Int. J. Oral Maxillofac. Surg. 2014; 43: 445–453
http://dx.doi.org/10.1016/j.ijom.2013.08.007, available online at http://www.sciencedirect.com

International Journal of Oral & Maxillofacial Surgery

Clinical Paper
Orthognathic Surgery

Is there consistency in cephalometric landmark identification amongst oral and maxillofacial surgeons?

M. Miloro[1,2], A. M. Borba[3], O. Ribeiro-Junior[3], M. G. Naclério-Homem[3], M. Jungner[1,4]

[1]Department of Oral and Maxillofacial Surgery, University of Nebraska Medical Center, Omaha, NE, USA; [2]Department of Oral and Maxillofacial Surgery, University of Illinois, Chicago, IL, USA; [3]Department of Oral and Maxillofacial Surgery, University of Sao Paulo – USP, Sao Paulo, Brazil; [4]Department of Oral and Maxillofacial Surgery, Karolinska University Hospital, Stockholm, Sweden

M. Miloro, A. M. Borba, O. Ribeiro-Junior, M. G. Naclério-Homem, M. Jungner: Is there consistency in cephalometric landmark identification amongst oral and maxillofacial surgeons?. Int. J. Oral Maxillofac. Surg. 2014; 43: 445–453.

Abstract. There may be significant variation amongst oral and maxillofacial surgeons (OMFS) in the identification and placement of cephalometric landmarks for orthognathic surgery, and this could impact upon the surgical plan and final treatment outcome. In an effort to assess this variability, 10 lateral cephalometric radiographs were selected for evaluation by 16 OMFS with different levels of surgical knowledge and experience, and the position of 21 commonly used cephalometric landmarks were identified on radiographs displayed on a computer screen using a computer mouse on a pen tablet. The database consisted of real position measurements (x, y) to determine the consistency of landmark identification between surgeons and within individual surgeons. Inter-examiner analysis demonstrated that most landmark points had excellent reliability (intra-class correlation coefficient >0.90). Regardless of the level of surgeon experience, certain landmarks presented consistently poor reliability, and intra-examiner reliability analysis demonstrated that some locations had a higher average difference for both x and y axes. In particular, porion, condylion, and gonion showed poor agreement and reliability between examiners. The identification of most landmarks showed some inconsistencies within different parameters of evaluation. Such variability among surgeons may be addressed by the consistent use of high-quality images, and also by periodic surgeon education of the definition of the specific landmarks.

Key words: cephalometric; landmarks; maxillofacial; orthognathic.

Accepted for publication 14 August 2013
Available online 19 September 2013

For the oral and maxillofacial surgeon (OMFS), knowledge and analysis of cephalometric measurements are commonly used skills required for the evaluation and planning of orthognathic surgical procedures.[1–4] Unlike other surgical procedures, these types of surgery involve extensive presurgical treatment planning and laboratory preparation. The surgeon completes a detailed facial and dental evaluation including clinical and photographic analysis, and imaging studies including cephalometric analyses. Presurgical records also include dental impressions, inter-occlusal bite registration, face-bow transfer, and clinical facial measurements.

The analysis of cephalometric lateral skull radiographs is critically dependent

0901-5027/040445 + 09 $36.00/0

upon the accurate location of carefully defined anatomical as well as constructed landmarks (lines and angles). Errors in landmark identification, both systematic and random, are a significant potential source of error in the diagnosis and treatment phases of orthognathic surgical patient care.[2,3,5] It has been argued that the degree of error most likely depends upon individual surgeon misconceptions of landmark definition and misperception of landmark location, rather than on education and training or surgical experience.[6] The reproducibility of inter-observer cephalometric tracings has been studied and it has been determined that there are significant differences in the identification of certain anatomic landmarks.[7,8] Also, it has been established that tracing accuracy is a limiting factor in cephalometric analysis, and that the variation for each landmark is highly dependent upon the quality of the two-dimensional (2D) cephalographic image.

Some techniques are commonly used to identify and record landmarks in cephalometric studies, such as the use of overlay tracings on the lateral skull radiograph on a lightbox, followed by establishment and measurement of lines and angles on the tracing paper using a ruler, compass, and protractor. However, despite the value of this method, it has recently essentially been replaced with three-dimensional (3D) computer analysis in surgical training programmes and in some surgical practices, at least for bimaxillary and complex asymmetry osteotomy cases. This is commonly performed by identifying and marking anatomical and constructed points on a computer screen using computer software, with a scanned radiograph or digitized lateral skull radiograph obtained by direct digitization of the lateral skull film using a digitizer connected to a computer.[4] This computer method is still plagued by potential inaccuracies imposed via potential variability in landmark identification.

Several studies have examined the accuracy and reproducibility of landmark identification using these different methods of radiographic analysis. Direct digitization of radiographs is reported to be the most reproducible, and therefore, the most accurate method,[9] although the difference between methods is small and not statistically significant.[3,10,11] Studies of computerized methods for the identification of cephalometric landmarks by the use of edge-based algorithms that detect the edges of anatomical structures, have concluded that further development may be necessary.[12]

Whether the surgeon uses any of the three methods described above, the need for manual reading, detection, and marking of the specific anatomical landmarks is present, and this introduces a certain degree of human error and variability into the treatment planning process. Also, despite the current use of computerized tomography (CT) images and cone beam CT (CBCT) scans, the ability to accurately identify craniofacial landmarks is not improved over conventional lateral skull films.[13] It is interesting to note that studies regarding the reproducibility of cephalometric measurements among radiologists have also shown inconsistency in these evaluations.[14] These variations amongst OMFS in the placement and identification of cephalometric landmarks might be significant, and would therefore impact the presurgical planning and model surgery, as well as the final treatment outcome for the patient.

The overall objective of the present study was to determine whether there are certain landmarks that are more difficult to identify, and which factors (surgeon characteristics or image characteristics) influence the reproducibility and reliability of cephalometric measurements. In considering a sample of OMFS with different levels of education and clinical experience, the questions posed by this study included the following: What is the inter-examiner accuracy among the given landmarks within different lateral cephalograms? Does the quality of the lateral cephalogram affect the magnitude of discrepancies for landmark identification? What is the intra-examiner accuracy for all landmarks within a certain lateral cephalogram? Does the level of education of the surgeon influence landmark identification accuracy?

Methods

Ten consecutive lateral cephalometric radiographs (PM 2002 CC; Planmeca, Roselle, IL, USA) of patients who presented for an orthognathic surgical consultation were selected for evaluation. The patients ranged in age from 19 to 35 years (mean 22.4 years); five were male and five were female. For inclusion in the study, the radiographic film had to have been taken at a standard source-to-object and object-to-film distance, the image needed to be of sufficient quality to permit identification of the planned landmarks, and the radiographic system ruler needed to be clearly visible on the film in order to permit calibration of the images into the software program. This study was performed under the principles of the Declaration of Helsinki and received approval from the necessary institutional review board.

The cephalometric radiographs were digitized using digital photographs taken with a 5 megapixel digital camera (Sony DSC-T7; Sony Corporation, Tokyo, Japan) on a horizontal X-ray viewer. These images were then imported into the mapping software (GraphClick 2.9; Arizona Software, Zurich, Switzerland) using an Apple MacBook Core Duo 2.0 MHz computer with OS 10.4.2 version software (Apple Corp., USA) and 1.0 megabyte of internal random access memory (RAM). The images were calibrated using the calibration tool in relation to the system ruler on the radiographs, in order to ensure that the positions of the landmarks were correlated to the actual placement with up to 1/10 ml accuracy.

The study group consisted of 16 OMFS with varying levels of surgical experience, including eight postgraduate residents and eight faculty members of the medical centre, who were asked to evaluate 10 cephalometric radiographs and mark 21 cephalometric landmarks on the radiographs. At the time of the study, all OMFS were actively providing evaluation and management services for patients in need of orthognathic surgery in clinical practice. The surgeons were provided with instructions for marking the cephalometric landmarks (described in Table 1 and illustrated in Fig. 1) on a computer screen using a computer mouse on a pen tablet similar to other commercially available orthognathic planning software programs (Graphire 4, $6'' \times 8''$; Wacom Technology Corporation, WA, USA). The data consisted of real position measurements (x, y) that were exported to a software spreadsheet (Excel for Mac 2004; Microsoft Corp., USA) for statistical analysis.

Prior to commencement of the landmark identification on individual cephalograms, the subjective quality of the radiograph was assessed by the OMFS on a scale of one to three, as follows: 1, poor; 2, good; 3, excellent. The ratings for the quality of the radiographs were averaged for each film. If the average rating was >2, then the image was considered high (good) quality; if the average rating was <2, then the image was rated as low (poor) quality.

All 16 surgeons located 21 cephalometric landmark points on each image, and the coordinates (x, y) of each of the locations were recorded by the software program. Inter-examiner evaluation was assessed with regards to the degree of