ISRRT Chesney Research Grant – 2016 Project:
An investigation into the effectiveness of thyroid shielding as a dose optimisation tool when carrying out radiographic imaging prior to, or during, orthodontic treatment of children

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The following is a general summary of the research study that was funded by the ISRRT Chesney Research Fund following a call for research proposals on the theme ‘A novel approach on optimization and/or justification of medical exposures by radiographers for radiation protection and safety.’ Complete data will not be presented here but will be published in due course in a peer reviewed academic journal.

Approximately one fifth of all X-ray examinations are performed by dentists and a high proportion of those images are carried out on children and young people. Dental radiology predominantly involves low dose techniques;\(^1,2\) however, some radiosensitive organs and tissues are in close proximity to the radiation beam and/or scatter, including the thyroid gland.\(^3\) Globally, guidelines on the use of lead collars to protect the thyroid differ widely and the evidence-base is limited. For example, US guidelines specify that thyroid shielding must always be used for dental radiography,\(^4,5\) while UK guidelines only suggest that it is used if the thyroid gland is in line of the primary beam.\(^6\) The development of Cone Beam CT (CBCT) for dental examinations, which has radiation doses typically an order of magnitude greater than those of conventional radiography and sometimes higher, has raised the potential importance of shielding. It has also highlighted the impact that high atomic number materials used in thyroid shields can have on image quality.\(^7\)

Limiting X-ray beam size to the smallest required is an obvious means of dose limitation. Rectangular collimation of the X-ray beam for intraoral radiography has been recommended for at least two decades and is now available from manufacturers as a standard equipment specification. A recent UK survey found that 67% of intraoral X-ray sets had rectangular collimation.\(^8\) It is possible that a reduced beam size might itself lower thyroid dose by excluding it from the primary beam and reducing scatter. If so, thyroid shielding might have less impact on dose or none at all.

This research project was therefore designed to provide evidence as to whether putting lead shielding on young patients to protect the thyroid significantly reduces the radiation dose to the thyroid during a variety of dental radiographic examinations. It also aimed to identify if wearing a thyroid collar had an impact on the image quality, and therefore the diagnostic value of extraoral images taken, especially in the case of CBCT. A final objective was to identify if rectangular collimation can reduce thyroid dose when taking intraoral dental radiographs.
To be able to ascertain whether thyroid shielding and/or rectangular collimation are an effective way to reduce the dose to the thyroid received by children and young adults when they are undergoing dental radiographic imaging, the research team set up a series of dosimetry scenarios in a manner similar to the method previously used by Hidalgo et al.⁹ An anthropomorphic phantom (Figure 1b) filled with thermoluminescent dosemeters (TLDs) at the level of the thyroid (Figure 1c), was positioned and exposed to radiation as if it were a patient undergoing the examination (including scout projections for CBCT).
Figure 1: Images of Cone Beam Computed Tomography study investigations being undertaken

a. The 3D Accuitomo CBCT equipment made by the J. Morita Company, Japan; installed at the University Dental Hospital of Manchester.

b. The ATOM® 706-C anthropomorphic phantom (Computerized Imaging Reference Systems Inc., Norfolk, VA) representing a 10-year-old child positioned in the CBCT scanner

c. One of the slices of the ATOM® 706-C with 4 TLDs loaded in (circled in red)

d. The small adult female skull from a historic collection held in the Division of Dentistry at the University of Manchester in a head-shaped water bath to simulate soft tissues being imaged in the 3D Accuitomo F170 CBCT scanner (J. Morita, Kyoto, Japan)

e. A screen shots of a lower third molar image bank scan in the Image J software (version 1.52g, National Institutes of Health, Bethesda, MD) with contrast-to-noise measurements being taken.
The scenarios and types of thyroid shielding tested can be seen in Table 1. Two basic designs of thyroid shield were used:

- Rothband™ 0.25mm Pb (Rothband & Co. Ltd, Rossendale, UK.) – a flexible collar design fixed using Velcro at the back of the neck
- Protectoray 0.5 mm lead lined thyroid shield (Hager & Werken, Duisburg, Germany) – a rigid flat design normally held in place by the patient in clinical use

Many alternative thyroid shields are available, with designs varying in size and shape, but these two were chosen to represent those most typically used by dentists. The rigid design of the Protectoray shield results in it being impractical for CBCT and Panoramic radiography examinations as it impedes correct patient positioning and in some cases the rotation of the machine. The Protectoray shield was therefore only used for the intraoral scenarios being considered.

<table>
<thead>
<tr>
<th>Examination</th>
<th>Types of thyroid collar</th>
<th>With and without rectangular collimation</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Rothband™ 0.25mm Pb (Rothband &amp; Co. Ltd, Rossendale, UK.)</td>
<td></td>
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<tr>
<td></td>
<td>Protectoray 0.5 mm lead lined thyroid shield (Hager &amp; Werken, Duisburg, Germany)</td>
<td></td>
</tr>
<tr>
<td>Intraoral anterior periapical</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Intraoral upper maxillary occlusal</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Panoramic radiograph</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Small FoV* CBCT scan of the anterior mandible</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Small FoV* CBCT scan of the posterior mandible (impacted wisdom teeth)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Small FoV* CBCT scan of the anterior maxilla</td>
<td>✓</td>
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*FoV stands for field of view

The results of this first section of the study demonstrated that rectangular collimation can statistically reduce the radiation dose to the thyroid for periapical radiography (Figures 2b, 2c & 2d); but that a shielding device such as the Protectoray (Figures 2a & 2c) is required to reduce radiation dose to the thyroid significantly for the anterior maxillary occlusal projection. The results also suggested that a thyroid collar reduces the radiation dose received by the thyroid in patients undergoing dental CBCT examinations in many cases. However, the results demonstrated that the use of lead shielding does not reduce the dose to the thyroid when a panoramic radiograph is being taken (Figure 2e).
Figure 2: Images of two dimensional imaging study investigations being undertaken

The ATOM® 706-C anthropomorphic phantom (Computerized Imaging Reference Systems Inc., Norfolk, VA) representing a 10-year-old child positioned for two-dimensional dosimetry studies

- a. Occlusal imaging using the Planmeca Intra (Planmeca Oy, Helsinki, Finland) with the Protectoray 0.5 mm lead lined thyroid shield (Hager & Werken, Duisburg, Germany) & no rectangular collimation

b to d show periapical imaging using the Planmeca Intra (Planmeca Oy, Helsinki, Finland) and a holder for paralleling technique with:

- b. No thyroid collar or rectangular collimation
- c. A Protectoray 0.5 mm lead lined thyroid shield (Hager & Werken, Duisburg, Germany) & rectangular collimation
- d. A Rothband™ 0.25mm Pb (Rothband & Co. Ltd, Rossendale, UK.) thyroid collar & rectangular collimation

- e. Panoramic radiographic examination set up with a Rothband™ 0.25mm Pb (Rothband & Co. Ltd, Rossendale, UK.) thyroid collar in the Planmeca Promax (Planmeca Oy, Helsinki, Finland)

All X-ray equipment used are in the clinical department at the University Dental Hospital of Manchester.
The second phase of the study investigated the impact that wearing a thyroid collar has on image quality when undertaking small field of view CBCT examinations. To do this a bank of images was created of the two small field of view mandible scenarios, using a small adult female skull from a historical collection held in the School of Dentistry of the University of Manchester positioned in a head-shaped water bath to simulate soft tissues following the method of Shelley et al.\textsuperscript{10} (Figures 1d & 1e). 50% of the scans were taken with the thyroid collar in-situ and 50% without. Five specialist dental and maxillofacial consultant radiologists, who were blinded to thyroid collar use, then gave their opinions on the image quality of each scan via a questionnaire. In addition, the image quality of each of the CBCT scans was measured quantitatively using contrast-to-noise ratio on multiple scan slices. The results of both the subjective and quantitative image quality studies carried out in this phase of the study demonstrated that CBCT image quality was not reduced, either quantitatively or subjectively, by thyroid shielding.

The results of the study are helpful in expanding the evidence base in this area of radiation protection in dental radiography. The key points for practitioners to consider include:

- Rectangular collimation is the most effective way of reducing radiation dose to the thyroid when performing intraoral periapical imaging, but the Rothband\textsuperscript{TM} 0.25mm Pb thyroid collar also resulted in a significant dose reduction to the thyroid if rectangular collimation is not available.
- When maxillary occlusal projections are undertaken, radiation dose to the thyroid can be reduced by the use of a Protectoray thyroid shield. However, the Rothband\textsuperscript{TM} 0.25mm Pb thyroid collar does not reduce the thyroid dose.
- The use of a Rothband\textsuperscript{TM} 0.25mm Pb thyroid collar can reduce the dose to the thyroid of young patients undergoing CBCT imaging without reducing the diagnostic quality of the resultant images.

However, it also needs to be noted that there was a difference in effectiveness of the two thyroid shielding designs, so a general recommendation to use thyroid shields may be too simplistic. The two thyroid shield designs in this study are not the only ones available, so caution is needed before extrapolating the results of this study to other designs.
References