TECHNICAL REPORT

Validation of anatomically shaped cranial collimation (ACC) in orthodontic lateral cephalography

R C Hooegeveen, P J Guicherit, S R Gopie, P F van der Stelt and W E R Berkhouit

Department of Oral and Maxillofacial Radiology, Academic Center for Dentistry Amsterdam, Amsterdam, Netherlands

The use of an anatomically shaped cranial collimator (ACC) to reduce patient dose in orthodontic lateral cephalography was investigated in this study. The aim was to evaluate the potential interference of the ACC on landmark identification for orthodontic cephalometry. Consecutive orthodontic patients underwent a total of 100 cephalograms using an ACC mounted on a Veraviewepocs[®] 3D X550 (J. Morita Co., Kyoto, Japan) X-ray unit. 10 observers were asked whether the identification of 5 landmarks close to the collimated area was hindered or rendered impossible by the presence of the collimator. Of the 500 landmarks that were judged by the 10 observers, 496 (99.2%) were reported to lack hindrance. In three landmarks, a minority of the observers reported hindrance. In 1 landmark, 8 of the 10 observers reported hindrance by the collimator. In no instance did the observers state that the identification of landmarks was impossible as a result of the collimation. Application of the ACC on the cephalostat of the X-ray unit is a viable way of reducing patient dose, as it only marginally interferes with the diagnostic yield of the exposure. The need to retake images when the ACC is applied was found to be extremely low.

Dentomaxillofacial Radiology (2014) **43**, 20130396. doi: 10.1259/dmfr.20130396

Cite this article as: Hooegeveen RC, Guicherit PJ, Gopie SR, van der Stelt PF, Berkhouit WER. Validation of anatomically shaped cranial collimation (ACC) in orthodontic lateral cephalography. *Dentomaxillofac Radiol* 2014; **43**: 20130396.

Keywords: radiation protection; cephalometry; orthodontics; dental records

Introduction

Cephalograms are commonly used for orthodontic diagnosis and treatment planning. Orthodontists perform cephalometric analyses on these images by identifying landmarks and structures and measuring distances and angles. In commonly used cephalometric protocols, the landmarks and structures identified are limited to an area anteroinferior to the skull base. On these cephalograms, an area without diagnostic information is defined to be posterosuperior to the skull base. Owing to the potential detrimental effects of ionizing radiation, clinicians are obliged to shield areas of no interest when “reasonably achievable” as defined by the as low as reasonably achievable (ALARA) principle stated in international guidelines.^{1,2} The literature contains descriptions of a number of collimators that have been

developed to comply with these guidelines.^{3–7} Unfortunately, these collimators have not achieved wide acceptance in the orthodontic field.⁸ This could be because the proposed collimators were designed for dedicated cephalometric X-ray installations but not for the currently used combined panoramic–cephalometric machines. Another reason could be that the collimators that were proposed shield the aforementioned cranial area together with the area of the thyroid gland below the mandible. Clinicians might be rejecting these collimators because of the significant likelihood of a loss of diagnostic information when the mandible is partly obstructed by overcollimation as a result of the anatomical variability of the mandible.

To overcome these problems and search for broad clinical acceptance an anatomically shaped cranial collimator (ACC) was designed and presented in a technical report by the authors of this article.⁹ This design was

Correspondence to: Mr Reinier C. Hooegeveen. E-mail: r.hooegeveen@acta.nl
Received 25 October 2013; revised 1 January 2014; accepted 8 January 2014

based on the average anatomy of a group of Dutch orthodontic patients and the geometry of a panoramic–cephalometric X-ray unit. It was designed to be mounted on the ear rod of the cephalostat. The ACC reduces the irradiated area of the patient by 31.2% [standard deviation (SD), 1.94%; range, 27.2–35.5%].⁹ Similar to the use of rectangular collimation in intraoral radiography, the reduction of patient dose comes with a disadvantage. In the case of rectangular collimation, this disadvantage is the occurrence of cone cutting, which is acceptable because it is outweighed by the benefits of the reduction of field size. With the use of the ACC, the disadvantage could be the interference with landmark identification owing to the collimation of relevant structures. To assess the overall performance of ACC, it is necessary to determine the

frequency of this interference. The thyroid area is not shielded with this device; however, clinicians can use alternative measures to shield this area.

The aim of this study was to evaluate the extent of interference by the use of the ACC on the diagnostic process of landmark identification on cephalograms made for orthodontic purposes.

Methods and materials

To investigate the possibility of obstruction of diagnostically relevant anatomical landmarks by the ACC, five structures in the vicinity of the border of the ACC were chosen. These landmarks were the basion, porion, sella, nasion and the soft-tissue contour of the

Figure 1 Cephalogram made with the use of the anatomically shaped cranial collimator (A) and thyroid shielding with a thyroid collar (B). Cephalometric landmarks involved in this study: basion (1), porion (2), sella (3) and nasion (4).

forehead (Figure 1). From their position on the cephalogram and the form of the ACC, it can be deduced that, if identification of these structures is not hindered, no other relevant anatomical structures will be obscured by the presence of the ACC. Of these five structures, it can be assumed that they are always visible on cephalograms made without the ACC. This led to a research design where observers were shown cephalograms made with the ACC to assess the interference in landmark identification of the five structures. It was assumed that, when an observer stated that identification of the landmark was unhindered, the cephalometric measurements based on the use of this structure would have the same accuracy as if the cephalogram was taken without the ACC present. An alternative study design in which two cephalograms of the same patient, one with and one without the ACC, could be compared by cephalometric analysis was considered. It was rejected because of the additional X-ray dose to the patient and the anticipated small effect of the collimation on the cephalometric values, thus requiring a large number of double cephalograms to obtain adequate power to draw statistically significant conclusions.

A total of 100 consecutive cephalograms that were recorded with the use of the ACC and conducted in the context of orthodontic treatment planning were retrieved from the records held at the office of the first author. If a cephalogram had to be retaken during this series, the first image was included in this survey, and the second image was excluded. The characteristics of the patients involved are presented in Table 1. All patients provided written consent for the use of their records for research purposes. The exposures were made with a Veraviewepocs® 3D X550 (J. Morita Co., Kyoto, Japan) equipped with a charge-coupled device sensor, following the manufacturer's settings, operated at 90 kV and a tube current with a programmed shift (maximum of 10 mA "density compensation" setting) and a 4.9 s/exposure.

10 observers viewed the cephalograms, which were displayed on a high-resolution, 30-inch screen monitor (UltraSharp U3011 R; Dell Inc., Round Rock, TX). The observers comprised eight orthodontic residents, one orthodontist and one maxillofacial radiologist. The observers were not allowed to adjust the contrast or brightness of the images or to use zoom. They were asked to judge if the identification of five anatomical structures was unaffected, hindered or made impossible as a result of the use of the ACC. These structures were the basion, porion, sella, nasion and the soft-tissue contour of the forehead. If the observers reported hindrance of the

identification of any of these structures on a cephalogram, they were asked to state if they thought that a retake of this cephalogram would be necessary in clinical orthodontic practice.

Statistics

As this is an observational study that did not compare different modalities, the statistics were predominantly limited to descriptive statistics. The percentage of images without hindrance reported by all of the observers was calculated, as was the percentage of the 500 structures (5 structures on 100 cephalograms) unanimously judged to be without hindrance. Also, the percentage of structures that were judged to be impossible to identify by one or more of the observers was calculated, the same requirements were used for the percentage of images that were considered to require a retake by one or more of the observers.

To assess observer agreement, the percentage of unanimous rulings of the 500 independent structures was calculated. All calculations were performed using Microsoft® Office Excel™ 2003 (Microsoft, Redmond, WA).

Results

The results of the observations are shown in Figure 2. In 97 of the 100 images (97%), no hindrance was reported in identifying the 5 structures by any observer. Of the 500 structures that were judged, 496 structures (99.2%) were unanimously judged as unhindered by the ACC. In no instance (0%) did an observer rate a structure to be impossible to identify. Of the 5000 total judgements made, 14 noted hindrance. Sella was reported hindered by 8 of the 10 observers on 1 image and by 3 of the 10 on another. Nasion and porion were never rated as hindered, basion was reported hindered once by 1 of the 10 observers; and the soft-tissue contour of the forehead was reported hindered by 2 of the 10 observers on 1 image. In two instances, 1 of the 10 observers (different observers on different images) stated that they thought a retake of the image was necessary. The agreement of the observers was high as they decided unanimously in 99.2% of the judgements made.

Discussion

A total of 100 cephalograms were assessed by 10 observers. For only three images, hindrance by the presence of the ACC was reported. Only in 1 case, a majority (8 of 10 observers) agreed on hindrance in identifying the landmark sella; for the other instances, a minority reported hindrance. In no case did the observers make the judgement that identification of a structure was impossible. In general, it can be stated that hindrance was extremely limited and did not significantly reduce diagnostic yield.

Table 1 Characteristics of patients who underwent cephalograms

Gender	Frequency	Age (mean)	(SD)
Male	44	12.1	3.5
Female	56	12.4	4.9
Total	100	12.3	4.4

SD, standard deviation.

95% of the patients were white.

Figure 2 Schematic representation of the results of the observations. ACC, the anatomically shaped cranial collimator; Hindr, identification of landmark/structure is hindered by the presence of the ACC; Imposs, identification of landmark/structure is impossible owing to the presence of the ACC; LM, landmark or structure; NoHindr, identification of landmark/structure is unhindered by the presence of the ACC; ST, forehead, soft-tissue contour of the forehead.

Only twice did 1 of the 10 observers indicate that a retake of an image was necessary. The fact that the observers did not concurrently rate any landmark impossible to identify appears contradictory. Apparently, these two observers thought that the hindrance on that single image could result in inadequate cephalometric diagnostics. Overall, only 2 of the 1000 judgements on retakes noted that a retake was required; thus, the retake frequency was negligible.

One observer noted that a retake was indicated because a landmark that was not required to be assessed in this study (sphenoethmoidal intersection) was not identifiable. This landmark is not part of commonly used orthodontic cephalometry; therefore, it was not included in this study. If the landmark sphenoethmoidal intersection, or other landmarks posterosuperior to the skull base, are to be identified on cephalograms, the outline of the ACC could be adapted to this use, or it could be considered that the ACC should not be used in this situation.

This study involved cephalograms of a Dutch orthodontic population, 95% of whom were white. Other

ethnic populations might have a different anatomy of the skull base. Therefore, the use of the ACC for populations of a different ethnic origin remains to be evaluated.

In this study, the cephalograms were made with the same cephalometric X-ray unit. In systems with a different geometry of the source–object and the source–image distance, the magnification factors of the projection of the ACC relative to the projection of the anatomy of the patient might be a few millimetres different. In the design of the ACC, the anatomical variability of the population was taken into account. This anatomical variability is of the order of five times greater than the differences found by a different geometry with different X-ray systems.⁹ Therefore, it is not expected that hindrance in landmark identification would be significantly different with a different X-ray system.

The reduction of the irradiated area of the patient with the ACC is accomplished with minimal negative consequences. One could argue that the fact that the ACC does not cause significant hindrance means that it has been constructed too small. A larger design might lead to increased obstruction of diagnostically relevant areas;

however, the balance between dose reduction and diagnostic yield might still be superior. Theoretically, this might be correct reasoning; however, in orthodontic practice, it might lead to interference of the diagnostic processes and discontinuation of the use the ACC. The ACC was designed to be readily integrated into the dental office without the need to disassemble or reposition it for individual patients; this feature should hopefully lead to higher acceptance. The fact that there is some diagnostic interference, but not enough to require retakes, is likely to signify that its dimensions are suitable for its intended purpose.

References

1. ICRP. 1990 recommendations of the International Commission on Radiological Protection. *Ann ICRP* 1991; **21**: 1–41.
2. European Commission. *Radiation protection 136. European guidelines on radiation protection in dental radiology: the safe use of radiographs in dental practice*. Luxembourg: Office for Official Publications of the European Communities; 2004. Cited 18 January 2014. Available from: http://ec.europa.eu/energy/nuclear/radioprotection/publication/doc/136_en.pdf.
3. Alcaraz M, García-Vera MC, Bravo LA, Martínez-Beneyto Y, Armero D, Morant JJ, et al. Collimator with filtration compensator: clinical adaptation to meet European Union recommendation 4F on radiological protection for dental radiography. *Dentomaxillofac Radiol* 2009; **38**: 413–20.
4. Gijbels F, Sanderink G, Wyatt J, Van Dam J, Nowak B, Jacobs R. Radiation doses of collimated vs non-collimated cephalometric exposures. *Dentomaxillofac Radiol* 2003; **32**: 128–33.
5. L'Abée EM, Tan HT. Improved radiation hygiene in lateral cephalometry and a method to obtain good reproduction of the soft tissue profile. *J Clin Orthod* 1982; **16**: 381–6.
6. Hirschman PN, Lovelock DJ, Gravely JF, Senior WB. The reduction of the dose to patients during lateral cephalometric radiography. Report of a joint working party of the British Society for the Study of Orthodontics and the British Society of Dental and Maxillofacial Radiology. *Br J Orthod* 1985; **12**: 176–8.
7. Mandall NA, O'Brien KD, Worthington HV. Radiation reduction using a modified collimated lateral skull radiograph during orthodontic treatment. *Clin Orthod Res* 1999; **2**: 179–85.
8. Hujoel P, Hollender L, Bollen AM, Young JD, Cunha-Cruz J, McGee M, et al. Thyroid shields and neck exposures in cephalometric radiography. *BMC Med Imaging* 2006; **6**: 6. doi: 10.1186/1471-2342-6-6
9. Hoogveen RC, van der Stelt PF, Berkhout WER. Anatomically-shaped cranial collimation (ACC) for lateral cephalometric radiography: a technical report. *Dentomaxillofac Radiol* 2013; **43**: 20130203. doi: 10.1259/dmfr.20130203