RESEARCH

Utility of thyroid collars in cephalometric radiography

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Objective: A study was carried out to investigate the rationale that use of a thyroid collar (TC) in cephalometric radiography hampers the diagnostic and descriptive quality of lateral cephalogram.

Methods: A randomized observer blinded study was designed. The study consisted of two groups. The first group data were retrieved from the oral radiology archival system having lateral cephalogram without a TC. The second group was selected from the oral radiology department of patients where lateral cephalogram was taken using a TC. Lateral cephalogram was taken on direct digital system, the Kodak 9000 unit (Eastman Kodak, Rochester, NY). 2 observers blinded about the aim of the study were appointed to identify 15 sets of landmarks on the lateral cephalogram. Interobserver variance was also analysed for the study.

Results: 50 lateral cephalograms in each group were studied. Out of 15 sets of landmarks, 12 were identified consistent with the TC group. Three landmarks, namely the hyoid bone, second cervical vertebra and third cervical vertebra could not be identified on the TC group. There was no significant difference in the interobserver markings on lateral cephalogram.

Conclusions: TCs do mask a few landmarks on the lateral cephalogram. These landmarks are mainly used for analysis of skeletal maturity index (SMI). Lead TCs are probably the most convenient and easily available means to protect the thyroid from unwanted radiation while taking lateral cephalogram. It is therefore encouraged to use a TC during routine cephalometric radiography where SMI information is not needed.

Dentomaxillofacial Radiology (2011) **40**, 471–475. doi: 10.1259/dmfr/25040799

Keywords: radiation protection; cephalometric radiography; thyroid collar; orthodontics

Introduction

Lead collars are commonly found in the armamentarium of the oral radiology unit. A thyroid collar (TC) is possibly one of the cheapest and most convenient ways to protect the thyroid gland from radiation, yet TCs remain one of the most underused radiation protection tools. In most dental radiographic examinations, the thyroid gland usually falls in the area of radiation exposure. Exposure to the thyroid can have a deleterious effect on the patient. There is increased risk of thyroid cancer arising from the follicular epithelium after radiation exposure.¹ Females and children are more susceptible to thyroid cancers, but childhood is the time when most orthodontic treatment is sought. Cephalometric radiography is one of the common radiographic investigations needed before initiating orthodontic treatment. A thyroid collar was introduced in cephalometric radiography (CR) in 1977.²

Cephalometric radiography is commonly done in patients who are in their growth spurt phase and therefore it is vital to protect the thyroid gland during cephalometric exposures. Presently there are no universal guidelines on the use of TCs in CR. The American Dental Association strongly recommends TCs in dental radiography.³ The European guidelines on radiation protection in dental radiology states that wherever possible, lateral cephalograms should be collimated to limit the field to the area required for diagnosis.⁴ “The Radiation Protection Guidelines for the Practicing Orthodontists”, a report from the US National Council on Radiation Protection and Measurements, does not mention the use of TCs for cephalometric radiography.^{2,5} Given this ambiguity on the use of TCs, it is understandable that TCs, are not routinely used in cephalometric radiographs.

The relationship between dental radiation exposure during pregnancy and low birthweight infants, even when the fetus is not exposed, has been established in a case-control study by Hujoel et al.⁶ However, exposure

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Received 26 June 2010; revised 9 September 2010; accepted 30 September 2010

to which particular organ in the dental radiation field leads to low birthweight infants remains unanswered. Epidemiological^{7,8} and experimental animal studies⁹ indicate that exposure to the thyroid gland may be responsible for such an association. This association between dental radiation exposures and fetal growth retardation raised several concerns on the cause of such an association. One of the prominent causes discussed refers to the lack of documentation on the use of TCs and increased cephalometric exposures to a magnitude of one order.^{10–14} With this background of increased risk and non-uniform guidelines it becomes the moral responsibility of the oral radiologists to protect the thyroid during dental exposures in general and in CR in particular.

An attempt was made to collimate the beam and exclude the thyroid from the primary beam.¹⁵ However, limiting the beam to exclude the thyroid may fail to capture part of the mandible as the upper thyroid pole is located at the level of fourth cervical vertebra, lateral poles at the level of the fifth and sixth tracheal rings and the pyramidal lobe ascending to the hyoid bone.

A TC could overcome the drawbacks of beam collimators. There are no reasons, medical or ethical, to refuse a TC. The general apprehension by the orthodontists that the use of TCs would affect landmark identification, thus affecting its diagnostic quality, could be a reason for the sparse use of TCs in CR. It was therefore decided to carry out a study to check if the use of TCs affects cephalometric landmark identification.

A null hypothesis that the use of a TC affects cephalometric landmark identification and in turn affects its diagnostic quality was proposed.

Materials and methods

This study was planned as an observer blinded diagnostic study. Patients were divided into 2 groups of 50 each. One group consisted of patients for whom a CR was done with a TC (TC group) in the oral radiology unit. The other group consisted of CR without a TC (non-TC group) retrieved from the oral radiology archives. The study was approved by the local institutional review board. Informed consent was obtained from patients in the TC group. Exclusion criteria for the TC group included patients in whom the skeletal maturity index needed to be studied and patients of craniofacial syndromes with short necks.

CR was done on a Kodak 9000 (Eastman Kodak, Rochester, NY) direct digital cephalometric unit with 2.5 mm aluminium filter. The distance from the mid-sagittal plane of the patient to the X-ray source was fixed at 5 ft. The Frankfurt horizontal plane was parallel to the floor. Teeth were placed in occlusion and lips at relaxed or reposed position. The distance from the mid-sagittal plane to the film varied depending on the head size of the patient but an average distance was

15 cm. Exposure parameters were set at 72 Kvp and mAs ranged from 9 to 12.

All the images from both the TC and the non-TC group were transferred to a separate workstation in two separate folders labelled as observer 1 and observer 2. Two observers (FK and VK) were appointed to identify landmarks in all 100 images. All identification tags were removed from the images and a code number assigned. The observers were allowed to use the tools of digital imaging and communications in medicine (DICOM) to aid in landmarks identification. The observers were asked to put their initials in the header of the images after the identification was complete. A set of 15 landmarks mainly located in the head and the neck region were selected for identification (Figure 1). The observers were asked to mark the points as either detected or not detected. The observers were blinded to the aim of the study. All the data were then pooled into two separate folders labelled as TC group and non-TC group. The available data were decoded and analysed for landmarks commonly missing in the TC group and interobserver variance using Mann–Whitney test.

Figure 1 Lateral cephalogram showing the landmarks used for the study. (1) Most anterior point on lower lip; (2) deepest concavity of inferior labial sulcus; (3) most anterior point of soft-tissue chin; (4) lower incisor apex; (5) deepest midline concavity of anterior symphysis; (6) most anterior point of symphysis; (7) most inferior point of symphysis; (8) most posterior point of symphysis; (9) lower first molar distal root apex; (10) superior-anterior point of hyoid bone; (11) deepest impression of mandibular corpus in front of masseter insertion; (12) most anterior point of atlas bow; (13) most posterior-superior point of dens axis; (14) inferior-anterior point of body of CV2; (15) inferior-anterior point of body of CV3

Table 1 Total number of times cephalometric landmarks were found obliterated by observers 1 and 2

Variables	Landmark 10	Landmark 14	Landmark 15
Observer 1	33	45	46
Observer 2	36	48	48

Results

A total of 50 patients were selected in each group (TC and non-TC) and were analysed by blinded observers. Archived images were retrieved for the non-TC group. In the TC group, landmarks masked by the collar were hyoid bone, second cervical vertebra and third cervical vertebra. Out of 50 radiographs assessed by observer 1 and 2, hyoid bone was not visualized 35 and 36 times, second cervical vertebra 45 and 48 times and third cervical vertebra 46 and 48, respectively (Table 1). The average number of points seen in lateral cephalograph by observer 1 and 2 was 13.80 and 13.90 with standard deviations of 0.76 and 1.05, respectively (Table 2).

In the non-TC group all the landmarks were identified by both the observers.

Both the TC and non-TC groups were also subjected for interobserver variance by applying the Mann–Whitney test. The interobserver variance was found to be non-significant ($P > 0.05$), indicating that there was a consistent interobserver reproducibility of the landmarks.

Discussion

The objective of this study was to check if use of a TC during CR affects landmark identification, thereby affecting the diagnostic quality of the radiograph. This hypothesis was tested by taking two sets of cephalometric radiographs ($n = 50$), the TC and the non-TC group, and subjecting all of the 100 images for cephalometric landmark identification by two unbiased observers.

The results of this study revealed that three landmarks in the neck region were consistently undetected in the TC group by both the observers. The three landmarks are the hyoid bone, the second cervical vertebra and the third cervical vertebra. This confirmed our hypothesis that cephalometric landmark identification was affected when using a TC. In the non-TC group all the 15 landmarks could be detected by both the observers. Thus, the interobserver variance was not significant ($P > 0.05$). This confirms the reproducibility of findings by both the observers. In this study the interobserver reproducibility was used as it better reflects clinical routine as opposed to intraobserver reproducibility, which is mainly used for treatment research and growth studies.

Table 2 Average number of points seen by observer 1 and 2 in thyroid collar (TC) group

	Observer 1(FK)	Observer 2(VK)
Average	13.80	13.90
Standard deviation	0.76	1.05

It needs to be asked whether any of the landmarks masked are of clinical value and thus justify refusal of a TC. The cervical landmarks affected in the TC group are mainly used to study the skeletal maturity index (SMI). However, there have been attempts to promote the developmental stages of the middle phalanx of the third finger (MP3) on a periapical film as an indicator in assessing the SMI. In a study conducted by Madhu and others,¹⁶ it was concluded that cervical vertebrae and middle phalanx of the middle finger (MP3) could be used for maturity index with the same confidence. Rajagopal and Kansal¹⁷ compared the six stages of skeletal maturity observed on the MP3 as reported by Hagg and Taranger¹⁸ with the six maturation indicators of cervical vertebrae (MICV) proposed by Hassel and Farman¹⁹ on a radiographic film appropriate for the periapicals instead of a hand–wrist radiograph. The authors concluded that the modification of technique is accurate, simple, practical and economical, in addition to showing an intimate correlation with the MICVs. The MP3 radiograph on a periapical film also helps in protecting the thyroid. Thus, the diagnostic quality of CR with a TC will not be affected.

Although there have been human and animal studies denying a risk associated with dental exposures,^{20,21} epidemiological data suggest that dental exposures during pregnancy could lead to fetal growth retardation.⁶ Since women may not always be aware of their pregnancy status, there is a need to protect the thyroid of women of reproductive age.

Children and adolescents have increased susceptibility to radiation-induced damage. They also have a relatively longer life expectancy in which to express this risk. Children and adolescents are also the ones who commonly seek orthodontic intervention. Protecting the thyroid gland of these children and adolescents is therefore vital given its susceptibility to carcinoma post-radiation exposure. CR is the most widely used radiograph in orthodontic diagnosis and therapy as well as in the study of occlusion, skeletal growth and sagittal relationship of the jaws. CR is probably the only radiograph in oral and maxillofacial radiology where the thyroid lies directly in the field of irradiation.

Few studies have reported the absorbed dose to the thyroid for one lateral cephalogram. Gilda and Maillie²² reported an absorbed dose of 57 μ Gy, Tyndall²³ reported an absorbed dose of 31 μ Gy, Tyndall²⁴ et al again reported a dose of 9.1 mrd and Eliasson²⁵ reported a dose of 5 μ Gy to the thyroid in one lateral cephalogram. All these doses are the maximum absorbed dose to the thyroid. Block et al²⁶ in their phantom study concluded that there was a reduction of the absorbed dose by the thyroid varying from 50% to 80% after use of a TC in CR.

Sporadic attempts have been made to protect the thyroid by excluding it from the field of radiation. Gijbels et al¹⁶ used a collimator for CR on a head phantom. Alcaraz et al⁴ used a compensated filtration collimator (CFC) and excluded the thyroid from the

field of radiation. They concluded reduction in absorbed dose by the thyroid is only 61.4%, meaning that thyroid was not completely excluded. However, it could be hypothesized that extra-focal radiation could be the cause of absorbed dose. Extra-focal rays are back-scattered, secondary radiation, unfocused primary rays that land outside the focal spot or rays scattered by the window or other parts of the tube in such a way so as to appear extra-focused.²⁷ It could therefore be concluded that collimating the beam does not completely protect the thyroid.

Lead TCs were first introduced in 1977.² TCs are time tested, easy to use and readily available tools to protect the thyroid. A study done at the University of Washington revealed that a TC was used in only 19.2% of CRs taken between 1973 and 2003.²⁸ A recent report suggests that use of TCs in CR leads to increased landmark placement error but emphasized the use of TC as it is low cost and convenient to use. Three landmarks, the hyoid, the second cervical vertebra and the third cervical vertebra, showed greatest interference with overall reproducibility in the TC group in this study.²⁹

Our study suggests that of the various landmarks of CR, only three landmarks are not detected when TC was used. The three landmarks masked are mainly used for study of SMI. It could be proposed that a CR should be done with a TC in place to protect the thyroid, and when SMI needs to be analysed MP3 on a periapical film could serve the purpose.

Strengths of our study includes observers blinded to the purpose of the study ensuring unbiased perception

and conception of cephalometric landmarks, standardized image processing equipment and tools, facilitating anonymity of the data, standardized analytical processes and consistent image quality over wide exposures.

Weaknesses of our study include an incomplete landmark set used in the study, but it would have been inappropriate to use landmarks in the upper half of the face in a bid to study the influence of TCs in landmark identification. Interobserver variance used in this study is less accurate than intraobserver variance; however, ours was a clinical study as opposed to a growth study. Also, extra focal rays emanating from the subject may still reach the thyroid in spite of the use of TCs; however, the idea was to reduce the thyroid exposure to a minimum.

Conclusion

Beam collimators do not ensure complete protection and also involve a major change in cephalometric unit architecture. Lead thyroid shielding is currently the most efficient way to reduce radiation to the thyroid gland. It could therefore be concluded that the use of thyroid collars should be encouraged in CR in patients where information on SMI is not needed. TCs are easily available, easy to use and are a low cost device to protect the thyroid from ionizing radiation, with the underlying principle being to keep exposure to ionizing radiation "as low as reasonably achievable".

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