Patient movement and motion artefacts in cone beam computed tomography of the dentomaxillofacial region: a systematic literature review

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Objectives. To undertake a systematic review on the current knowledge regarding patient movement detection and patient motion artefacts related to cone beam computed tomography (CBCT) imaging of the dentomaxillofacial region.
Methods. The MEDLINE (PubMed) bibliographic database was searched for a period up to June 2015 for studies evaluating patient movement and/or motion artefacts in CBCT. The search strategy was restricted to English language publications using the following combined terms: (movement OR motion) AND (CBCT OR cone beam CT).
Results. The search strategy yielded eight publications, which qualitatively or quantitatively evaluated patient movement and/or patient motion artefacts in CBCT.
Conclusions. The literature suggests that patient movement usually presents itself in CBCT images as stripe-like and ring-like patterns, double bone contours, and overall lack of sharpness. Studies monitoring patients during CBCT examination reported a prevalence of movement in approximately 20% of the cases, and studies based on image artefact recognition to define patient movement reported prevalence as high as 41.5%. There seems to be a consensus on the fact that young patients (children and adolescents) often move during the examination. (Oral Surg Oral Med Oral Pathol Oral Radiol 2016;121:425-433)

Cone beam computed tomography (CBCT) has emerged as a potentially low-dose CT technique for the visualization of bone structures in the head and neck region.[1-4] In CBCT, one single rotation of the X-ray beam source is performed to collect the data needed to reconstruct the examined tissue volume; this increases the spatial resolution of the image sections and in most instances lowers the dose to the patient, compared with fan beam CT.[3]

CBCT may be an efficient diagnostic tool compared with fan beam CT, since it provides a higher resolution and a significantly lower patient dose.[5-7] There is an ongoing effort to provide high-level evidence for the use of CBCT for dentistry-related diagnostic tasks.[8] Besides the limited visualization of soft tissues provided by CBCT, the presence of artefacts in the final reconstructed images is a major disadvantage of the method.[9] In CBCT imaging, an artefact is defined as "a visualized structure in the reconstructed data, which is not present in the object under investigation."[9] Two systematic reviews recently agreed that artefacts may arise as a result of unit-related (e.g., scatter, aliasing, and unit motion artefacts), and object-related or patient-related factors.[9,10] Related to the object or patient, there are beam-hardening, exponential edge-gradient, and extinction artefacts.[9,10] In addition to these, there are patient motion artefacts.[9,10] These artefacts are normally seen in CBCT images as stripe-like and ring-like patterns, double bone contours, and overall lack of sharpness.[9]

Among the artefact types that arise in CBCT images, motion artefacts are especially interesting, since their existence is directly connected to some of the basic differences between CBCT and CT, and yet they remain relatively unexplored. One should consider that these could be related to unit motion (e.g., inconsistencies in the source-detector geometric path during image acquisition) and patient motion. Focusing on patient motion artefacts, one can speculate that they are particularly present in CBCT images because of a much longer exposure time compared with CT.[1,2,11-13] At the present time, no systematic review regarding patient movement and patient motion artefacts in CBCT imaging exists in the literature. Therefore, the objective of the present study was to undertake a systematic review on the current knowledge regarding patient movement detection and patient motion artefacts related to CBCT imaging of the dentomaxillofacial region.

Statement of Clinical Relevance

This is the first systematic review of patient movement and motion artefacts in cone beam computed tomography. It presents the current understanding of patient movement and the methods used to recognize it. Further knowledge on these topics is relevant for defining guidelines for cone beam computed tomography.

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Received for publication Jul 30, 2015; returned for revision Nov 20, 2015; accepted for publication Nov 29, 2015.

2212-4403/$ - see front matter
http://dx.doi.org/10.1016/j.oooo.2015.11.019

MATERIAL AND METHODS

Literature search and systematic review

The electronic literature search included the MEDLINE (PubMed) bibliographic database (searched for the period from 1995 to June 2015) for studies evaluating simulated head movements/patient movement and/or patient motion artefacts in CBCT. The search strategy was restricted to English language publications using the following combined terms: (movement OR motion) AND (CBCT OR cone beam CT). Systematic reviews, reviews, conference abstracts, and case reports were excluded. Studies that assessed patient movement and/or patient motion artefacts in CBCT of the dentomaxillofacial region qualified for inclusion.

The PRISMA statement was followed during data assessment and extraction.[14] Data extraction included information regarding (1) the method for head movement simulation, (2) patient monitoring methods, (3) reference standard for patient movement definition, (4) parameters for image acquisition (field-of-view and voxel size), and (5) parameters for image evaluation, when present.

The presence of a gold standard or reference standard to validate if the patient moved/did not move was recognized, but it was not mandatory for a study to be included. A manual search was additionally conducted on the basis of the reference lists of the selected papers and of other previous reviews. All studies were screened by the two authors, and data extraction was performed separately. In cases of disagreement regarding study inclusion or data extraction, a consensus between the authors was reached by discussing the concerned topics.

RESULTS

The search strategy yielded 801 publications in MEDLINE (PubMed). Initial screening of the publications was performed using abstracts and key words, and it yielded 10 papers that potentially met the inclusion criteria. No supplementary studies were added after the manual search. Two studies were excluded, since the full text revealed that they did not fulfill the inclusion criteria. One of them suggested a method for patient monitoring but did not show its application,[15] and the second suggested a method for reducing the effect of patient motion on image quality, but without testing its application in a specific population/sample of patients.[11] Eventually, eight studies were identified as eligible for inclusion in this systematic review.

Two of the included studies were ex vivo and assessed the influence of predefined, simulated head movements on CBCT image quality (Table I).[16,17] In both studies, head movements were simulated, and CBCT images of examinations without movement were used as controls. One study evaluated the effects of only one simulated head movement pattern (rotation).[16] The authors found no differences between images acquired with and without simulated movements with regard to the measurement of distances between anatomic landmarks and the assessment of radiographic image density.[16] The other study evaluated 10 simulated head movement patterns involving all movement axes and found lower overall image quality in the presence of simulated movements, the worst being tremor.[17] Stripe-like patterns were the most commonly observed artefacts, but double bone contours and overall lack of sharpness were also reported to be frequently present in the images.[17]

Six of the studies were in vivo studies: Three presented a method to monitor patient movement during CBCT examination (Table II),[13,18,19] and the other three retrospectively defined that patient movement had occurred, based on the appearance of artefacts in the images (Table III).[20-22] The studies that monitored patient movement prospectively utilized the observation of video recordings: One study[13] used one high-speed camera, and the other two studies used two cameras.[18,19] In these cases, the reference standard for movement was based on the tracked position of markers displayed and marked in video image frames[13,19] or simply on observation of the video recordings.[18] One study reported the magnitude of patients' movement to be, on average, 1.1 mm,[13] and the other studies reported the prevalence of patients who moved to be approximately 20%.[18,19]

In the studies with no patient monitoring, the prevalence of artefacts, suggested to originate in patient movement, ranged from 4.5% to 41.5%.[20-22]

DISCUSSION

In a simplified model, CBCT image artefacts may be seen to have two major causes: (i) possible discrepancies between the real physical conditions of the image acquisition setup (i.e., the CBCT unit's settings together with the characteristics of the object/patient under examination), and (ii) the non-optimal mathematical approach (algorithms) used for three-dimensional reconstruction.[9] Artefacts usually appear as stripe-like and ring-like patterns (black-and-white), double contours, and blurring in the reconstructed images.[9,10] Patient motion artefacts may have an effect on image quality,[9,23] but, as can be seen in this systematic review, not many studies reported in the literature have focused on such artefacts. Establishing ways to recognize and reduce patient movement and gain knowledge on the impact of motion artefacts on diagnosis will be relevant in defining future guidelines for CBCT examination.