Orthodontists and the thyroid gland

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This paper questions the adequacy of orthodontists' full appreciation of the issues associated with the routine prescription of extra-oral radiography, particularly that related to a high risk of thyroid gland exposure to ionising radiation. There does not appear to be adequate application of the ALARA principle in the consideration of justifiable options to minimise the cumulative effects of radiation exposure in young patients.


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Introduction
Parents concerned about their children's present and future health will often confront members of the dental profession with questions about the dangers of, and need for, special dental radiography. The answers to these questions may be sought initially by computer searches for information, which are not totally reliable. It is imperative that orthodontists are prepared to respond with authority and accuracy to questions from parents and patients. However, there can be 'devil in the detail' of knowledge and experience when attempting to justify the application of the general principle of ALARA (‘As low as reasonably achievable’) in taking simultaneous account of the risks and benefits of radiography.

There are numerous sources that cover a range of authoritative information concerning health risks of, and protection from, ionising radiation,1-7 and all include references to health risks associated with dental radiography. Some additional 'detail' relating to radiation protection needs to be considered by clinicians in arriving at ALARA decisions.

Because so much attention is paid to the risk of harm to the thyroid from cephalometric radiography, this will be the main focus of this commentary. (In the professional literature, the thyroid gland is frequently referred to simply as, 'the thyroid'.)

Orthodontic history
Franklin (1953)8 associated cephalometric radiography with ‘radiation hazards to both patients and operators’. The nature of the adverse effects was not specified apart from ‘cumulative lethal effects’, but the focus was on the technical aspects of radiation minimisation and protection. No reference was made to the thyroid gland but awareness was likely because of publications by pathologists Duffy and Fitzgerald (1950).9 Reports of thyroid cancer in children and adolescents were traced back to the 1920s, whereupon it was noted, with qualification, that ‘the potential carcinogenic effects (while rare) of irradiation become increasingly apparent, and could be related to thymic irradiation in early life.’

Block, Geopp and Mason (1977)10 appeared to be the first in orthodontic circles to specifically focus on the problem of thyroid exposure during cephalometric radiography. The thyroid was located between the cervical vertebrae levels at C4 to C7 and thyroid protection was introduced by means of a lead collar or shield.

O'Reilly and Yanniello (1988)11 cited Lamparski's (1972) longitudinal retrospective growth study of previously collected lateral cephalometric radiographs (LCRs) which assessed skeletal age utilising cervical vertebral bodies. Both were morphometric studies of the cervical vertebrae from C2 to C6. It can only be
conjectured whether Lamparski’s earlier work triggered the introduction of the thyroid protective collar by Block et al.

Hassel and Farman (1995) continued Lamparski’s work. The available LCRs and hand-wrist radiographs (HWRs) of subjects were used from the Bolton-Brush Growth Study of Case Western Reserve University (1920–1950). Although not citing the earlier publication of Block et al., the study focused on C2, C3 and C4, noting that these vertebrae ‘could be visualised even when a thyroid protective collar was worn during radiation exposure’ (emphasis added). This assumption was not tested since the study was not repeated prospectively with live subjects.

The work of Hassel and Farman was subsequently developed in a series of papers by Franchi, Baccetti and McNamara who, in their initial paper (2000) compared mandibular growth with growth of cervical vertebrae C2 to C6. This generated an ‘improved version of the Cervical Vertebral Maturation (CVM) method’ (2002, 2005).14,15 A morphometric examination of the vertebral bodies C2, C3, and C4 was applied and, following the caution of Hassel and Farman, it was noted that these vertebrae ‘can be visualised when a protective collar is worn by the patient’ (again, emphasis added). This CVM method for assessing and predicting craniofacial growth from childhood to post-adolescence has since been widely adopted by orthodontists for treatment planning, partly because it provided ‘two for the price of one’: the use of a lateral cephalometric radiograph (LCR), a routine diagnostic tool for most orthodontists that includes an image of the cervical spine, and obviating need for an additional hand-wrist radiograph (HWR) traditionally used in growth studies. Thus the justifications for using CVM were reduced patient radiation and financial cost, provided that a thyroid protective collar (TPC) was used.

Patcas et al. (2013) advocated cessation of the use of the CVM method and implied that it was impractical to position the thyroid protection collar to effectively mask the thyroid and cervical vertebrae below C4 from radiation exposure, particularly of children initially having a higher position of the thyroid gland. Evidence was provided that the benefit of reverting to the HWR method of skeletal growth status while using a TPC far outweighed the radiation risks associated with the CVM method while attempting to use a TPC.

This critique of the CVM method must also include comment on orthodontic publications that refer to the use of the CVM method and include radiographic images. These invariably show no evidence of thyroid collar use. The images are always cropped but show at least part, if not all, of the vertebral body of C5, even some extending to C6. This is contrary to the stated intention of those who promote the CVM method.

**Thyroid gland location and use of a thyroid protective collar**

The key question is, ‘Where is the thyroid located in relation to the cervical spine vertebrae, C1 to C7?’ Descriptive anatomy commonly reports that the thyroid gland is located between C5 and C7.17-19 Block et al.10 noted the thyroid reaching the level of C4–C5. The position of the isthmus of the thyroid may be found by palpation18 provided there is no excess of fat in the neck. An additional report has located the gland usually at C4–C5.20 It is not clear whether this reference is to the usually present central mass of the isthmus of the thyroid or to its lateral pyramidal lobes, which reach higher in the neck and are not easily palpable.

The changing position of the thyroid through childhood to adulthood needs to be taken into account when prescribing cephalometric radiography. Kim et al.21 reported the imaging of a group of adult subjects in a comparison of high resolution ultrasound (US) with computed tomography (CT). It was found with CT that the superior tips of the pyramidal lobes of the thyroid may occasionally reach the level of the hyoid bone and thyro-hyoid membrane at C3–C4. The US generally matched the CT findings.

More important is a consideration of the developing thyroid. Ozguner and Sulak22 dissected foetuses of gestational age from the 33rd week to 10 months. It was reported that: ‘The levels of the superior poles of the thyroid lobes were located at the cervical (C) C1–C3 vertebral bodies. The levels of the inferior poles of the thyroid lobes were located at C4–C5 vertebral bodies . . . [and] . . . the distance between the superior poles of the thyroid gland and the hyoid bone increased throughout the foetal period.’ Vertical physical growth from the foetal stage through childhood to adolescence and adulthood leads to progressive lowering of the thyroid gland. This means that parts of the gland will be at least in the vertical
range of C3–C4 for an extended period, as noted by Patcas et al.\textsuperscript{16}

It may be concluded that there is no reliable clinical method of determining the location of the thyroid gland with respect to specific vertebrae. Therefore, to protect the thyroid from radiation, the only position to set the TPC around a patient’s neck is as high as possible.

**Thyroid pathology**

Epidemiological data from the Australian Institute of Health and Welfare for the period 1982–2012\textsuperscript{23} demonstrated a steady rise in thyroid cancer morbidity in Australia. Estimated annual incidence of thyroid cancer per 100,000 for males was less that 1 up to age 10–14 years and then with a fairly steady increase up to approximately 12 by ages 70 to 80 years. Incidence of females with thyroid cancer was similarly low, also starting to rise at 10–14 years, but more significantly than males. Thus, by 50 to 54 years of age the incidence was approximately 25 per 100,000, but dropping to male levels at later ages.

Thyroid pathology covers a large spectrum of disorders,\textsuperscript{26} some with possible change from early benign states to later malignancies. While X-rays have been conjectured to be the most likely primary causal factor in the development of thyroid cancer, only one record has been found directly linking the risk of thyroid cancers to dental radiography, ‘particularly from multiple exposures’.\textsuperscript{27} The evidence is circumstantial and dependent on available records of an individual’s cumulative radiation exposures. Repeat studies are still required but the necessary epidemiological data of effective doses (ED), a standard measure of an episode of exposure of body tissues to ionising radiation of individual probands in a population, is generally lacking. The uncertainty concerning radiation-induced morbidities is that population data of cumulative radiation doses for modern populations are necessarily retrospectively derived. There are difficulties related to the lack of precise information regarding sources of radiation, with underestimations, inadequate recording of exposures, and under-reporting.\textsuperscript{1,6,28,29}

**ALARA**

ALARA is the acronym for ‘As low as reasonably achievable’, where radiography may be deemed to be essential for an adequate diagnosis, and might be used as justification for dispensing with the use of a thyroid protective collar. Not using such protection should be an exceedingly rare situation, whether for 2D or 3D imaging. Orthodontists make highly questionable use of the LCR besides diagnosing malocclusion. These include assessing pharyngeal airway changes with growth,\textsuperscript{16,30} which should be the primary responsibility of medical specialists; assessing the location of ectopic maxillary canines that can mostly be managed by combining clinical examination and 2D, even single image, intra-oral radiography;\textsuperscript{30,31} and justifying cephalometric imaging, particularly 3D imaging, for the possibility of finding craniofacial pathology, which is not an orthodontist’s primary function.\textsuperscript{33}

(There may be legal issues\textsuperscript{34} in justifying the expanded diagnostics of 3D cephalometric imaging with higher effective doses (EDs) of radiation compared with lower EDs using 2D imaging\textsuperscript{35} even when the use of a TPC is applied and appropriate for both imaging methods.)

The American Academy of Oral and Maxillofacial Radiology\textsuperscript{36} offered recommendations to orthodontists regarding the application of ALARA in differentiating categories of patients for the appropriate use of cone beam computed tomography (CBCT). Surprisingly, the recommended use of torso and thyroid protection carried the caveat ‘when possible’, while also noting the use of a restricted field of view (FOV) available on some CBCT devices for ‘maxillary only scan’.

Questions are being raised about orthodontists’ frequent lack of use of LCRs for most of their clinical diagnosis and treatment planning, whether because of their experience or lack of concern about any litigious consequence of not maintaining the traditional set of patient records.\textsuperscript{37-42} It is unknown whether there is also concern about costs and risks versus benefits to the patient.

**Thyroid protective collar (TPC)**

A ‘Collar’ may be the preferred descriptor to the occasionally-used cervical ‘shield’ since it at least implies a high position around the neck as is prescribed. Despite Block et al.\textsuperscript{10} advocating the use of a radiopaque TPC, both reported that clinical and LCR illustrations did not provide confirmation that the TPC had been correctly applied around the patient’s neck. Hujoel et al. (2006)\textsuperscript{43} showed reproductions of
cephalometric radiographic images with the presence of lead shielding but with doubtful presence, or actual absence, of thyroid protection.

Importantly, it must be added that all published orthodontic case reports and research that include LCR images show no sign, and rarely state the use, of a TPC, or the images are cropped, which removes evidence of whether a TPC had been used. One published exception was the report of Choudhary et al.,44 which specifically illustrated the correct use of a TPC.

There is ample evidence from radiation monitoring with a special phantom head of the benefits of a correctly placed TPC in reducing the effective radiation dose (ED), which is the standard measure of ionising radiation absorbed in all tissues and organs from any source.45,46 Considering the changing thyroid location, a TPC should be placed as high as is comfortable around the neck, even adding a second collar posteriorly for maximal thyroid protection. This will not mask essential information that orthodontists may require from LCRs or CBCT. Collars used with antero-posterior cephalometric and panoramic imaging procedures will mask the anterior part of the mandible.47

Concluding comments

All human (and biological) tissues and organs can be adversely affected by ionising radiation.

Age and growth changes are associated with progressive lowering of the superior tips of the lateral thyroid lobes from neck positions above C4, where there is a real radiation risk.

Orthodontists typically use a large field of view (FOV) for lateral cephalometric radiography (and CBCT), and so expose the cervical spine of patients of all ages to ionising radiation. When using a large FOV, there are reported risks of harm to other organs such as the brain, salivary glands, and eyes.29,37

It is rare among most orthodontic publications to mention thyroid gland radiation, let alone the use of a thyroid protective collar.

Even if the risk of thyroid morbidity from diagnostic dental radiography is low, the uncertainty surrounds which of the two to four individuals in every 100,000 of population27 might have adverse cumulative effects that cannot be predicted. In the absence of certainty that parents desire, one must expect the voiced concern that, ‘It might be my child who will be affected.’

Radiographic devices are being continuously modified for delivering reduced effective doses of ionising radiation, but there will always be the risk. It must be noted that presently available devices, particularly CBCT, do not all deliver the same doses for routine use.45,48,49

Orthodontic academics have been noted to make more use of craniofacial radiography than private specialists.50 Since academics are equally concerned about radiation risks and ALARA, they must also be prepared to rationalise their use of radiography.

The advent of low dose digital radiography has encouraged dentists (and possibly orthodontists) to use more radiography.51

Orthodontists may encourage false confidence among parents by optimistically promoting the benefits of modern digital radiography: that it offers lower radiation doses than traditional film radiography. Digital radiography still utilises ionising radiation.

Informed consent is always required in order to proceed with diagnostic radiography.

There are reports of morbidity related to other organs following exposure to radiation from head and neck imaging as used in orthodontic practice.5,26,29,35

Practitioners should keep accurate records of all radiographic procedures, including the device settings used, whether the procedure is in-house or provided elsewhere. In the future, this would enable potentially more useful retrospective information about the extent of adverse radiation effects than is presently available.51

There is a need to avoid duplication of radiography for patients referred between clinicians as an additional radiation protection measure, now made possible through ready transfer of digital imaging.

Recently, Engel et al.52 showed that the CVM method failed to satisfactorily predict craniofacial growth through pre-adolescent to adolescent growth of a group of nine-year-old females from the Nijmegan Growth Study commenced in 1967. This study used LCRs and HWRs taken twice a year from age four to fourteen years. These authors recognised that ‘... if this region (C2 to C4) of the cervical spine is to be visualised, no thyroid shield can be worn during radiographic exposition.’ This in itself is sufficient
reason for not using the CVM method. More importantly, it confirmed that thyroid protection is required for all lateral cephalometric radiography.

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