38.068	30	47.818	399	1	400
Youngest age	112	30	6.714	6	3.733	19	1	20

Next, the following table summarizes the descriptive statistics conducted on the categorical variables with the results presented separately for those in Australia and those in Jordan. First, with regard to respondent age, respondents aged 20-29 were substantially more common in the Jordanian sample, with those aged 50 or above being over-represented in the Australian sample. Next, with regard to respondent gender, a substantially higher proportion of female respondents were indicated in the Jordanian sample. The Australian sample was found to have a higher proportion of general practitioners, with the Jordanian sample having a higher proportion of specialists. Additionally, having an X-ray machine in the respondent's clinic was substantially more likely in the Australian sample. The following question asked respondents who takes the X-rays in their practice. Dental practitioners were substantially more likely to take the X-rays in the Australian sample as compared with the Jordanian sample, with nurses being much more likely to take the X-rays in the Jordanian sample. With regard to whether respondents have a periodic check up for the X-ray equipment, this was found to be substantially more likely in the Australian sample.

Following this, respondents were asked whether they or their assistant hold the X-ray film with their finger while taking radiographs. This was found to be substantially more likely in the Jordanian sample. With regard to whether the respondent uses a personal dosimeter to measure the radiation dose, responses to this question were found to be approximately equal between these two samples. However, Australian respondents were overwhelmingly more likely to use a film holder while taking radiographs as compared with Jordanian respondents. Additionally, Australians were also substantially more likely to use the paralleling technique for periapical radiography, as compared with Jordanians, who were substantially more likely to use the bisecting angles technique. With regard to the type of collimator used, responses were found to be similar between Australian and Jordanian samples. Next, with regard to the length of the collimator used, Australians were substantially more likely to use a 20 cm collimator, with Jordanians substantially more likely to use a 30 cm, 40 cm, or no collimator.

With regard to the type of radiographic receptor used, Australians were substantially more likely to use a digital receptor, with Jordanians substantially more likely to use a film receptor. Responses relating to film speed also differed substantially between samples. Specifically, Australians were substantially more likely to use a film speed of type E, with Jordanians substantially more likely to use a film speed of type D. With regard to whether the walls of the X-ray room are lead-lined, this was found to be substantially more likely in the Australian sample. Additionally, Australians were also substantially more likely to use a leaded apron and thyroid shield for patient protection. Australians were also more likely to feel that the role of imaging in dentistry was very important, with Jordanians more likely to feel that this was less important. Jordanians were also more likely to feel that the most important organ in radiation protection was the gonads, bone marrow, or eyes, with Australians more likely to state that this was the thyroid.

Respondents were then asked which radiographic technique delivers more radiation. Australians were more likely to respond with full mouth radiographs, with Jordanians more likely to state that the panoramic radiographic technique delivers more radiation. Australians were also more likely to take periapical radiographs from a pregnant woman. With regard to the adjustment of exposure time, Australians were more likely to decrease exposure time from a fat patient to a thin patient, with Jordanians more likely to make no change. Australians were more likely to increase exposure times or to make no change from anterior teeth to posterior teeth, with Jordanians more likely to decrease exposure time in this case. Finally, with regard to the adjustment of exposure time from maxilla to mandible, Australians were more likely to make no change, with Jordanians more likely to decrease or increase exposure time.

Table 2:3

Descriptive statistics: by country

Measure	Australia			Jordan		
	N	%	Valid %	*N*	%	Valid %
Age						
20-29	7	11.5	11.7	27	33.3	34.6
30-39	21	34.4	35.0	27	33.3	34.6
40-49	12	19.7	20.0	17	21.0	21.8
50+	20	32.8	33.3	7	8.6	9.0
Total	60	98.4	100.0	78	96.3	100.0
System	1	1.6		3	3.7	
Total	61	100.0		81	100.0	
Gender						
Female	15	24.6	26.3	28	34.6	35.9
Male	42	68.9	73.7	50	61.7	64.1
Total	57	93.4	100.0	78	96.3	100.0
Missing	4	6.6		3	3.7	
Total	61	100.0		81	100.0	
Current position						
General practitioner	50	82.0	83.3	55	67.9	70.5
Specialist	10	16.4	16.7	23	28.4	29.5
Total	60	98.4	100.0	78	96.3	100.0
Missing	1	1.6		3	3.7	
Total	61	100.0		81	100.0	
Do you have an X-ray machine in your clinic?						
No	4	6.6	6.7	11	13.6	14.5
Yes	56	91.8	93.3	65	80.2	85.5
Total	60	98.4	100.0	76	93.8	100.0
Missing	1	1.6		5	6.2	
Total	61	100.0		81	100.0	

Who takes the X-rays in your practice?						
Dental practitioner	53	86.9	94.6	50	61.7	73.5
Dental radiographer	2	3.3	3.6	6	7.4	8.8
Nurse	1	1.6	1.8	12	14.8	17.6
Total	56	91.8	100.0	68	84.0	100.0
Missing	5	8.2		13	16.0	
Total	61	100.0		81	100.0	
Do you have periodic check ups for your X-ray equipment?						
No	16	26.2	28.1	25	30.9	37.9
Yes	41	67.2	71.9	41	50.6	62.1
Total	57	93.4	100.0	66	81.5	100.0
Missing	4	6.6		15	18.5	
Total	61	100.0		81	100.0	
You or assistant hold the X-ray film with finger while taking radiographs?						
No	52	85.2	91.2	34	42.0	50.0
Yes	5	8.2	8.8	34	42.0	50.0
Total	57	93.4	100.0	68	84.0	100.0
Missing	4	6.6		13	16.0	
Total	61	100.0		81	100.0	
Do you use a personal dosimeter to measure the radiation dose?						
No	49	80.3	90.7	58	71.6	89.2
Yes	5	8.2	9.3	7	8.6	10.8
Total	54	88.5	100.0	65	80.2	100.0
Missing	7	11.5		16	19.8	
Total	61	100.0		81	100.0	
Do you use a film holder while taking radiographs?						
No	7	11.5	12.7	45	55.6	70.3
Yes	48	78.7	87.3	19	23.5	29.7
Total	55	90.2	100.0	64	79.0	100.0
Missing	6	9.8		17	21.0	
Total	61	100.0		81	100.0	
Which technique do you use for periapical radiography?						
Bisecting angles	17	27.9	31.5	26	32.1	40.6
Paralleling	37	60.7	68.5	38	46.9	59.4
Total	54	88.5	100.0	64	79.0	100.0
Missing	7	11.5		17	21.0	
Total	61	100.0		81	100.0	
Which type of collimator do you use?						
Rectangular	7	11.5	12.7	11	13.6	17.5
Round	48	78.7	87.3	52	64.2	82.5
Total	55	90.2	100.0	63	77.8	100.0
Missing	6	9.8		18	22.2	
Total	61	100.0		81	100.0	

What is the length of your collimator?						
20 cm	34	55.7	65.4	23	28.4	43.4
30 cm	12	19.7	23.1	16	19.8	30.2
40 cm	4	6.6	7.7	6	7.4	11.3
No collimator	2	3.3	3.8	8	9.9	15.1
Total	52	85.2	100.0	53	65.4	100.0
Missing	9	14.8		28	34.6	
Total	61	100.0		81	100.0	
Which type of radiographic receptor do you use?						
Digital receptor	37	60.7	67.3	23	28.4	35.4
Film	18	29.5	32.7	42	51.9	64.6
Total	55	90.2	100.0	65	80.2	100.0
Missing	6	9.8		16	19.8	
Total	61	100.0		81	100.0	
Which film speed do you use for periapical radiography?						
D	10	16.4	27.0	29	35.8	50.9
E	18	29.5	48.6	16	19.8	28.1
F	9	14.8	24.3	12	14.8	21.1
Total	37	60.7	100.0	57	70.4	100.0
Missing	24	39.3		24	29.6	
Total	61	100.0		81	100.0	
Are the walls of the X-ray room lead-lined?						
No	20	32.8	36.4	33	40.7	55.0
No idea	5	8.2	9.1	9	11.1	15.0
Yes	30	49.2	54.5	18	22.2	30.0
Total	55	90.2	100.0	60	74.1	100.0
Missing	6	9.8		21	25.9	
Total	61	100.0		81	100.0	
Do you use a leaded apron and thyroid shield for patient protection?						
No	17	27.9	30.9	35	43.2	57.4
Yes	38	62.3	69.1	26	32.1	42.6
Total	55	90.2	100.0	61	75.3	100.0
Missing	6	9.8		20	24.7	
Total	61	100.0		81	100.0	
How important is the role of imaging in dentistry?						
High	9	14.8	16.7	17	21.0	24.3
Low	0	0.0	0.0	3	3.7	4.3
Moderate	1	1.6	1.9	8	9.9	11.4
Very high	44	72.1	81.5	42	51.9	60.0
Total	54	88.5	100.0	70	86.4	100.0
Missing	7	11.5		11	13.6	
Total	61	100.0		81	100.0	

Most important organ in radiation protection in dental radiography?						
Gonads	8	13.1		23	28.4	
Bone marrow	1	1.6		9	11.1	
Thyroid	49	80.3		39	48.1	
Eyes	1	1.6		2	2.5	
Which of the following radiographic techniques delivers more radiation?						
Full mouth	35	57.4	64.8	37	45.7	53.6
Panoramic	19	31.1	35.2	32	39.5	46.4
Total	54	88.5	100.0	69	85.2	100.0
Missing	7	11.5		12	14.8	
Total	61	100.0		81	100.0	
Would you take any periapical radiographs from a pregnant woman?						
No	13	21.3	24.1	32	39.5	47.1
Yes	41	67.2	75.9	36	44.4	52.9
Total	54	88.5	100.0	68	84.0	100.0
Missing	7	11.5		13	16.0	
Total	61	100.0		81	100.0	
Adjust exposure time from fat patient to thin patient?						
Decrease	15	24.6	28.8	12	14.8	20.0
Increase	5	8.2	9.6	6	7.4	10.0
No change	32	52.5	61.5	42	51.9	70.0
Total	52	85.2	100.0	60	74.1	100.0
Missing	9	14.8		21	25.9	
Total	61	100.0		81	100.0	
Adjust exposure time from anterior teeth to posterior teeth?						
Decrease	3	4.9	5.8	10	12.3	16.7
Increase	27	44.3	51.9	27	33.3	45.0
No change	22	36.1	42.3	23	28.4	38.3
Total	52	85.2	100.0	60	74.1	100.0
Missing	9	14.8		21	25.9	
Total	61	100.0		81	100.0	
Adjust exposure time from maxilla to mandible?						
Decrease	4	6.6	7.7	9	11.1	15.3
Increase	9	14.8	17.3	21	25.9	35.6
No change	39	63.9	75.0	29	35.8	49.2
Total	52	85.2	100.0	59	72.1	100.0
Missing	9	14.8		22	27.9	
Total	61	100.0		81	100.0	

The following table presents the results of the chi-square analyses conducted on the data, in which responses to the survey questions were examined for significant differences on the basis of country. As shown, statistical significance was indicated in relation to the chi-square analyses conducted on the following variables: who takes the X-rays in the respondents' practice, whether the respondent or their assistant holds the X-ray film with their finger, whether they use a film holder while taking radiographs, the type of radiographic receptor used by the respondent, whether the walls of the X-ray room are lead-lined, whether the respondent uses a leaded apron and thyroid shield when taking radiographs, how important they feel the role of imaging is in dentistry, gonads, bone marrow, and the thyroid consisting of the most important organ in radiation protection in dental radiography, whether they would take radiographs from a pregnant patient, and whether they would adjust exposure time from the maxilla to the mandible.

Table 2:4

Chi-square analyses: differences by country

Measure	χ^2 (*df*)	*p*
Do you have an X-ray machine in your clinic?	2.083 (1)	.149
Age of your X-ray machine	23.203 (18)	.183
Who takes the X-rays in your practice?	10.331 (2)	.006
Do you have periodic checkup for X-ray equipment?	1.324 (1)	.250
You or assistant hold the X-ray film with the finger?	24.554 (1)	<.001
How many radiographs do you take in clinic per week?	33.661 (23)	.070
Do you use a personal dosimeter to measure the radiation?	.074 (1)	.785
Personal dosimeter type	2.000 (1)	.157
Do you use a film holder while taking radiographs?	39.869 (1)	<.001
Which technique do you use for periapical radiography?	1.057 (1)	.304
Which type of collimator do you use?	.509 (1)	.476
What is the length of your collimator?	6.685 (3)	.083
Which type of radiographic receptor do you use?	12.117 (1)	<.001
Which film speed do you use for periapical radiography?	5.810 (2)	.055
Are the walls of the X-ray room lead-lined?	7.128 (2)	.028
Do you use a leaded apron and thyroid shield?	8.192 (1)	.004
How important is the role of imaging in dentistry?	9.038 (3)	.029

Most important organ in radiation protection in dental radiography		
Gonads	4.761 (1)	.029
Bone Marrow	4.769 (1)	.029
Thyroid	15.289 (1)	<.001
Eyes	.116 (1)	.734
Which radiographic technique delivers more radiation?	1.563 (1)	.211
Would you take X-rays from a pregnant patient?	6.830 (1)	.009
Pregnant: under what circumstances?	45.000 (39)	.235
Radiographic exposure factors: maxillary molar	47.819 (48)	.480
Radiographic exposure factors: mandibular incisor	57.328 (51)	.252
Adjust exposure time from fat patient to thin patient	1.210 (2)	.546
Adjust exposure time from anterior teeth to posterior teeth	3.237 (2)	.198
Adjust exposure time from maxilla to mandible	7.783 (2)	.020
Youngest age	20.474 (14)	.116
Where do you stand?	91.705 (77)	.121

The following set of tables present the cross tabulations between country and all variables found to achieve statistical significance in the chi-square analyses presented in the previous table. These tables serve to further illustrate the association between these variables in cases where significance was achieved. First, the following table focuses upon who takes the X-rays in their practice. This being done by the dental practitioner was much more likely in Australia, with this being done by the dental radiographer or nurse being more likely in Jordan.

Table 2:5

Chi-square analysis: who takes the X-rays in your practice?

	Who takes the X-rays in your practice?			
	Dental practitioner	Dental radiographer	Nurse	Total
Australia				
Count	53	2	1	56
% within Country	94.6%	3.6%	1.8%	100.0%
% within X-rays	51.5%	25.0%	7.7%	45.2%
% of Total	42.7%	1.6%	.8%	45.2%

Jordan				
Count	50	6	12	68
% within Country	73.5%	8.8%	17.6%	100.0%
% within X-rays	48.5%	75.0%	92.3%	54.8%
% of Total	40.3%	4.8%	9.7%	54.8%
Total				
Count	103	8	13	124
% within Country	83.1%	6.5%	10.5%	100.0%
% within X-rays	100.0%	100.0%	100.0%	100.0%
% of Total	83.1%	6.5%	10.5%	100.0%

Next, the following table presents the cross tabulation associated with whether the respondent or their assistant holds the X-ray film with their fingers. As shown, this was found to be significantly more likely in Jordan as compared with Australia.

Table 2:6

Chi-square analysis: do you or your assistant hold the X-ray film with your fingers?

	You or assistant hold the X-ray film with your fingers?		
	No	Yes	Total
Australia			
Count	52	5	57
% within country	91.2%	8.8%	100.0%
% within hold film	60.5%	12.8%	45.6%
% of total	41.6%	4.0%	45.6%
Jordan			
Count	34	34	68
% within country	50.0%	50.0%	100.0%
% within hold film	39.5%	87.2%	54.4%
% of total	27.2%	27.2%	54.4%
Total			
Count	86	39	125
% within country	68.8%	31.2%	100.0%
% within hold film	100.0%	100.0%	100.0%
% of total	68.8%	31.2%	100.0%

With regard to whether the respondent uses a film holder while taking radiographs, this was found to be significantly more likely in Australia as compared with Jordan.

Table 2:7

Chi-square analysis: do you use a film holder while taking radiographs?

	Do you use a film holder while taking radiographs?		
	No	Yes	Total
Australia			
Count	7	48	55
% within country	12.7%	87.3%	100.0%
% within film holder	13.5%	71.6%	46.2%
% of total	5.9%	40.3%	46.2%
Jordan			
Count	45	19	64
% within country	70.3%	29.7%	100.0%
% within film holder	86.5%	28.4%	53.8%
% of total	37.8%	16.0%	53.8%
Total			
Count	52	67	119
% within country	43.7%	56.3%	100.0%
% within film holder	100.0%	100.0%	100.0%
% of total	43.7%	56.3%	100.0%

Next, the following table summarizes the results of the cross tabulation between country and which type of radiographic receptor the respondent uses. Film was found to be used significantly more often in Jordan, with a digital receptor being used significantly more frequently in Australia.

Table 2:8

Chi-square analysis: which type of radiographic receptor do you use?

	Which type of radiographic receptor do you use?		
	Digital receptor	Film	Total
Australia			
Count	37	18	55
% within country	67.3%	32.7%	100.0%
% within type	61.7%	30.0%	45.8%
% of total	30.8%	15.0%	45.8%

Jordan			
Count	23	42	65
% within country	35.4%	64.6%	100.0%
% within type	38.3%	70.0%	54.2%
% of total	19.2%	35.0%	54.2%
Total			
Count	60	60	120
% within country	50.0%	50.0%	100.0%
% within type	100.0%	100.0%	100.0%
% of total	50.0%	50.0%	100.0%

Next, with regard to whether the walls of the X-ray room are lead-lined, this was found to be substantially more likely in Australia as compared with Jordan, with the percentage of individuals having no idea being substantially higher in Jordan as compared with Australia.

Table 2:9

Chi-square analysis: are the walls of the X-ray room lead lined?

	Are the walls of the X-ray room lead lined?			
	No	No idea	Yes	Total
Australia				
Count	20	5	30	55
% within country	36.4%	9.1%	54.5%	100.0%
% within walls	37.7%	35.7%	62.5%	47.8%
% of total	17.4%	4.3%	26.1%	47.8%
Jordan				
Count	33	9	18	60
% within country	55.0%	15.0%	30.0%	100.0%
% within walls	62.3%	64.3%	37.5%	52.2%
% of total	28.7%	7.8%	15.7%	52.2%
Total				
Count	53	14	48	115
% within country	46.1%	12.2%	41.7%	100.0%
% within walls	100.0%	100.0%	100.0%	100.0%
% of total	46.1%	12.2%	41.7%	100.0%

Next, the following table presents the results of the cross tabulation conducted between country and whether a leaded apron and thyroid shield is used for patient protection. This was found to be the case significantly more frequently in Australia as compared with Jordan.

Table 2:10

Chi-square analysis: leaded apron and thyroid shield for patient protection

	Leaded apron and thyroid shield for patient protection		
	No	Yes	Total
Australia			
Count	17	38	55
% within country	30.9%	69.1%	100.0%
% within shield	32.7%	59.4%	47.4%
% of total	14.7%	32.8%	47.4%
Jordan			
Count	35	26	61
% within country	57.4%	42.6%	100.0%
% within shield	67.3%	40.6%	52.6%
% of total	30.2%	22.4%	52.6%
Total			
Count	52	64	116
% within country	44.8%	55.2%	100.0%
% within shield	100.0%	100.0%	100.0%
% of total	44.8%	55.2%	100.0%

With regard to how important the respondent felt the role of imaging is in dentistry, a response of “very high” was substantially more likely in Australia, with a response of “high”, “moderate”, or “low” being substantially more likely in Jordan.

Table 2:11

Chi-square analysis: how important is the role of imaging in dentistry

	How important is the role of imaging in dentistry				
	High	Low	Moderate	Very high	Total
Australia					
Count	9	0	1	44	54
% within country	16.7%	0.0%	1.9%	81.5%	100.0%
% within importance	34.6%	0.0%	11.1%	51.2%	43.5%
% of total	7.3%	0.0%	.8%	35.5%	43.5%

Jordan					
Count	17	3	8	42	70
% within country	24.3%	4.3%	11.4%	60.0%	100.0%
% within importance	65.4%	100.0%	88.9%	48.8%	56.5%
% of total	13.7%	2.4%	6.5%	33.9%	56.5%
Total					
Count	26	3	9	86	124
% within country	21.0%	2.4%	7.3%	69.4%	100.0%
% within importance	100.0%	100.0%	100.0%	100.0%	100.0%
% of total	21.0%	2.4%	7.3%	69.4%	100.0%

The following set of significant results focus upon what respondents felt was the most important organ in relation to radiography. First, the following table presents the results of the cross tabulation conducted focusing upon gonads. These results indicate that respondents in Jordan were significantly more likely to state that the most important organ in radiography was the gonads.

Table 2:12

Chi-square analysis: most important organ: gonads

	Most important organ: gonads		
	No	Yes	Total
Australia			
Count	53	8	61
% within country	86.9%	13.1%	100.0%
% within gonads	47.7%	25.8%	43.0%
% of total	37.3%	5.6%	43.0%
Jordan			
Count	58	23	81
% within country	71.6%	28.4%	100.0%
% within gonads	52.3%	74.2%	57.0%
% of total	40.8%	16.2%	57.0%
Total			
Count	111	31	142
% within country	78.2%	21.8%	100.0%
% within gonads	100.0%	100.0%	100.0%
% of total	78.2%	21.8%	100.0%

The following significant result focused upon the statement that bones were the most important organ in radiography. As shown in the following table, individuals in Jordan were significantly more likely to state that bones were the most important organ as compared with those in Australia.

Table 2:13

Chi-square analysis: most important organ: bones

	Most important organ: bones		
	No	Yes	Total
Australia			
Count	60	1	61
% within country	98.4%	1.6%	100.0%
% within bones	45.5%	10.0%	43.0%
% of total	42.3%	.7%	43.0%
Jordan			
Count	72	9	81
% within country	88.9%	11.1%	100.0%
% within bones	54.5%	90.0%	57.0%
% of total	50.7%	6.3%	57.0%
Total			
Count	132	10	142
% within country	93.0%	7.0%	100.0%
% within bones	100.0%	100.0%	100.0%
% of total	93.0%	7.0%	100.0%

Following this, the table presented below focused upon the thyroid. In this case, it was significantly more likely for individuals in Australia to indicate that the thyroid was the most important organ in radiography as compared with those in Jordan.

Table 2:14

Chi-square analysis: most important organ: thyroid

	Most important organ: thyroid No	Yes	Total
Australia			
Count	12	49	61
% within country	19.7%	80.3%	100.0%
% within thyroid	22.2%	55.7%	43.0%
% of total	8.5%	34.5%	43.0%
Jordan			
Count	42	39	81
% within country	51.9%	48.1%	100.0%
% within thyroid	77.8%	44.3%	57.0%
% of total	29.6%	27.5%	57.0%
Total			
Count	54	88	142
% within country	38.0%	62.0%	100.0%
% within thyroid	100.0%	100.0%	100.0%
% of total	38.0%	62.0%	100.0%

The following significant result focused upon whether respondents stated that they would take any periapical radiographs from a pregnant woman. As presented in the following table, individuals in Australia were significantly more likely to respond in the affirmative to this question as compared with those in Jordan.

Table 2:15

Chi-square analysis: would you take any periapical radiographs from a pregnant woman?

	Would you take any periapical radiographs from a pregnant woman? No	Yes	Total
Australia			
Count	13	41	54
% within country	24.1%	75.9%	100.0%
% within pregnant	28.9%	53.2%	44.3%
% of total	10.7%	33.6%	44.3%

Jordan			
Count	32	36	68
% within country	47.1%	52.9%	100.0%
% within pregnant	71.1%	46.8%	55.7%
% of total	26.2%	29.5%	55.7%
Total			
Count	45	77	122
% within country	36.9%	63.1%	100.0%
% within pregnant	100.0%	100.0%	100.0%
% of total	36.9%	63.1%	100.0%

Next, the following table presents the results of the cross tabulation conducted with whether respondents adjust the exposure time from maxilla to mandible radiographs. A response of "no change" was substantially more likely among Australian respondents, with a response of either "decrease" or "increase" being substantially more likely among those in Jordan.

Table 2:16

Chi-square analysis: adjust exposure time from maxilla to mandible

	Adjust exposure time from maxilla to mandible			
	Decrease	Increase	No change	Total
Australia				
Count	4	9	39	52
% within country	7.7%	17.3%	75.0%	100.0%
% within adjust	30.8%	30.0%	57.4%	46.8%
% of total	3.6%	8.1%	35.1%	46.8%
Jordan				
Count	9	21	29	59
% within country	15.3%	35.6%	49.2%	100.0%
% within adjust	69.2%	70.0%	42.6%	53.2%
% of total	8.1%	18.9%	26.1%	53.2%
Total				
Count	13	30	68	111
% within country	11.7%	27.0%	61.3%	100.0%
% within adjust	100.0%	100.0%	100.0%	100.0%
% of total	11.7%	27.0%	61.3%	100.0%

Next, an identical set of chi-square analyses were conducted with experience, with experience defined as total years since graduation, with this measure then being dichotomized based on a median split, with the median of this measure consisting of 14 years of experience. The results of these analyses are summarized in the following table. Within these analyses, statistical significance was only indicated with respect to the chi-square analysis conducted on which technique was used by the respondents for periapical radiography.

Table 2:17

Chi-square analyses: differences by years of experience

Measure	χ^2 (*df*)	*p*
Do you have an X-ray machine in your clinic?	.359 (1)	.549
Age of your X-ray machine	22.546 (17)	.165
Who takes the X-rays in your practice?	.625 (2)	.732
Do you have periodic check-up for X-ray equipment?	2.887 (1)	.089
You or assistant hold the X-ray film with the fingers?	.044 (1)	.833
How many radiographs do you take in clinic per week?	27.496 (22)	.193
Do you use a personal dosimeter to measure the radiation?	.008 (1)	.927
Personal dosimeter type	2.000 (1)	.157
Do you use a film holder while taking radiographs?	.188 (1)	.664
Which technique do you use for periapical radiography?	4.422 (1)	.035
Which type of collimator do you use?	.344 (1)	.557
What is the length of your collimator?	3.831 (3)	.280
Which type of radiographic receptor do you use?	1.816 (1)	.178
Which film speed do you use for periapical radiography?	.635 (2)	.728
Are the walls of the X-ray room lead-lined?	4.855 (2)	.088
Do you use a leaded apron and thyroid shield?	.342 (1)	.559
How important is the role of imaging in dentistry?	2.042 (3)	.564
Most important organ in radiation protection in dental radiography?		
Gonads	3.126 (1)	.077
Bone Marrow	1.476 (1)	.224
Thyroid	3.157 (1)	.076
Eyes	.281 (1)	.596
Which radiographic technique delivers more radiation?	.006 (1)	.939
Would you take X-rays from a pregnant patient?	.147 (1)	.701
Pregnant: under what circumstances?	37.158 (36)	.415
Radiographic exposure factors: maxillary molar	47.819 (48)	.480
Radiographic exposure factors: mandibular incisor	52.523 (51)	.415
Adjust exposure time from fat patient to thin patient?	1.242 (2)	.537
Adjust exposure time from anterior teeth to posterior teeth?	3.309 (2)	.191
Adjust exposure time from maxilla to mandible	.631 (2)	.730
Youngest age	14.608 (13)	.332
Where do you stand?	75.494 (75)	.462

The following table summarizes the cross tabulation conducted on this one significant chi-square analysis. As shown, the bisecting angles technique was used significantly more frequently among those with a number of years experience greater than the median, with the paralleling technique being used significantly more frequently among those with a number of years of experience less than the median.

Table 2:18

Chi-square analysis: which technique do you use for periapical radiography?

	Which technique do you use for periapical radiography?		
	Bisecting angles	Paralleling	Total
Years of experience < Median			
Count	15	43	58
% within experience	25.9%	74.1%	100.0%
% within technique	39.5%	60.6%	53.2%
% of total	13.8%	39.4%	53.2%
Years of experience > Median			
Count	23	28	51
% within experience	45.1%	54.9%	100.0%
% within technique	60.5%	39.4%	46.8%
% of total	21.1%	25.7%	46.8%
Total			
Count	38	71	109
% within experience	34.9%	65.1%	100.0%
% within technique	100.0%	100.0%	100.0%
% of total	34.9%	65.1%	100.0%

Finally, the qualitative data collected for the purposes of this study were analyzed. These interviews consisted of a series of initial background questions, which asked respondents whether they work as a general practitioner or specialist, whether they use ionizing radiation in their practice, and whether they use film or digital imaging methods. Following this, respondents were asked about their understanding of radiation dose in relation to dental radiography, about ALARA, how they apply radiation safety practices in their clinic, their understanding of the ionizing risks associated with dental radiography, whether they explain the ionizing risks associated with radiography to their patients, and the impact of distance, time, and amount of exposure on radiation protection. A qualitative review of the Jordanian as well as the Australian transcribed interviews revealed that responses provided by Australian individuals suggested a more accurate and comprehensive level of knowledge regarding radiation as compared with individuals working in Jordan. These results appear to correspond with those found in the quantitative analyses conducted for this study, while overall, these results pertain only to those respondents who participated in this study. The following chapter will discuss these results and provide a series of conclusions resulting from this study.

Discussion and Conclusion

While imaging using ionizing radiation in dental clinics has become more common in recent years due to a number of advantages, concerns continue to exist relating to potential negative effects associated with the use of ionizing radiation in dental practice. Previous research has found a link between exposure to ionizing radiation and the risk of several types of cancer and has also been linked to leukaemia in children (Timins, 2011). Despite this research, dentists' level of knowledge on these health hazards is generally substandard, with previous research indicating that most dentists are unaware of these health hazards (Khatib et al., 2000; Lguy et al., 2005; Shahab et al., 2011). This study served to determine the level of understanding of ionizing radiation and its health hazards among the dentists working in Australia and Jordan. The current study contacted potential participants with a unique questionnaire being designed and administered for this study. This questionnaire consisted of 33 questions incorporating demographic measures, while also measuring variables relating to qualifications and experience, knowledge of radiographic equipment and techniques, and ionizing radiation safety measures. Additionally, of this sample, a subsample of dentists from Australia and Jordan were also interviewed in order to gain further information in relation to their answers. These consisted of structured interviews.

When comparing the results of this study to previous literature, similarities as well as differences were indicated. It has been found that dentists' level of knowledge on health hazards relating to ionizing radiation is generally substandard, with previous research indicating that most dentists are unaware of these health risks (Khatib et al., 2000; Lguy et al., 2005; Shahab et al., 2011). This study did find substandard knowledge, though primarily with regard to the Jordanian sample as compared with those dentists practicing in Australia. Additionally, previous research has also indicated that academic institutions and doctors use guidelines very rarely (Kantor, 2006). Literature conducted in this area has also found the vast majority of doctors to not be aware of the radiation dose provided to patients (Arsalanoglu, Bilgin, & Kubal, 2007), while the majority of doctors also score below average with respect to their awareness of ionizing radiation (Sove & Patterson, 2008). Doctors also commonly incorrectly believe that MRI and ultrasound use ionizing radiation, while the majority of doctors underestimate the radiation dose, with a substantial minority believing that knowledge of ionizing radiation is not really important or is not important at all (Zhou, Wong, & Nguyen, 2010). Another study found that the majority of dentists failed to accurately estimate the radiation dose (Bosanquet, Green, & Bosanquet, 2011). While this literature review suggests a large gap in the knowledge held by doctors and dentists with regard to dental radiography and ionizing radiation, the current study found this to be the case, though significantly and substantially more so with regard to the Jordanian sample as compared with dentists practicing in Australia. The results of this study found a higher and more accurate level of knowledge among dentists practicing in Australia as compared with Jordanian dentists, with Australians having a more accurate and comprehensive level of knowledge with respect to ionizing radiation and, more generally, with respect to the practice of dental radiography. The results of this study do confirm that much work must be done in order to improve the knowledge of dentists about ionizing radiation as well as more generally with respect to the practice of dental radiography in Jordan as well as locations in which a similar level of knowledge exists. However, the findings of this study also suggest an acceptable level of knowledge regarding ionizing radiation and the practice of dental radiography in other areas of the world. Therefore, the results of this previous research are reflected within the current study, but are more localized to specific areas which need improvement.

Summary

In this study, quantitative and qualitative data has been collected from dentists across Australia and Jordan. A review of this data indicated a higher and more accurate level of knowledge among Australian dentists as compared with Jordanian dentists. Overall, the responses provided by Australian individuals did suggest a more accurate and comprehensive level of knowledge regarding radiation as compared with those in Jordan. Overall, the qualitative and quantitative results both suggest that those in Australia are substantially more knowledgeable and educated in relation to dental radiography and ionizing radiation as compared with those in Jordan.

These results indicate that, in order to minimize any unnecessary radiation, a need exists to improve dentists' knowledge about radiation dose reduction techniques in Jordan as the results of this study indicated that respondents from Jordan evidenced a lack of knowledge and sub-par dental practices as compared with their Australian counterparts. While this study highlights the inadequacy of dentists' knowledge and practice, further research should be made into strategies to improve dental practice aiming to reduce radiation hazards.

The significance of this research is that it identifies widespread poor dental practice, particularly in Jordan concerning the risks presented by dental radiography with patients and staff being unnecessarily exposed to hazards which could be prevented by implementing current safety precautions. This study highlights to need for further research into ways to enforce higher standards across the profession which has the potential of lowering cancer rates worsened by poor practice within dental surgeries.

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Appendix A

The questionnaire included these following 33 questions:

1. Enter your name?

2. Enter your age

- ☐ 20-29
- ☐ 30-39
- ☐ 40-49
- ☐ 50>

3. Year gender

- ☐ Male
- ☐ Female

4. Enter your country, and year of graduation

5. Enter your city of practice

6. Do you work as…?

- ☐ General practitioner
- ☐ Specialist

7. Do you have an x-ray machine in your clinic?

☐ Yes ☐ No

If no, go to question 23

8. What is the age of your x-ray machine?

9. Who takes the x-rays in your practice?

- ☐ Dental practitioner
- ☐ Dental technician
- ☐ Nurse

10. Do you have periodic check up for your x-ray equipment?

☐ Yes ☐ No

11. Do you or your assistant hold the x-ray film with the finger while taking periapical radiographs?

☐ Yes ☐ No

12. How many radiographs do you take in your clinic weekly?

13. Which type of radiographic examination do you usually prescribe in the initial visit?

- ☐ Bite wing Selective
- ☐ Periapical view
- ☐ Panoramic
- ☐ Full mouth periapical view

14. Do you use a personal dosimeter to measure the radiation dose for the staff and the patient?

☐ Yes ☐ No

If you do, Please indicate the type

15. Do you use film holder while taking radiographs?

☐ Yes ☐ No

16. Which technique do you use for periapical radiography?

- ☐ Paralleling technique
- ☐ Bisecting angles technique

17. Which type of collimator do you use?

- ☐ Round
- ☐ Rectangular

18. What is the length of your collimator?

- ☐ No collimator (pointed cone)
- ☐ 20 cm
- ☐ 30 cm
- ☐ 40 cm

19. Which type of radiographic receptor do you use?

- ☐ Film
- ☐ Digital receptor

20. Which film speed do you use for periapical radiography?

- ☐ D
- ☐ E
- ☐ F

21. Are the walls of the x-ray room covered with lead?

☐ Yes ☐ No ☐ No idea

22. Do you use leaded apron and thyroid shield for patient protection?

☐ Yes ☐ No

23. In your opinion, how important is the role of imaging in dentistry?

- ☐ Very low
- ☐ Low
- ☐ Moderate
- ☐ High
- ☐ Very high

24. What is the aim of radiation protection in dental radiography?

25. What is the most important organ in radiation protection in dental radiography?

- ☐ Gonads
- ☐ Bone marrow
- ☐ Thyroid
- ☐ Skin

26. In your opinion, which of the following radiographic techniques delivers more radiation to patient?

- ☐ Panoramic
- ☐ Full mouth

27. Would you take any periapical radiographs from a pregnant woman?

☐ Yes ☐ No

If so under what circumstances?

28. What radiographic exposure factors do you use for the periapical view of the following areas?

Maxillary molar ----------------------- Mandibular incisor ----------------------

29. How do you adjust exposure time in the following conditions? : From fat patient to thin patient:

- ☐ Increase
- ☐ Decrease
- ☐ No change

30. How do you adjust exposure time in the following conditions? : From anterior teeth to posterior teeth:

- ☐ Increase
- ☐ Decrease
- ☐ No change

31. How do you adjust exposure time in the following conditions? : From maxilla to mandible:

- ☐ Increase
- ☐ Decrease
- ☐ No change

32. What is the youngest age you take for any perapical radiography?

33. If there is no barrier between you and patient, in which area do you stand according to the x-ray tube and what is your distance from the patient?

Qualitative Component

1. Do you work as general practitioner or specialist

2. Where do you use ionising radiation in your practice?

3. Do you use film or digital imaging methods?

4. What is your understanding of radiation dose in relation to dental radiography?

5. What is ALARA?

6. How do you apply radiation safety practice in your clinic?

7. What is your understanding of the ionising risks associated with dental radiography?

8. Do you explain the ionising risks associated with radiography to your patients?

9. What is the impact of distance, time and amount of exposure on radiation protection?