Knowledge assessment of radiation protection practices among dental professionals- A literature review

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Abstract

X-ray radiographs are common practice tools used by dental professionals to address clinical problems and provide valuable diagnostic information. Dental X-ray examinations release low doses of radiation with low biological risks. However, on a repetitive basis, low doses will lead to a cumulative high radiation dose on the long run and no basis exists to assume that dental radiology risk is zero. Hence, compliance to radiation protection protocols becomes vital and critical.

This systematic review paper attempts to address three main goals: assess the knowledge of dental professionals on radiation protection, determine any potential correlation between the knowledge and awareness of various categories of dental practitioners and their demographic parameters, and assess to what extent do dental professionals comply with the relevant associated regulations. For this study, 37 questionnaire based cross-sectional studies were utilized based on their titles, abstracts and keywords. Results showed lack of knowledge of dental professionals on radiation protection and a positive correlated relationship was determined between the years of experience and level of knowledge and awareness. However, no relation was drawn between gender and level of knowledge and awareness. Lastly, in relation to radiation protection guidelines, most dental professionals showed a weak awareness of the ALARA principle and a fair percentage of respondents were not aware of the ICRP recommendations.

Keywords: Dental radiology, Radiation protection, Radiation protocols, Knowledge, Compliance

1. Introduction

An adequate dental treatment is a sign of correct case diagnoses, which is not possible to achieve without the utilization of one critical diagnostic approach; Dental Radiographs. Valuable diagnostic information is obtained from dental radiograph examinations which benefit the dental professionals (i.e. dentists, dental radiologists, dental students and nurses) to address clinical problems. X-ray images are becoming more and more used in daily basis globally. This routine use of dental radiograph sometimes leads to unnecessary practitioners’ and patients’ exposure that can cause biological hazards.

Biological hazards are classified into deterministic and stochastic effects. Deterministic effects are those harmful effects that appear if a certain dose of ‘potentially harmful’ substance intake (threshold dose) is exceeded. Stochastic effects do not have threshold doses for biological damages to occur. In dental radiology, the exposure of dose is low, therefore, stochastic effect is more likely to occur [1]. Additionally, on a long-term basis, low doses can lead to a cumulative high radiation dose. To balance mindsets, no one, neither a dental practitioner nor a patient, exposed to radiation can be totally exempted from risk. As a result, safety precautions and radiation protection measure should be intensely considered and consequently applied by dental professionals.

The International Commission on Radiological Protection (ICRP) recommendations include a justification; all patients’ exposure to X-ray imaging must have a clinical justification and optimization; each exposure should have positive net benefit. One of the basic tenets of radiation safety is to follow the ALARA principle ‘As Low As Reasonably Achievable’ during dental professionals’ routine work. However, evidence suggests that the ALARA principle is not strictly applied in the field.

According to the latest United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) published report, the annual number of dental examinations worldwide was estimated to be 480 million dental examinations in 2008 [2]. Based on the researches done, there is no recent updated annual number of dental
examinations taken. However, the enormous number of dental X-rays reported even back in 2008 have widely opened the eyes of scholars and dental practitioners to figure out the sense behind this reported number, when logically extrapolated to current time.

It is true that continuous advanced technologies in the dental field have already resulted in less exposure of practitioners and patients to radiation risks. Despite this fact, there is a clear gap that can be identified between the use of these technologies and the dental professionals’ actual practices and attitudes, that should be reconsidered in many cases. These improper practices certainly contradict with the recommendations stated by the ICRP and other international guidelines (e.g. such as those issued by International Atomic Energy Agency (IAEA), European Academy of Paediatric Dentistry (EAPD), etc.). Therefore, there should be a striving movement towards better improving the implementation of various radiation protection measures.

This study will systematically review a number of field survey-based published literature with regard to dental radiation protection techniques and safety standards. The target of this review is to achieve the following objectives:

1) assess the knowledge of dental practitioners regarding radiation protection measures and protocols.
2) determine the relationship between the knowledge of the dental practitioners and their socio-demographic variables, and
3) determine the compliance level of dental practitioners with the international guidelines, specifically the ICRP recommendations.

2. Methodology
2.1 Articles search strategy
The literature search was conducted using multiple variations of keywords combinations such as radiation protection, dental radiology, knowledge among dentists, and dental radiological practice in the titles, abstracts and keywords of the following scientific literature databases: PubMed, BIR publications, Google Scholar and ResearchGate. Thirty-seven (n=37) articles were selected based on their topic relevance, abstract context, and citation number.

The collected articles were then classified based on their years of publication, origin countries, of study, and the targeted populations. Due to the diverse number of associated journal names, the studies were not classified accordingly, yet, most collected papers were published in ‘Dentomaxillofacial Radiology’ journal.

2.2 Articles classifications
2.2.1 Distribution of articles by year of publication
Figure 1 presents the distribution of articles based on their years of publication. Based on the selected studies, 2019 was the year with largest number of publications that assessed the knowledge and dental radiographical practice features among dental professionals. The earliest study was published in 1994 by Bohay et al. [3], which surveyed the radiographic equipment and techniques used by Canadian dentists to assess their knowledge relevant to the field. Since then, the number of publications have increased. The on-going publications in 2019 shows that dental radiation protection awareness is raised among dental practitioners and dental students in general. The trend is expected to increase in 2020 and beyond.
2.2.2 Distribution of articles by country of the study

It is observed in Figure 2 that India (35%), Kingdom of Saudi Arabia (KSA) (12%) and Iran (12%) hosted the larger numbers of studies that focused on assessing the knowledge of dental practitioners regarding radiation protection concerns. India recorded the highest number of publications in this literature review, with 13 out of 37 articles, and as it is the 145th among 195 countries in terms of quality in healthcare [4], this explains why India is open and working hard to improve their safety standards in regards to radiation protection measures. From other Middle Eastern countries, one research article was originated from each of Syria [5], Sudan [6], Egypt [7], and UAE [8]. Similarly, from Western countries one research article was originated from each of Australia [9], Canada [3], USA [10] and Sweden [11].

Figure 1. Distribution of collected articles by year of publication

Figure 2. Distribution of articles by origin country of publication
2.2.3 Distribution of articles by targeted populations.
The basic research methodology adopted by the collected articles was the administration of field surveys and questionnaires. The collection of data within the published articles is based on the distribution of questionnaires (or surveys) among dental students (undergraduates, interns and postgraduates) and experienced dentists (less and more than 10 years of experience). Most selected articles targeted the participation of dental practitioners only (31 out of 37 articles) as shown in Figure 3. This first group of articles assessed the knowledge and attitudes of active practitioners regarding radiation protection principles applied for their and their patients’ protection in general (including pregnant patients). In the first group of articles, out of the 67% articles, 3 studies; Prasad et al.[12], Zanata et al. [13] and Temur et al. [14] focused mainly on radiation protection measures on pregnant patients. In the second group of articles (28%), only dental students took part to their knowledge and attitudes towards radiation safety assessed. The remaining 5% of the articles targeted both dental practitioners and dental students, as indicated by the third group of articles.

Figure 3. Distribution of articles by the targeted populations

3. Results and discussion
After synthesizing all the selected articles, a general image is captured regarding the level of knowledge among dental professionals. This image is viewed throughout the following four sections: Demographic description of participants as indicated by their age, awareness of radiation protection guidelines for dental practices, the equipment and techniques used to manage risks of radioactivity within dental practices, and the relationship between perceived knowledge and the socio-demographic parameter of years of experience, as well as the relationship between perceived knowledge with actual practice and other social demographic variables. More details can be discussed as per the following sections.

3.1 Demographic data of participants as indicated by age
Figure 4 indicates the highest age group (mode) that was demonstrated in each paper. The figure shows that the most common age group of participants is between the middle of the 20s and 40s years of age. In this regards, it worth mentioning that the following papers: Kaur et al.[15], Balaji et al. [16], Aps [17], Bohay et al. [3], Faraz [18], Ardakani & Sarayesh [19], Hussein et al. [6], Zanata et al. [13], Svenson [11], Fakhar [20], Sinha et al. [21] and Luke [8] were excluded from this figure due to the irrelevant data regarding the age group.
3.2 Awareness of radiation protection measures and guidelines

Generally, all articles agreed on the lack of knowledge among dental professionals. Following the ICRP guidelines and recommendations is a very critical move by dental professionals to ensure the safety of patients. However, unfortunately, based on table 1, Srinivasan & Dharman [22], Arnout [7], Hussein et al. [6], Almohaimede et al. [23] and Ahmed et al.[24] articles showed that the number participants who did not know and were unaware of the ICRP recommendations had a larger frequency than those who were aware of it. Undergraduates and postgraduate students knowledge and awareness level were specifically highlighted in Arnout [7], Behal [25], Almohaimede et al. [23] and Swapna et al. [1] studies. The results showed that dental students do not have the sufficient required knowledge regarding this concern. Although knowledge of the ICRP guidelines was important, most questionnaires did not address it. Details are given by Table 1.

<table>
<thead>
<tr>
<th>Article</th>
<th>Are you aware of the ICRP guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahmed et al.[24]</td>
<td>3% Yes, 75% No</td>
</tr>
<tr>
<td>Behal [25]</td>
<td>43% Yes, 57% No</td>
</tr>
<tr>
<td>Arnout [7]</td>
<td>27% Yes, 61% No</td>
</tr>
<tr>
<td>Almohaimede et al. [23]</td>
<td>35% Yes, 65% No</td>
</tr>
<tr>
<td>Arnout &amp; Jafar [26]</td>
<td>24.5% Yes, 42% No</td>
</tr>
<tr>
<td>Hussein et al. [6]</td>
<td>29.8% Yes, 70% No</td>
</tr>
<tr>
<td>Swapna et al. [1]</td>
<td>35% Yes, 65% No</td>
</tr>
</tbody>
</table>

Out of the 37 articles selected, ALARA principle was only mentioned in the questionnaire of 7 articles. The majority of participants in Assiri et al. [27], Srinivasan & Dharman [22], Arnout & Jafar [26], Prabhat et al. [28] and Temur et al. [14] questionnaire indicated their awareness and application of the ALARA principle. However, Hussein et al. [6] and Arnout [7] indicated a very low number of respondents who were aware of ALARA principle, 26.3% and 30% respectively.

Temur et al. stated that lead apron can reduce the exposure at a rate of 98% to make it very low, however, many studies did not consider this protection measure, and ignored highlighting the importance of its use. Kaur et al. [15], Ranjith & Buvaneswari [16], Dhokar et al. [29], Sheikh et al. [30] and Kasat et al. [31] studies all showed very few respondents who apply the lead apron for patients. Studies originated from KSA; Almohaimede et al. [23], Ahmed et al. [24], Faraz...
[18] and Arnout & Jafar [26], showed that most respondents agreed to use of lead apron. Out of all the reviewed articles, the most aware participants of applying the lead apron are the dentists in United States [10]. The study originated from Uganda [32] recorded a higher level of awareness than Sudan [6], Turkey [33], Iran [34] and Egypt [7]. Details are given by Table 2.

Table 2. Participants’ responses regarding the lead aprons and thyroid collars

<table>
<thead>
<tr>
<th>Articles</th>
<th>Do participants use Lead Apron?</th>
<th>Do participants apply Thyroid collars and at what rate?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaur et al. [15]</td>
<td>23.8%</td>
<td>76.2%</td>
</tr>
<tr>
<td>Ranjith &amp; Buvaneswari [16]</td>
<td>44%</td>
<td>50%</td>
</tr>
<tr>
<td>Dhokar et al. [29]</td>
<td>10%</td>
<td>44.5%</td>
</tr>
<tr>
<td>Sheikh et al. [30]</td>
<td>19.2%</td>
<td>NM</td>
</tr>
<tr>
<td>Kasat et al. [31]</td>
<td>23%</td>
<td>28.3%</td>
</tr>
<tr>
<td>Almohaimede et al. [23]</td>
<td>80.2%</td>
<td>NM</td>
</tr>
<tr>
<td>Ahmed et al. [24]</td>
<td>53.8%</td>
<td>46.2%</td>
</tr>
<tr>
<td>Arnout &amp; Jafar [26]</td>
<td>54.8%</td>
<td>3%</td>
</tr>
<tr>
<td>Faraz [18]</td>
<td>54%</td>
<td>46%</td>
</tr>
<tr>
<td>Mutyabule &amp; Whaites [32]</td>
<td>77%</td>
<td>NM</td>
</tr>
<tr>
<td>Shahab et al. [34]</td>
<td>35%</td>
<td>NM</td>
</tr>
<tr>
<td>Arnout [7]</td>
<td>14%</td>
<td>25%</td>
</tr>
<tr>
<td>Lintag et al. [10]</td>
<td>89%</td>
<td>NM</td>
</tr>
<tr>
<td>Jacobs et al. [35]</td>
<td>14%</td>
<td>88%</td>
</tr>
<tr>
<td>Hussein et al. [6]</td>
<td>20.7%</td>
<td>69.25</td>
</tr>
<tr>
<td>Ilgu’y et al. [33]</td>
<td>8.7%</td>
<td>NM</td>
</tr>
<tr>
<td>Prabhat et al. [28]</td>
<td>45%</td>
<td>32%</td>
</tr>
</tbody>
</table>

*NM: not mentioned

3.3 Equipment & techniques used to manage risks of radioactivity within dental practices

Proper radiographic equipment and techniques will help to reduce the exposure to patients as well as dental practitioners. The amount of radiation exposure depends on many factors such as voltage and the specific technique used, film speed, and collimation [22]. Therefore, this section will mainly focus on these factors. It is stated by Kircos et al. [36] in 1987 that using rectangular collimator instead of circular collimator will cause a 47% dose reduction to the skull and 29% to the lens of the eye. However, recent papers, Faraz [18], Sheikh et al. [30] and Ihle et al. [9], showed that rectangular collimators were rarely used by dentists which shows a very clear gap of relevant knowledge and awareness.

Bisecting angle and parallel angle techniques are two common techniques used in dental radiology to capture the best image for the tooth. Figure 5 shows clearly how X-ray image is taken in each technique. Paralleling technique is the most accurate intraoral radiographic technique. The bisecting technique is used when it is difficult to capture the tooth using the paralleling technique [37].
Kircos et al. [36] study also demonstrated a dose reduction of 24% while using parallel angle technique. Fortunately, this review article showed a positive correlation of using parallel angle technique throughout the years. Table 3 shows that the bisecting angle technique is recently used less frequently.

To assess the knowledge of dentist, two factors are tested; the peak kilovoltage (kVp) of dental equipment, which refers to the voltage applied during the process of X-ray, and the speed film. Most studies as shown in table 3 demonstrated that high percentages of respondents did not know the kVp of the equipment, which means that in case of high voltages, dental practitioners might not notice associated risks as biological hazards might appear. Generally, Mutyabule & Whaites [32], Salti & Whaites [5], Ilgu’y et al. [33] and Sheikh et al. [30] articles provided a clear evidence that dental practitioners should further be educated and triggered to improve their knowledge and awareness in this critical regard. This is obviously indicated by the Ihle et al. [9] study as per table 3.

Table 3. Participants’ responses regarding the awareness and use of ICRP guidelines

<table>
<thead>
<tr>
<th>Articles</th>
<th>Year of publication</th>
<th>Rectangular collimator</th>
<th>Circular collimator</th>
<th>Parallel angle technique</th>
<th>Bisecting angle technique</th>
<th>E-speed film</th>
<th>Do not know the speed film</th>
<th>Did not know the kVp of equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>[3]</td>
<td>1994</td>
<td>8%</td>
<td>NM</td>
<td>52%</td>
<td>NM</td>
<td>11%</td>
<td>NM</td>
<td>NM</td>
</tr>
<tr>
<td>[32]</td>
<td>2002</td>
<td>NM*</td>
<td>NM</td>
<td>13%</td>
<td>74%</td>
<td>22%</td>
<td>40%</td>
<td>60%</td>
</tr>
<tr>
<td>[5]</td>
<td>2002</td>
<td>0%</td>
<td>69%</td>
<td>43%</td>
<td>57%</td>
<td>NM</td>
<td>13%</td>
<td>64%</td>
</tr>
<tr>
<td>[35]</td>
<td>2004</td>
<td>6%</td>
<td>NM</td>
<td>NM</td>
<td>44%</td>
<td>NM</td>
<td>66%</td>
<td>87%</td>
</tr>
<tr>
<td>[33]</td>
<td>2005</td>
<td>6%</td>
<td>NM</td>
<td>31%</td>
<td>62%</td>
<td>NM</td>
<td>66%</td>
<td>87%</td>
</tr>
<tr>
<td>[17]</td>
<td>2010</td>
<td>13%</td>
<td>40%</td>
<td>81%</td>
<td>14%</td>
<td>NM</td>
<td>NM</td>
<td>32%</td>
</tr>
<tr>
<td>[18]</td>
<td>2014</td>
<td>8%</td>
<td>50%</td>
<td>75%</td>
<td>25%</td>
<td>36%</td>
<td>45%</td>
<td>31%</td>
</tr>
<tr>
<td>[30]</td>
<td>2014</td>
<td>20.6%</td>
<td>NM</td>
<td>4.2%</td>
<td>94.1%</td>
<td>58.8%</td>
<td>10.8%</td>
<td>82.3%</td>
</tr>
<tr>
<td>[9]</td>
<td>2018</td>
<td>5%</td>
<td>95.1%</td>
<td>NM</td>
<td>NM</td>
<td>7%</td>
<td>23.8%</td>
<td>12%</td>
</tr>
</tbody>
</table>

*NM: not mentioned

3.4 The relationship between knowledge & practice and social demographic variables.

The most frequent question noticed in all the surveys is “Are dental X-rays harmful?”. Dental students, including graduates, undergraduates and interns, responded with a high percentage of “yes” [1], [7], [23], [25], [27], [28], [39]. Prasad et al. [12] study focused on pregnant patients where the survey included the question “Are dental X-rays harmful for pregnant ladies?” and most participants were aware of this issue, 96% respectively. In case of dental practitioners who have experience, it was determined that those who have more years of experience, specifically more than 10 years, are more aware of dental X-ray biological hazard than those who have less than 10 years of experience [6], [24].

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Dental professionals with more years of experience are more aware of the ALARA principle than those who just entered the field [6]. ALARA principle includes minimizing time of exposure, using an effective method of shielding and keep distance as far from any radiation source. Experienced dentists are aware of using E-speed film more than dentists with 1-2 years of experience [29]. E-speed film reduces the exposure time which means that they are aware of the ALARA principle as well. Also, lead apron for patients are mainly used in case of experienced (more than 10 years) practitioner. All practitioners had the knowledge of the safe distance unlike fresh experienced who were not fully aware of wearing lead aprons for patients. Ihle et al. [9] article stated that practitioners with the least experience had the highest rate of incorrect answers to knowledge-assessing questions. This study remarked the lack of knowledge and awareness for recently graduated dentists and it was recommended to add more radiograph education as part of university curricula. Similarly, Lintag et al. [10] declared that dentists with more years of experience use appropriate techniques to reduce exposure to ionizing radiation. Therefore, it was recommended to improve undergraduate education level and establish programs regularly regarding radiographic protection protocols [1], [7], [18], [23], [25], [27], [28], [39].

Binnal et al. [40] study assessed how dentists are welling to gain and implement knowledge on radiation hazards and protection into their practice. Ninety-four percent of practitioners were welling to improve their knowledge. In other words, they don’t have a strong background in radiation protection practices, therefore, the majority showed interest towards gaining knowledge in this field. Out of the 94%, 23% of the practitioners who have more than 10 years of experience are not welling to improve their knowledge and vice versa with the majority. This highlight the fact that experienced practitioners might tend to neglect the continual education programs. This also proves that studies that recommended the educational programs were right about it.

In terms of gender, Temur et al. [14] and Dhokar [29] articles showed that males are more likely to take radiographs for pregnant woman than female. Husseing et al. [6] study concluded that no difference was found between male and female dentists regarding their level of knowledge and awareness in regards to protection from dental radiology risks. Dhokar [29] showed that a higher percentage of female use rectangular collimators while a higher percentages of male use F-speed film. In another study, it was shown that more female dental practitioners wear lead apron than males. Thus, It is concluded that no relation is drawn between the gender of practitioners and their knowledge and actual practices done.

4. Conclusion
Dental professionals should have enough knowledge of dental radiation protection protocols. The main goals of this review study were to assess the knowledge and awareness of dental professionals on radiation protection, determine any potential correlation between the knowledge and awareness of various categories of dental practitioners and their demographic parameters, and then to assess to what extent do dental professionals comply with the relevant associated regulations.

Based on the current findings, a definite lack of knowledge and perception of radiation risk management within dental practices is experienced between dental professionals. It was expected that experienced dental practitioners are more aware of dental radiation protection techniques than freshly graduated students. The current review results confirmed our expectations where experienced dentist (of more than 10 years of practice) were aware of ALARA principle, the use of lead apron, and they are using the appropriate techniques in general. However, the two factors tested (kVp of equipment and speed film) showed that experienced practitioners still have a gap in their knowledge. No correlation was observed between demographic factor, gender, and the level of knowledge and awareness in the field under discussion. To determine whether the International Commission on Radiological Protection (ICRP) guidelines were followed, a simple table was constructed to present the percentages of awareness of dental practitioners of most critical involved guidelines of ICRP. Records from reviewed literature clearly showed that most dental professionals are not aware of the principle and a fair percentage of respondents did not know what the ICRP recommendation were.

Overall, the undergraduate dental students are the next generation dentists. This means that investing in more resources to improve their collective knowledge and awareness of the currently available radioactivity risk management tools within dental practices, and to correct and streamline their perceptions in the associated field will lead to a safer world, where radiation risks might come to nearly an end. Therefore, indeed the undergraduate education level should be improved, radiation protection courses should be added to the dentistry curriculum and continuous educational programs should be established to further develop skills and awareness experienced dentists regarding radiation protection.
References


Biographies

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**Walid A. Metwally** obtained his Ph.D. degree in Nuclear Engineering at North Carolina State University (NCSU) in 2003. While at NCSU he obtained a Master of Science degree in Operations Research in 2002. He remained at NC State University for one year as a Research Associate (Postdoctoral) before accepting a teaching position in 2004 in the Physics Department at the United Arab Emirates University. He stayed there for two and a half years before moving back to the United States to work as a Senior Engineer in the Nuclear Methods Group at General Electric (GE) - Global Nuclear Fuel (GNF) in Wilmington, NC. During that time, he obtained his Masters of Business Administration from the University of North Carolina - Wilmington. Following this he took the position of the Technical Leader of the Advanced Nuclear Methods group in GNF. Since 2012, Dr. Metwally has established and served as the chair of the Nuclear Engineering Department in the University of Sharjah, UAE. His expertise is concentrated in the fields of radiation transport, radiation measurement applications, automation tools, and nuclear spent fuel storage.