Repetition Rate of Scanning Due to Motion Artefacts in Cone-Beam Computed Tomography: a Retrospective Study

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ABSTRACT

Objectives: The objective of this retrospective study was to investigate the incidence of repeated cone-beam computed tomography scans due to motion artefacts in a Turkish subpopulation.
Material and Methods: A total of 6364 patients' cone-beam computed tomography data were analysed retrospectively to identify repeated scans due to motion artefacts. Patients were divided into eight age groups: 1) < 10-year-olds, 2) 10 to 19-year-olds, 3) 20 to 29-year-olds, 4) 30 to 39-year-olds, 5) 40 to 49-year-olds, 6) 50 to 59-year-olds, 7) 60 to 69-year-olds, and 8) > 70 year-olds. Chi-square test was applied to evaluate the repetition rate of scans by age and gender groups. Statistical significance was set at $P < 0.05$.
Results: Repeated scans due to motion artefacts were observed in 1.96% of the patients. The repetition rate of scans was significantly higher in males than in females ($P = 0.006$). Furthermore, the repetition rate of scans was significantly higher in patients < 10 years old compared to the other age groups. However, there was no significant difference in the repetition rate of scans due to motion artefacts among the other age groups ($P > 0.05$).
Conclusions: The present findings suggest that patient age and gender are associated with repeated cone-beam computed tomography scans due to motion artefacts. Males and children under the age of 10 had more common repeated scans due to motion artefacts.

Keywords: artifact; cone-beam computed tomography; movement; patient.

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INTRODUCTION

Radiological imaging plays a vital role in dental practice, helping with clinical evaluation and treatment planning [1]. Cone-beam computed tomography (CBCT) has emerged as a critical and essential diagnostic tool in oral and maxillofacial radiology due to its ability to produce high-resolution images of bone structures [2-4].

CBCT has a wide range of applications, mainly used in the evaluation of bone structures [1]. It is preferred over conventional two-dimensional images as it provides high-resolution three-dimensional images that show the extent and location of pathologies, the quantity and quality of bone, and the spatial relationship of an object to critical anatomical structures. Moreover, CBCT uses a lower dose of radiation than conventional computed tomography (CT) scans, making it a safer option. CBCT is used for a wide range of purposes, including localization of impacted teeth, placement of dental implants, orthodontic and surgical management of complex skeletal abnormalities, evaluation of the upper airway, assessment of morphologic changes in the temporomandibular joint, and evaluation of dentoalveolar trauma, etc. [5-7]. Although CBCT has numerous benefits, it also has some limitations. One of the major disadvantages of the CBCT system is the occurrence of image artefacts in the reconstructed images, which can be caused by various factors [8,9].

Artefacts can be defined as image defects that are not related to the object under investigation. Regardless of the type of technology used, artefacts affect diagnostic image quality [10]. Both CBCT and CT scanners are sensitive to artefacts stemming from a variety of factors [11]. According to their cause, artefacts in CBCT images can be classified as X-ray beam artefacts, patient-related artefacts, and scanner-related artefacts. In addition, noise and scatters (ray scattering) are also known to cause artefacts [10].

CBCT technology does have some deficiencies that hinder image quality and accuracy. Particularly, patient-related artefacts and scanner-related artefacts can significantly reduce the image quality [9,10,12,13]. Consequently, the patient may need to be re-scanned which results in a re-exposure to the radiation dose for the patient. However, the majority of the studies concerning this topic did not investigate the rate of patients requiring a re-scan due to motion artefact and the demographic characteristics of these patients. Furthermore, a limited number of patients were examined in the previous studies.

This retrospective study aimed to investigate the rate of repeated cone-beam computed tomography scans due to motion artefacts in a large patient population and to examine whether there is value in considering different age groups and genders in cases of repeated scans.

MATERIAL AND METHODS

This retrospective study was approved by the Izmir Katip Celebi University Non-Interventional Clinical Studies Institutional Review Board, Izmir, Turkey (IRB: 480). Additionally, written consent was obtained from all patients in the CBCT archive of Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Izmir Katip Celebi University, Izmir, Turkey to use their radiologic data for scientific research. Previously obtained CBCT images of a total of 6364 patients who underwent CBCT imaging between October 8, 2012 and December 6, 2021 were retrospectively analysed. There were no CBCT images of patients with special needs such as physical or mental disabilities in University's archive. The CBCT scans had been prescribed for various purposes, including the evaluation of impacted tooth position, dental implant planning, examination of pathologies in the maxillofacial region, orthognathic surgery, etc. A NewTom® 5G CBCT machine (QR S.r.l.; Verona, Italy) was used to obtain all images in the supine position, using the following parameters: 110 kVp and 1 to 20 mA. CBCT images were examined under dim lighting conditions using a 27-inch screen size monitor (Eizo Co.; Ishikawa, Japan) at a 2560 x 1440 resolution and NNT software version 11.5 (QR Verona, s.r.l.; Verona, Italy).

All images were evaluated by F.K. and E.A. in consensus and repeated scans of the patients due to motion artefacts (Figure 1) were recorded. The patients were categorized into eight groups based on their age range: 1) < 10-year-olds, 2) 10 to 19-year-olds, 3) 20 to 29-year-olds, 4) 30 to 39-year-olds, 5) 40 to 49-year-olds, 6) 50 to 59-year-olds, 7) 60 to 69-year-olds, and 8) > 70 year-olds. Intra-observer agreement on radiographic parameters was determined by calculating Cohen's kappa value by re-examining 200 randomly selected consecutive CBCT images at a three-week intervals. All kappa values were higher than 0.95.

Statistical analysis

The statistical analysis for this study was performed using IBM® SPSS® version 22.0 (IBM Corp.; Armonk,

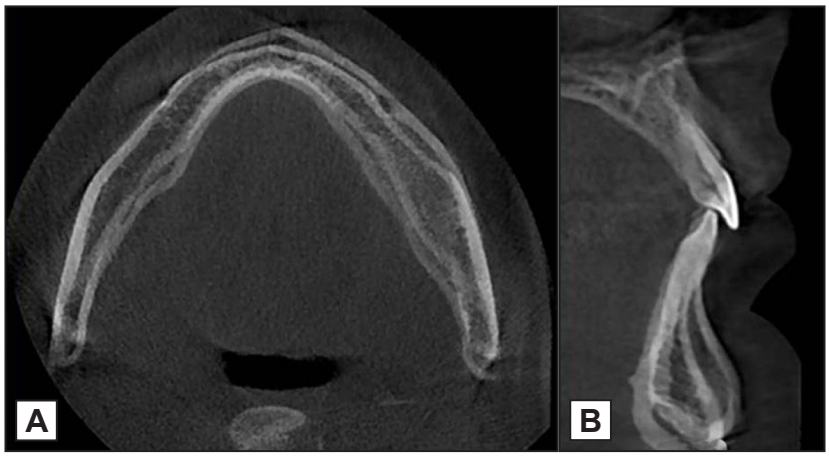

Figure 1. Representative axial (A) and cross-sectional (B) cone-beam computed tomography images of patient demonstrating generalized double contouring due to significant motion artefact.

NY, USA). Chi-squared test was used to compare the repetition rate of scans according to gender and age groups. The level of statistical significance for this study was set at $P < 0.05$.

RESULTS

A total number of 6364 patients' CBCT data were evaluated to determine the presence of repeated scans of the patients due to motion artefacts. This study evaluated a patient population consisting of 3323 (52.2%) females and 3041 (47.8%) males. The age of the patients in this study ranged from 6 to 100 years, with a mean age of 33.7 (SD 18.4) years. Repeated scans due to motion artefacts were detected in 125 of the 6364 patients and the repetition rate was found to be 1.96%.

When the repetition rate of scans due to motion artefacts was evaluated according to gender, the repetition of scans occurred in 1.5% of females and 2.5% of males. A statistically significant difference was observed in the repetition rate of scans between males and females ($P = 0.006$), with the repetition rate being higher in males than in females (Table 1).

A comparison of the repetition rate of scans due to motion artefacts between the age groups revealed significant differences ($P < 0.005$). The repetition rate of scans was observed to be significantly higher in < 10-year-old patients compared to the other age groups. Nevertheless, there was no significant difference in the repetition rate of scans due to motion artefacts between the other remaining age groups ($P > 0.05$) (Table 2).

DISCUSSION

CBCT has become a widely used CT imaging technique with reduced radiation exposure,

Table 1. Comparisons of the repetition rate of scanning due to motion artefacts between males and females

Repeated scan	Females	Males	P-value
	N (%)	N (%)	
Yes	50 (1.5)	75 (2.5)	0.006[a]
No	3273 (98.5)	2966 (97.5)	
Total	3323 (100)	3041 (100)	-

[a]Statistically significant at level $P < 0.05$ (Chi-Squared test).
N = number.

Table 2. Comparisons of the repetition rate of scanning due to motion artefacts between the age groups

Repeated scan	Age (years)								P-value
	< 10	10 to 19	20 to 29	30 to 39	40 to 49	50 to 59	60 to 69	70 >	
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	
Yes	18 (9.8)[a]	50 (2.5)	10 (1.1)	6 (0.7)	8 (0.9)	19 (2.4)	12 (2.2)	2 (1.3)	< 0.001[a]
No	165 (90.2)	2013 (97.5)	900 (98.9)	802 (99.3)	898 (99.1)	782 (97.6)	531 (97.8)	148 (98.7)	
Total	183 (100)	2063 (100)	910 (100)	808 (100)	906 (100)	801 (100)	543 (100)	150 (100)	-

[a]Statistically significant at level $P < 0.05$ (Chi-Squared test).
[a]Age categories, whose column proportions do not differ significantly from each other at the 0.05 level.
N = number.

specifically for visualizing bone structures in the head and neck region. Compared to CT, CBCT is regarded as a more effective diagnostic tool in the evaluation of bony structures due to its ability to provide higher resolution images and lower radiation exposure to patients. However, in addition to the limited visualization of soft tissues in the imaging provided by CBCT, the presence of artefacts is also a significant disadvantage. Motion artefacts are one of the more interesting among the types artefacts that occur in CBCT images [14]. Studies have shown that motion artefacts caused by patient movement can lead to geometric misrepresentation of the data in CBCT images, resulting in overall unsharpness and sometimes the presence of double contours in the reconstructed images [1].

CBCT images in dental exams are severely affected by patient movement during acquisition, so motion artefacts may occur in reconstructed images [15]. When the patient moves during the acquisition, pixel densities representing the same area are reflected back to different locations, resulting in artefacts that may be present in the reconstructed images [9,16]. Extreme movement by patients during CBCT acquisition results in images with low diagnostic quality that may be impossible to interpret by the radiologist.

Motion artefacts in CBCT imaging are related to the relatively long acquisition time of 5 to 40 seconds, as it is difficult to completely immobilize the patient; especially young children, and less cooperative elderly patients for such a long period of time. In the presence of motion artefacts that cause image quality deterioration, re-exposure may be required, which doubles the radiation dose to the patient [17].

Previous studies have shown a range of motion artefact prevalence in CBCT imaging, from 4.5 to 48.2% [18,19]. The variability in reported prevalence rates of motion artefacts in CBCT images can be explained by differences in assessment methods, patient demographics, CBCT devices, and imaging protocols. Based on the available literature [20], the incidence of motion artifacts in CBCT imaging does not appear to be significantly dependent on patient position, whether seated, standing, or supine in the CBCT machine.

The prevalence of the repetition rate of CBCT scanning due to motion artefacts showed differences in previous studies. In a previous study, Donaldson et al. [19] observed that 0.5% of 200 CBCT images needed a rescan due to motion artefacts. Nardi et al. [21] reported that the amount of repeated CBCT examination due to motion artefacts was 1.9% in 500 patients. Spin-Neto et al. [17] showed that 0.4% of 248 CBCT examinations needed to be redone due to severe motion artefact. In the study reported by Nardi et al. [18] the amount of repeated CBCT examinations was 5.4% in 750 patients. According to the current guidelines of the European Commission Directorate for Energy (https://energy.ec.europa.eu/), it is recommended that no more than 5% of CBCT images require a retake [1]. In the present study, the amount of repeated scans due to motion artefact was 1.96% in 6364 patients. This finding is not consistent with the majority of the studies mentioned above [17-19]. The differences in the amount of repeated scans can be attributed to several reasons. The age range of patients is often identified as a movement-related factor [17]. The incidence of motion artefacts in CBCT images of elderly and young patients was reported to be higher compared to other ages. The scan time is also a contributing factor to the occurrence and severity of motion artefacts in CBCT imaging. Longer scan times increase the risk of potential motion artefacts [21]. Patient positioning and stabilization can have an impact on patient movement during the scanning process and the resulting motion artefacts [20]. Uncomfortable rotation of the device's C-arm and the use of a cotton roll stabilizing patient's jaws can increase the patient movement during the scanning [17]. Since anxiety levels may differ according to races and geographical regions [22], different results may be obtained in the amount of motion artefacts in the studies involving varied patient populations.

The literature discusses several factors that contribute to the occurrence of movement artefacts. In this regard, the age range of patients has been suggested to be a relevant factor for the occurrence of motion artefacts [17]. Hung at al. [23] showed that patients younger than 12 years of age had a significantly higher risk for motion artefacts. Spin-Neto et al. [17] classified the patients into 3 different groups: under the age of 15, between the ages of 15 to 30, and over the age of 30. They found the highest rate of head movement in patients under the age of 15. Donaldson et al. [19] reported that patients under 16 years old and over 65 years old had an increased incidence of motion artefacts. Nardi et al. [18] classified the patients into 3 different groups as under 18 years old, 19 to 65 years old, and over 65 years old and they found the highest rate of images requiring repetition due to motion artefact in over 65-year-old patients. In our study, the patients were grouped into eight categories according to age: 1) < 10-year-olds, 2) 10 to 19-year-olds, 3) 20 to 29-year-olds, 4) 30 to 39-year-olds, 5) 40 to 49-year-olds, 6) 50 to 59-year-olds, 7) 60 to 69-year-olds, and 8) > 70 year-olds. Comparison of the repetition rate of scans due to motion artefacts between the age groups revealed significant differences.

The repetition rate of scans was found to be significantly higher in < 10-year-old patients than in the other age groups. However, there was no significant difference in the rate of repeat scans due to motion artefacts among the remaining age groups.
Evaluation of scanning repetition rate due to motion artifacts by gender showed that the scanning repetition rate was significantly higher in males than in females. The discrepancy in the repetition rate of scans due to motion artefacts between genders may be explained by the higher anxiety levels observed in females compared to males [24].

CONCLUSIONS

According to present findings, repeated scans due to motion artefacts were detected in 1.96% of patients. Repeated cone beam computed tomography examinations for motion artifact were found to be associated with age and gender differences. Repeated scans due to motion artefacts were more common in males and in children under the age of 10. Our findings highlight the importance of enhancing patient cooperation and minimizing movement during cone-beam computed tomography image acquisition, especially in paediatric patients.

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